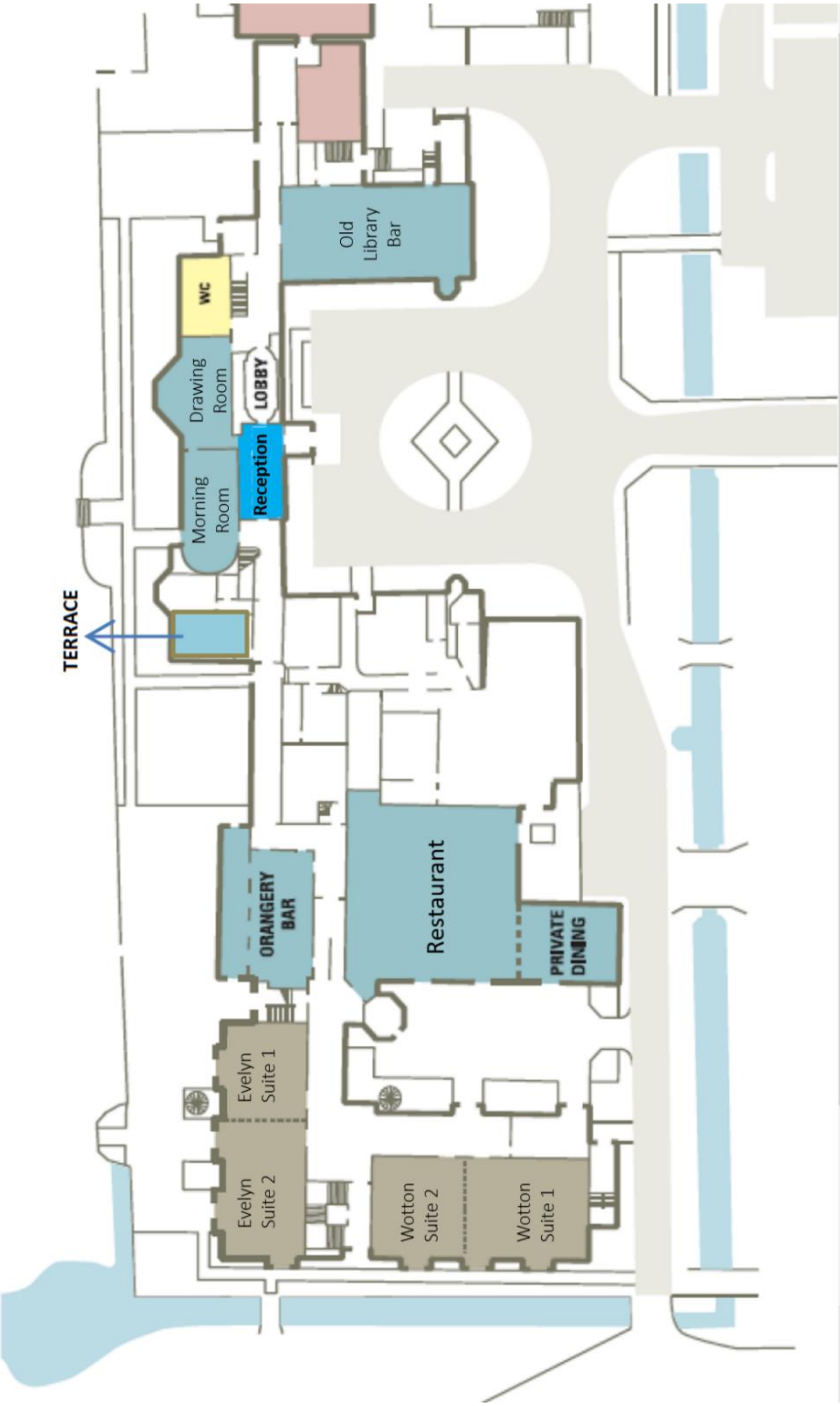
UK METAMATERIALS NETWORK CONFERENCE 2023

11 – 15 June 2023

Wotton House, Guildford Rd, Dorking, RH5 6HS

Image credit front page: Dina Fouad, University of Birmingham



Welcome

UK METAMATERIALS NETWORK CONFERENCE 2023

On behalf of the organising committee, it is our pleasure to welcome you to the UK Metamaterials Network Conference 2023.

This event brings together over 110 representatives from universities, industry, governmental agencies and other research institutions.

Talks, panels and discussion groups will take place in the WOTTON SUITES, the evening showcases will be take place in the EVELYN SUITES.

If we could make one request: where possible, please attend all of the sessions, including those outside of your usual core area, so that we can share collective understanding and knowledge across the community.

The concept of this conference will only work if you bring along your curiosity and your willingness to learn, question, and contribute - as an expert and a novice in any of the discussion topics. Enjoy your time. We are happy to have you here.

Sponsorship

The UK Metamaterials Network Conference 2023 is kindly sponsored by the Engineering and Physical Sciences Research Council (EPSRC) and the Defence Science and Technology Laboratory (Dstl).

Image credit: Samples manufactured by Tom Whittaker, University of Loughborough

Booklet contents

This conference booklet is designed to include all the key items of information related to the conference. If you have any additional questions during the conference, please approach one of the organisers (red lanyards) or ask the hotel staff.

Phone contact during the conference:
Wotton House reception 01306 730 000

Email contact for conference related queries prior/after the event:
Dr Helen Rance, h.j.rance2@exeter.ac.uk; info@metamaterials.network

***

Conference team

Session leads *(in order of session appearance in the schedule)*

Alastair Hibbins

University of Exeter

Claire Dancer

University of Warwick

Tom Allen

Manchester Metropolitan University

Olly Duncan

Manchester Metropolitan University

Calum Williams

University of Cambridge

Simon Pope

University of Sheffield

Katie Shanks

University of Exeter

Arseny Alexeev

Snap Inc.

Thomas Bassett

MBDA UK

Support Staff

Helen Rance — Conference delivery lead

H.J.Rance2@exeter.ac.uk

David Newman — Poster sessions, presentation & vevox support, photography

D.Newman4@exeter.ac.uk

Karen Pearson — Registration, general support

K.Pearson7@exeter.ac.uk

A substantial part of the conference was kindly prepared by the Networks' departing Co-Lead Dr Anja Roeding. She sends her best wishes to everyone.

Aim of the conference

The UK Metamaterials Network Conference 2023 will focus on exploring how metamaterials research and innovation may be able to address big societal challenges such as **Health, Space, and Sustainability**. We will also introduce pathways to **commercialise metamaterials research**: how to translate research ideas into business.

The conference provides a space for the community to come together and widen knowledge horizons beyond subject-specifics, to lay the foundation for future collaborations between and across UK academia and industry (e.g., addressing grand challenges, joint projects, research grants, consultancy work etc.).

Target audience: Academics (incl. Early Career Researchers at/beyond post-doc level), postdocs outside the ECR scope, representatives from industry, governmental and other non-Higher Education research organisations.

Family members including children are welcome to attend.

Bring your mobile device to the table!

We will use *Vevox* as an online platform to engage with you during the sessions for polls, to gather questions and collect your input.

Please bring a fully charged device that can be used to access the internet via the free "Wotton House Hotel" wifi to be able to scan the QR codes.

You will be able to access this conference booklet via either this QR code or the corresponding link: https://metamaterials.network/uk-metamaterials-network-conference-2023/

Remember to keep your device on mute.

Code of conduct

We invite all conference attendees to help us make this event a safe and positive experience for everyone.

EXPECTED BEHAVIOUR

- Be considerate and respectful.
- Be curious.
- Listen and contribute in equal measure. Don’t talk over others.
- Refrain from demeaning, discriminatory, or harassing behaviour and speech.

UNACCEPTABLE BEHAVIOUR

Unacceptable behaviour includes, but is not limited to:

- Intimidating, harassing, abusive, discriminatory, derogatory, or demeaning speech, materials, or conduct by any participants of the event.
- Violence, threats of violence, or violent language directed against another person.
- Personal insults; sexist, racist, homophobic, transphobic, or otherwise discriminatory jokes and language.
- Failure to obey any rules or regulations of the event venue.

CONSEQUENCES OF UNACCEPTABLE BEHAVIOUR

Unacceptable behaviour will not be tolerated. Anyone asked to stop unacceptable behaviour is expected to comply immediately. If a participant engages in unacceptable behaviour, the event organisers may take any action it deems appropriate, including expelling the offender from the event with immediate effect.

WHAT TO DO IF YOU WITNESS OR ARE SUBJECTED TO UNACCEPTABLE BEHAVIOUR

If you are subjected to unacceptable behaviour, notice that someone else is being subjected to unacceptable behaviours, or have any other concerns, please notify the event organisers (red lanyards) or the hotel reception as soon as possible. All reports will remain completely confidential.

About the venue

The Wotton House Estate dates back to the 16th Century, when it was sold by Henry Owen to the Evelyn family. John Evelyn, one of three sons of Richard Evelyn, was passionate about botanicals and arboriculture and was particularly spellbound by the Italian Renaissance gardens he had seen on his tour of Italy.

Inspired by what he had discovered on his travels, on his return to Wotton he constructed an Italian garden and temple, designed by his cousin, Captain George Evelyn, which was soon joined by a parterre garden complete with an Italian fountain.

Since this time, the estate has been passed through the Evelyn family, who have all been passionate about preserving John's legacy, whilst adding their own eccentricities to the estate. Not so long ago, you may have even discovered Kangaroos on the lawn.

The Estate was home to the Canadian Army during the Second World War and in 1947 it became a fire training centre for The Home Office. Soon afterwards, the house became the national Fire Service College.

Today, it is a home away from home with 13 acres of garden. Wotton Estate had the first Italian garden in England, completed in 1652, adorned with Roman temples and original mosaics. The gardens have been deemed worthy of protection and are unusually, individually Grade II listed. Built for intrigue, discover their mystical nature that is fit for any romantic explorer.

How to find the venue

Wotton House, Guildford Road, Dorking, Surrey RH5 6HS | Use RH5 6QQ for Sat Nav

Wotton House can be easily accessed by the M25, the M3 South, the A24 East, and the A3 from London. Parking is extensive and free for guests of the hotel, conference venue and leisure club.

The closest train station, Dorking Station, is just 4 miles or a 15 minute drive from the hotel. Direct links and connections from London Waterloo, London Victoria, Reading, and Gatwick Airport are available.

Parking

Car parking is plenty available, but there is no option to charge electric cars at this point. Secure bike parking facilities are in development but not yet available.

What else to do

As a guest of Wotton House, you have free access to the venue's gym facilities, their pool, and the gardens to walk around.

A walking map can be provided by the hotel reception.

Hotel contact details

Wotton House reception: 01306 730 000 | www.wottonhouse.co.uk
Wotton House, Guildford Road, Dorking, Surrey RH5 6HS | use RH5 6QQ for Sat Nav.

Practical details

Conference registration

To receive your lanyard and name badge, please go to our conference registration desk between the Evelyn and Wotton Suites.

Registration times: **Sunday** 5-6pm and 8-9pm; **Monday/Tuesday** 8.30-10 am and 4.30 – 6pm; **Wednesday** 8.30 – 10 am

What do the lanyard colours mean?

- Red = conference organisers
- Blue = Higher Education Institutions (academics, ECRs, postdocs)
- Yellow = Representatives from industry, governmental agencies, other
- Green = Family members of attendees

What is paid for, and what not?

Your accommodation, meals (incl soft drinks) and refreshment breaks are paid for by the Network. Anything else (drinks you are purchasing at the bar, items from the mini bar, etc.) will need to be paid for by yourself.

Gala Dinner (Wednesday night in the Evelyn Suites): Soft drinks, wine and beer are included in this package. Any other alcoholic drinks will need to be paid for by yourself.

Wifi

To access the internet, we recommend to log in to the free 'Wotton House Hotel' Wifi. Use your browser to access the Wotton House Wifi page where you need to enter your email address to connect. The Wifi will work in both the meeting spaces and bedrooms. If there are problems, please ask at reception for support.

Need a taxi?

There are a few taxi providers operating: FBR Taxi – 01306 885533; DM Taxi – 01306 304050; Magnum Cars – 01483 281111.

Please ask the hotel reception staff for support, in particular to coordinate sharing of taxis to Dorking Station on the last conference day.

Wotton House reception: 01306 730 000

Travel expenses

If you need support to cover your travel expenses, we can offer some funding in particular to postdocs/ECRs. Before making a claim, please consider if there are other ways to cover your expenses. Any budget we can save here will enable us to fund other network activities.

Those of you who are in need of support, please complete the attached claim form for claims in GBP: UK GBP Payment Request Form[1]. If your claim is in non GBP currency please use this form: International Payment Request Form [2]

Please return your form as an **EXCEL file** (not pdf) with scanned/electronic copies of all receipts/online booking confirmations to Deb Lee at info@metamaterials.network.

Receipts must be retained for the expenditure incurred in case a copy is requested for HRMC requirements or audit purposes. **Payment processing may take up to 3 weeks**.

Eligible items

- ***Rail travellers*** are expected to travel standard class.
- Fully flexible (i.e. open) first class rail tickets must not be booked and cannot be reimbursed.
- Other first class rail tickets may only be booked if costs are equivalent to a standard ticket. Specific details of how cost is lower or equivalent must be provided with each claim and evidence (such as a screen print on the booking page) provided.
- ***Sea crossings*** over 6 hours, standard cabin accommodation is permitted.
- ***Air travel:***

Flight Duration	Class
Any flight duration	economy
Over 4 hrs up to 7 hrs	Premium economy
Over 7 hours	Business
Not permitted	First

- ***Taxis*** are not permitted for long journeys, but may be claimed where there is no public transport for short journeys e.g. between a train station and venue.
- ***Mileage claims:*** Claimants using their private vehicle are paid a standard mileage rate as outlined in the table below.

Transport	Miles	Rate
Private Motor Car (Per daily journey)	1 - 100 Miles	45p
Private Motor Car (Per daily journey)	Over 100 Miles	25p
Motorcycles	All mileage	24p
Bicycle	All mileage	20p

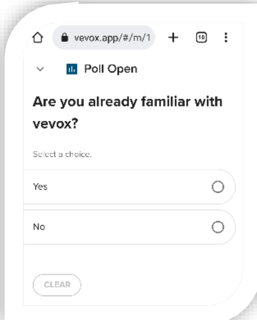
[1] https://www.exeter.ac.uk/media/universityofexeter/financeservices/forms/UK_GBP_Payment_Request_Form_-_Oct_21.xlsx
[2] https://www.exeter.ac.uk/media/universityofexeter/financeservices/forms/International_Payment_Request_Form.xlsx

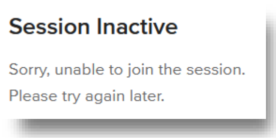
Introduction to Vevox

To include an interactive element that enables the sharing of thoughts and input from as many participants as possible (and as quickly as possible), we will be using Vevox as an online platform to engage with you during most of the sessions.

What you need: a charged device (e.g. mobile phone, tablet) with an internet connection and the ability to scan QR codes or to type / click on links to the Vevox sessions.
How to: Scan the QR code or use the link for the relevant session as displayed in this booklet (see schedule section) or on the screen during the conference.

Once the session is live, you should see a poll question appear on your screen.



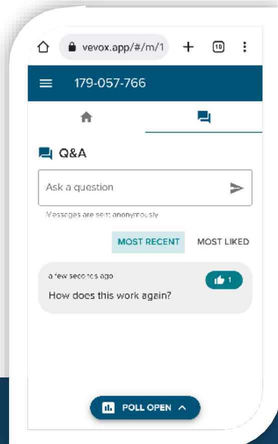


*(The link will only be active during the conference sessions. Outside of the session time, you may receive a "**Session Inactive**" notification.)*

***

There is also a **Q&A** function (speech bubble icon).
You can use this to add your questions/comments and up-vote other participants' input.

Please note: We will monitor the Q&A box only when there is an active Q&A element in any given session. You can use it at any time once the session is live, but we may not be able to react in real time outside of the session.



Do not worry: There will be a "*How to use Vevox*" test run during the Welcome Talk session and people at your table to give a hand when needed throughout the week.

QR codes to access Vevox during the conference sessions

Monday – Welcome session

Wednesday – Closing session

Monday – Metamaterials for Health

Tuesday – Metamaterials for Space

Wednesday – Metamaterials for Sustainability

Wednesday – Commercialising Metamaterials

CONFERENCE SCHEDULE

Sunday 11 June 2023

- Arrival from 4 pm

- Registration between 5 – 6 pm and 8 – 9 pm (in front of Evelyn Suites)

- Showcase material setup (posters, demonstrators) *Group A: 8 – 9 pm* (in Evelyn Suites)

- Dinner in the Restaurant 6 – 9.30 pm

***

Showcase material setup times

Group A Sunday evening 8 – 9 pm, Monday 5.30 – 6 pm | **Group B** Tuesday 8.15 – 9 am, 5.30 – 6 pm

See further details in the "**About the showcase sessions**" section

Monday 12 June 2023

time	Sessions	Speaker
09:00 - 10:00	**Welcome** • Update on the Network Activities and Future Plans; • Conference practicalities; • Update on Metamaterials Definition	Prof Alastair Hibbins (University of Exeter) Dr Claire Dancer (University of Warwick)
10:00 - 10:30	**Metamaterials for Health** 1. Introduction 2. Healthcare theme	1. Dr Tom Allen (Manchester Metropolitan University) 2. Dr Calum Williams (University of Cambridge)
10:30 - 11:00	BREAK	
11:00 - 12:00	**Keynote talk: Metamaterials for Healthcare**	Prof Amir Zadpoor (Delft University of Technology)
12:00 - 12:45	Round table discussions: **Opportunities for MM in Healthcare**	Chair: Dr Calum Williams (University of Cambridge)
12:45 - 14:15	LUNCH BREAK (in the restaurant)	
14:15 - 15:30	**Metamaterials for Healthy Living** 1. Healthy living theme introduction 2. Key note talk: Healthy living	1. Dr Oliver Duncan (Manchester Metropolitan University) 2. Marc Douglas (World Rugby)
15:30 - 16:00	BREAK	
16:00 - 16:50	Round table discussions: **Opportunities for MM in Healthy Living**	Chair: Dr Oliver Duncan (Manchester Metropolitan University)
16:50 - 17:00	**Summary & close**	Dr Tom Allen (Manchester Metropolitan University)
18:30 - 21:00	Dinner & showcase session in & around the Evelyn Suites	

Tuesday 13 June 2023

time	Sessions	Speaker
09:00 - 09:10	**Metamaterials for Space:** Introduction	Dr Simon Pope (University of Sheffield)
09:10 - 10:30	**Current status and future direction of the Space sector** 1. "Metamaterials in Space: Exploring the UK Landscape, Challenges, Opportunities, and Perspectives" 2. "Metamaterials and The Space Environment"	Chair: Prof Alastair Hibbins (University of Exeter) 1. Dr Mauro Augelli (UK Space Agency) 2. Dr Gemma Attrill (Dstl)
10:30 - 11:00	BREAK	
11:00 - 11:45	**Opportunities for metamaterials in the space sector** *3.* "UK civil space technology roadmap and the opportunities and challenges for materials" 4. "Design and Manufacturing of Transparent Antennas for Satellite Communications"	Chair: Prof Alastair Hibbins (University of Exeter) 3. Dr Neelam Mughal (Innovate UK) 4. Dr Themos Kallos (META)
11:45 - 12:30	Round table discussions: **MM for Space Application Opportunities**	Chair: Dr Simon Pope (University of Sheffield)
12:30 - 14:00	LUNCH BREAK (in the restaurant)	
14:00 - 14:45	**Idea formulation and development of projects for metamaterials in Space** Tutorials *1. "Structural Metamaterials for frequency control and vibration mitigation during launch"* *2. "Metamaterial antennas challenges and opportunities for space applications"* *3. "Metamaterials for spacecraft thermal control"* *4. "Metamaterials for optical communication and imaging, opportunities and challenges"*	Chair: Dr Simon Pope (University of Sheffield) 1. Prof Matthew Santer (Imperial College London) 2. Prof Will Whittow (Loughborough University) 3. Dr Kai Sun (University of Southampton) 4. Dr Sebastian Schulz (University of St Andrews)
14:45 - 15:45	Round table discussions: **Project development**	Chair: Dr Simon Pope (University of Sheffield)
15:45- 16:15	BREAK	

Tuesday 13 June 2023 (continued)

time	Sessions	Speaker
16:15 - 16:45	**Project development summaries & ideas sharing**	Chair: Dr Simon Pope (University of Sheffield)
16:45 - 17:00	**Summary & close**	Dr Simon Pope (University of Sheffield)
17:00 - 17:20	**Group photo** *(gather in the conference room to be guided to the group photo spot)*	
18:30 - 21:00	Dinner & showcase session in & around the Evelyn Suites	

Wednesday 14 June 2023 (Morning session)

time	Sessions	Speaker
09:00 - 09:05	**Metamaterials for Sustainability:** Introduction	Dr Katie Shanks (University of Exeter)
09:05 - 10:30	**10 minutes talk series** 1. “Towards a tipping point in engineering culture” 2. “Environmentally Sustainable Materials” 3. "Tackling global issues as an academic" 4. "Thermochromics and phase-change technologies for sustainable photonics" 5. “Metaplasmonics for Net-Zero” 6. "Opportunities for Metamaterials in optics for Solar Energy"	Chair: Dr Claire Dancer (University of Warwick) 1. John Kraus (Engineers Without Borders) 2. Dr Zaffie Cox (EPSRC) 3. Dr Raphaëlle Haywood (University of Exeter) 4. Prof Otto Muskens (University of Southampton) 5. Prof Anatoly Zayats (King's College London) 6. Dr Katie Shanks (University of Exeter)
10:30 - 11:00	BREAK	
11:00 - 11.45	**10 minutes talk series (Exemplars)** 7. *"Metamaterials for Wave Energy Harvesting’"* 8. *"Heat transport in 3D nanostructured metamaterials"* 9. *"Non-volatile magnetic components for low-loss electronics and photonics"*	7. Prof Deborah Greaves (University of Plymouth) 8. Dr Iris Nandhakumar (University of Southampton) 9. Prof Robert J. Hicken (University of Exeter)
11:45 - 12:30	Round table discussions: **Moonshots for Sustainability focused metamaterials**	Chair: Dr Katie Shanks (University of Exeter)
12:30 - 14:00	LUNCH BREAK (in the restaurant)	

Wednesday 14 June 2023 (Afternoon session)

time	Sessions	Speaker
14:00 - 14:10	**Commercialising Metamaterials:** Introduction	Dr Arseny Alexeev (Snap)
 14:10 - 14:40 14:40 - 15:30	**Talk series** 1. Pathways into commercialising research 2. Introductions to DASA, Ploughshare, and the Space Applications Catapult *(Q&A after break)*	Chair: Tom Bassett (MBDA) 1. Dr Bruno Reynolds (Oxentia) 2a. Paul Alderton (DASA) 2b. Dr Sandy Fisher John (Ploughshare) 2c. Paul Fevbre (SA Catapult)
15:30 - 16:00	BREAK	
16:00 - 16:45	**Panel session & Q&A**	Chair: Prof Christopher Tuck (University of Nottingham) Speakers as above; Prof Chris Stevens (Imperial College London); Dr Themos Kallos (META)
16:45 - 17:00	**Conference summary & close**	Prof Alastair Hibbins (University of Exeter)
19:00 - 23:00	Gala Dinner in the Evelyn Suites	

Thursday 15 June 2023

Departure after breakfast

About the showcase sessions

The technical posters and demonstrators will be allocated a number and correlating spot in the Evelyn room. There will be 2 groups, A and B, one being displayed during the showcase session on Monday and the other one on Tuesday.

Poster boards are numbered 1 – 16, tables for demonstrators are labelled A – E.

Group A

Setup: Sunday evening 8 – 9 pm, Monday 5.30 – 6 pm

Presentation: Group A1 – Monday 7 – 7.45 pm; Group A2 – Monday 7.45 – 8.30 pm

Takedown: Monday evening at the end of the showcase session

Group B

Setup: Tuesday 8.15 – 9 am, 5.30 – 6 pm

Presentation: Group B1 – Tuesday 7 – 7.45 pm; Group B2 – Tuesday 7.45 – 8.30 pm

Takedown: Tuesday evening at the end of the showcase session

Colour code

The technical abstracts below include a colour code to indicate which challenge areas the research may contribute to.

Green = Sustainability

Blue = Space/Aviation

Red = Health

Yellow = Commercialisation

Showcase group allocation

First name	Last Name	Title	Group	Board no
Peter	Petrov	A comparative study of plasmonic materials for refractory applications.	B2	6
Mitchell	Kenney	A practical demonstration of visible metalenses for imaging	A2	D
Anton	Souslov	Active elastocapillarity for shape-shifting soft materials	B2	13
Richard	Watson	Active metamaterials to enhance ultrasound imaging	A1	10
Mahdi	Bodaghi	Adaptive meta-laminar jamming actuators by 4D printing	B2	5
Zafer	Kazanci	Application of cellular auxetics to ballistic helmets	A1	A
Mayela	Romero-Gómez	Au-based plasmonic metasurfaces	B2	7
Reece	Oosterbeek	Designing materials and metamaterial structures for orthopaedic implants	B1	10 & D
Mitchell	Kenney	Dielectric Metasurfaces for Visible Light	A2	8
Changxu	Liu	Disordered metasurfaces for passive display	A2	15
Sebastian	Schulz	Enhancing optical devices through controlled light scattering	B2	16
Yi	Wang	Exploring new manufacturing technologies for millimetre- wave and sub-terahertz metamaterials	B2	14
Shwe	Soe	Head Injury Mitigation of an Elastomeric Honeycomb Helmet: A Computational Investigation	A1	2
Jiafeng	Zhou	Implantable Patch Antenna Based on Elliptic Spiral Split Rings	B2	15
Imran	Bashir	Lithium-Ion Battery degradation characterisation using metamaterial’s enhanced ultrasonic signatures	B1	9
Qicheng	Zhang	Manufacturing and mechanical properties of open cell auxetic polyurethane foam	B1	3
Bryn	Davies	Mathematical theory for periodic approximations of quasiperiodic metamaterials	A2	7
Stefan	Szyniszewski	MetaGenome - Metamaterials community shared database with developed material topologies and associated properties	B1	1 & A
Sherjeel	Khan	Metamaterial for tuneable compressive response in prosthetic liners	B1	11 & E
Muhammad	Ansari	Metasurface enabled multifunctional microscopy	A2	13
Felicity	Freeman	Microstructurally controlled lattices for functionally graded performance	B2	8
Stephen	Henthorn	Microwave Metamaterials – Not just a PCB	B2	B
Tongjun	Liu	Nano-opto-mechanical Metamaterials: Parametric Frequency Mixing, Frequency Combs and Photonic Time Crystals	A1	17
Aaron	Vance	Numerical investigation of Poisson’s ratio and the influence of re-entrant Auxetic unit cell arrangement	A1	9
Mohsen	Rahmani	Optical Metasurfaces: building blocks of tomorrow’s technologies	A2	14
Alasdair	Clark	Plasmonic metasurfaces as cross-reactive artificial taste buds	A1	1
Diane	Roth	Plasmonic nanorod metamaterials for sensing and catalysis	A1	B

Rhea	Sam	Position Nano-metrology with Topologically Structured Light	A2	6
Feiran	Wang	Scalable and Multifunctional Sensors by Inkjet Printed Graphene Network	B1	2
Matthew	Santer	s-SNOM as an interrogation technique of optical modes of Structural Metamaterial Optimization	A2	11 & E
Simon	Pope	Structurally reconfigurable and reusable metamaterials	A1	4
Jisun	Im	Two photon polymerisation for metamaterials application	B2	12
Andrew	Henning	Ultracompact metasurface based instrumentation for manufacturing applications	A1	12
Marc	Holderied	Ultrathin broadband sound absorber panels inspired by a natural acoustic metamaterial	A2	16
Oksana	Trushkevych	Visualising acoustic fields with liquid crystals	A1	5 & C
Andrew	Alderson	Wetting of auxetic metamaterials	A1	3
Jiafeng	Zhou	Wireless Charging with High Flexibility and Reliability	B2	15
Marcello	Ferrera	Zero-Index photonics	B1	4
Will	Whittow	3D-Printed RF Devices	B1	17

TECHNICAL POSTERS & DEMONSTRATORS

A comparative study of plasmonic materials for refractory applications

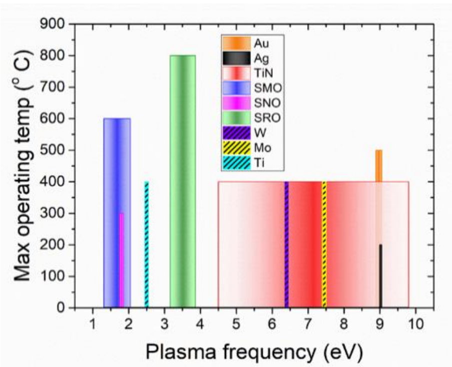
Petrov PK

Department of Materials, Imperial College London, London SW7 2AZ, UK

Contact: p.petrov@imperial.ac.uk

A Comparative Study of Materials for Refractory Plasmonic Applications Materials such as W, TiN, and SrRuO3 (SRO) have been suggested as promising alternatives to Au and Ag in plasmonic applications owing to their refractory properties [1]. However, investigation of the reproducibility of the optical properties after thermal cycling at high temperatures in the air is so far lacking.

Here, thin films of W, Mo, Ti, TiN, TiON, Ag, Au, and $SrRuO_3$ are investigated to assess their viability for robust refractory plasmonic applications [2]. Films ranging in thickness from 50 - 180 nm are deposited using various deposition methods, before characterisation using AFM, XRD, spectroscopic ellipsometry, and DC resistivity. Measurements are conducted before and after annealing in air at temperatures ranging from 300 - 1000° C for one hour, to establish the maximum cycling temperature and potential longevity at the temperature for each material.



It is found that $SrRuO_3$ retains metallic behaviour after annealing at 800° C, however, importantly, the optical properties of TiN and TiON are degraded as a result of oxidation[3]. Nevertheless, both TiN and TiON may be better suited than Au or SRO for high-temperature applications operating under vacuum conditions.

Figure Operating regimes for the materials under study.

References

[1] Doiron, B. et al., 2019, https://doi.org/10.1021/acsphotonics.8b01369.

[2] Wells, M. P. et al., 2018 https://doi.org/10.1364/OE.26.015726.

[3] Braic, L. et al, 2017 https://doi.org/10.1021/acsami.7b07660.

Active elastocapillarity for shape-shifting soft materials

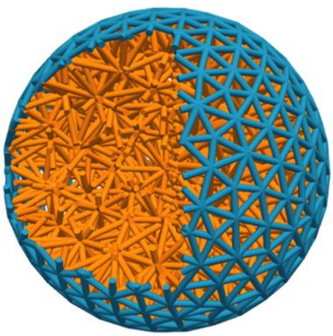
Binysh, J.[1], Souslov, A.[1]

[1] Department of Physics, University of Bath, Somerset BA2 7 AY

Contact: jacb23@bath.ac.uk, a.souslov@bath.ac.uk

Active solids consume energy to allow for actuation, shape change, and wave propagation not possible in equilibrium. Whereas active interfaces have been realized across many experimental systems, control of three-dimensional (3D) bulk materials remains a challenge. This challenge is particularly pressing on the microscale, for example in tailoring the shape of nanoparticles for drug delivery.

Here, we develop continuum theory and microscopic simulations that describe a 3D soft solid whose boundary experiences active surface stresses. The competition between active boundary and elastic bulk yields a broad range of previously unexplored phenomena, which are demonstrations of so-called active elastocapillarity. In contrast to thin shells and vesicles, we discover that bulk 3D elasticity controls snap-through transitions between different anisotropic shapes. These transitions meet at a critical point, allowing a universal classification via Landau theory. In addition, the active surface modifies elastic wave propagation to allow zero, or even negative, group velocities.



These phenomena offer robust principles for programming shape change and functionality into active solids, from robotic metamaterials down to shape-shifting nanoparticles.

References

[1] J. Binysh, T. R. Wilks and A. Souslov, *Active Elastocapillarity in Soft Solids with Negative Surface Tension*, Sci. Adv. **8** eabk3079 (2022).

Active metamaterials to enhance ultrasound imaging

Watson, R.[1], Hutchins D.[1], Astolfi, L.[1], Thomas, P.[1], Laureti, S.[2], Ricci, M.[2], Clare, A.[3], Askari, M.[3], Freear, S.[4], Nie, L.[4]

[1] School of Engineering, University of Warwick, Coventry, CV4 7AL, UK
[2] Department of Informatics, Modelling, Electronics and Systems Engineering, University of Calabria, Via PietroBucci, 87036 Arcavacata di Rende, CS, Italy
[3] Department of Mechanical, Material and Manufacturing Engineering, University of Nottingham, University Park NG7 2RD, Nottingham, UK
[4] School of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT, UK

Contact: r.watson.2@warwick.ac.uk

Resolution in imaging with ultrasound is limited by the wavelength used, shorter wavelengths provide greater resolution with traditional imaging techniques. Unfortunately the effective penetration with shorter wavelengths is lower due to the increased attenuation these wavelengths suffer. To overcome this limitation use of longer wavelengths for improved penetration coupled with subwavelength imaging to improve the resolution. Previous work at Warwick has investigated the manufacture and properties of acoustic metamaterials in water including negative refraction and subwavelength imaging [1,2]. The limitation of individual metamaterial designs are that resonances are at limited frequencies dependent on their dimensions. Development of active metamaterials with active fluids may overcome this design limitation to widen the operational range of imaging. Acoustic metamaterial resonance depends on the interaction between the metamaterial structure and the fluid with which it is surrounded, and which is needed to transmit the acoustic waves. This is controlled by differences in fluid and material acoustic impedances. To investigate control of the frequency response of these metamaterials which have already been designed and characterised, a new approach using active fluids is being investigated to control these acoustic impedance differences. Magnetorheological fluids are under investigation to allow control of fluid properties through the application of external magnetic fields.

References

[1] Astolfi, L et al., Proceedings of 2019 IEEE International Ultrasonics Symposium (IUS), Glasgow, UK., pp. 2529-2532, (2019)
[2] Astolfi, L. et al., The Journal of the Acoustical Society of America **150**, 74, (2021)

Adaptive meta-laminar jamming actuators by 4D printing

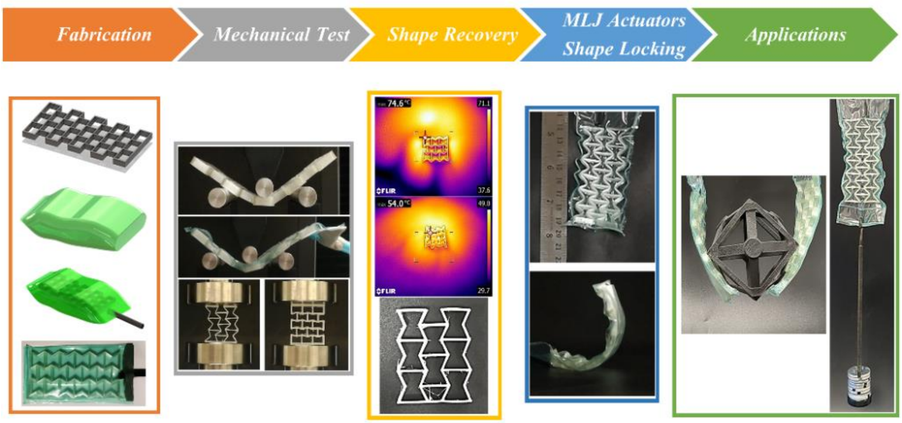
Lalegani Dezaki M., Bodaghi M.

Department of Engineering, School of Science and Technology, Nottingham Trent University, Nottingham NG11 8NS, UK

Contact: mahdi.bodaghi@ntu.ac.uk

Laminar jamming (LJ) technology allows for a transition from conventionally high-force rigid robots to quick, precise, flexible, and secure soft robots. An LJ actuator must be lightweight, precise and, at the same time, strong enough to tolerate moments caused by external forces/shocks and perform required tasks. A major challenge with pneumatic LJ actuators is that the negative pressure should always be on to hold the actuator in a required position that increases energy consumption massively. Therefore, a sustainable smart design could reduce power consumption and system control complexity.

This research [1] introduces a novel conceptual design of meta-laminar jamming (MLJ) actuators with shape recovery, shape locking, and zero-power holding features. Shape memory meta-structure cores with circle, rectangle, diamond, and auxetic patterns are designed, 4D printed and embedded into an ultra-flexible bag to make smart robots. They are programmed via hot air and negative pressure. The lightweight metamaterial core allows for excellent structural compliance and the shape memory effect allows for zero-power shape-locking. The actuator can lift load weights and grasp objects with different shapes and weights with zero input power. Their potential soft robotic applications as end-effectors and grippers are demonstrated opening new avenues for sustainable robotics with low energy consumption.



Reference

[1] M. Lalegani Dezaki and M. Bodaghi, Soft Matter, 19, no. 12, 2186-2203 (2023).

Application of cellular auxetics to ballistic helmets

Fisher, T., Almeida, H., Kazancı, Z.

[1] Advanced Composites Research Group, School of Mechanical and Aerospace Engineering, Queen's University Belfast, Belfast BT9 5AH, UK.

Contact: z.kazanci@qub.ac.uk

The primary cause of death on the battlefield is head injuries. Head impacts can lead to traumatic brain injuries (TBIs), with symptoms ranging from comas to seizures and depression. High numbers of armed forces personnel suffer from heat stroke and heat exhaustion each year. There is therefore a clear need to improve the protection offered by combat helmets, as well as reduce their weight.

The hard composite shell of a combat helmet protects from perforation, but a high energy absorbing layer is required to reduce the behind helmet blunt trauma. Mechanical metamaterials offer a potential solution to this. Additive manufacturing allows for complex cellular architectures with tailored properties to be realised. These can be designed to have a negative Poisson's ratio (auxetic) which has many benefits for energy absorption. Auxetics are capable of absorbing more energy than their non-auxetic counterparts (eg honeycombs) and densify in areas of local loading inhibiting indentation. Auxetics also undergo synclastic (dome-shaped) curvature, as opposed to the anti-clastic (saddle-shaped) curvature of non-auxetics making them ideal for forming to the shape of a helmet. Cellular structures may also help to reduce weight and increase airflow.

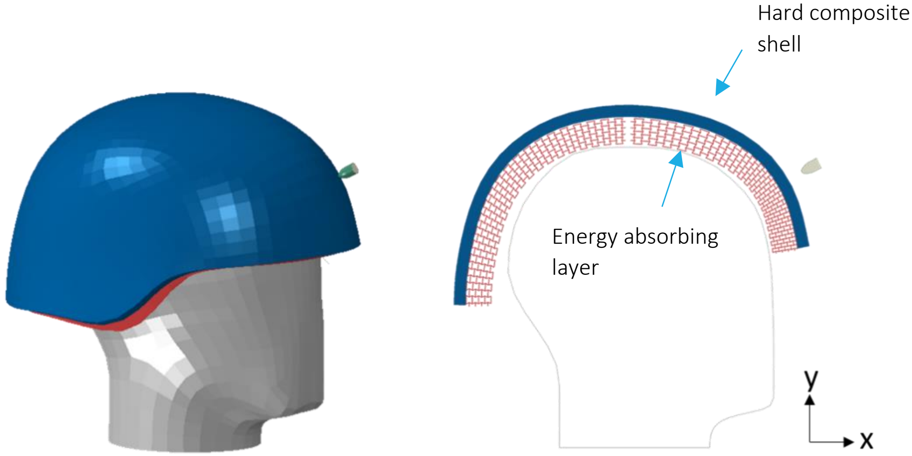


Figure 1: Finite element model of concept combat helmet utilising an auxetic re-entrant cellular core.

A practical demonstration of visible metalenses for imaging

Kenney, M.[1], Cousins, R. [2], Mellor, C.[2]

[1] Faculty of Engineering, University of Nottingham, Nottingham, NG7 2LD, UK
[2] School of Physics, University of Nottingham, Nottingham, NG7 2LD, UK

Contact: Mitchell.Kenney@Nottingham.ac.uk

Metamaterials are intelligently designed optical components constructed using nanostructures such as dielectrics or metals, which can exhibit novel and unique properties not found in nature. In general, metamaterials are 3D, but most works in recent years focus on their 2D variants termed metasurfaces. These are ultrathin yet efficient devices that could potentially be used to replace a myriad of conventional optical components, which rely on bulky glasses or crystals.

A particularly useful alternative of lenses are metalenses [1], which can focus light to diffraction limited spots yet are less than 1µm thick and exhibit efficiencies rivalling off-the-shelf glass lenses. Whilst a metalens by itself is not exciting, the fact that they can be fabricated using microelectronics processes could lead to mass manufacture at the wafer level for a fraction of the cost and space that normal lenses do, which is of particular interest to handheld imaging systems (e.g. mobile phone cameras). Arrays of these metalenses can be fabricated, creating a fly-eye effect – lens arrays are an essential part of many advanced imaging technologies, such as in wavefront sensing.

One such focus of my research is using dielectric (Silicon Nitride) metalenses which work across the visible spectrum for the computation imaging technique termed *light-field imaging* [2] which can involves sub-images being focussed from a main lens onto an imaging sensor and then reconstructed into 2.5D, allowing refocussing, parallax, and depth of field estimations to be processed from a single Light Field image. The figure above highlights this concept by multiple viewpoints of a fruit fly imaged using a metalens array made at Nottingham. Whilst typical lens arrays can be used for this, metalens arrays are much easier to design and fabricate and are not limited to numerical aperture (NA) values. Work is underway to incorporate High Dynamic Range contrast, polarimetry, and aberration-correction into the lens arrays for life sciences and commercial imaging.

References

[1] M. Kenney et al, SPIE Optical Metrology, 110570C (2019)
[2] R. J. Lin al., Nature Nanotechnology, 14, p227 -231 (2019).

Au-based plasmonic metasurfaces

Romero-Gómez, M.[1], Severs-Millard, T.[1,2], Vincent, T.[3], Xiao, X.[2], Huáng, N. J.[1], Oulton, R.[2], and Kazakova, O.[1]

[1] Quantum Technologies Department, National Physical Laboratory, Teddington TW11 OLW, UK
[2] Experimental Solid State, Department of Physics, Imperial College London, London SW7 2AZ, UK
[3] Photon Science Institute, Department of Electrical and Electronic Engineering, University of Manchester, Manchester M13 9PL, UK

Contact: mayela.romero@npl.co.uk

Plasmonic metasurfaces and metamaterials have emerged as a workhorse in non-linear nano-optics, given their ability in tailoring, and enhance light-matter interactions at the nanoscale, controlling properties such as amplitude, phase, and polarisation of light, and providing a compact, ultrathin design, suitable for low-volume device integration. Spontaneous parametric down conversion (SPDC), for example, has effectively benefited from the substitution of traditional non-linear crystals by dielectric and plasmonic metasurfaces, since they enable ultrafast, broadband, phase-mismatch free, frequency conversion sources, with enhanced Purcell factor [1-3]. The accurate characterisation of their locally induced optical resonances can be achieved by implementing high-resolution probe techniques, such as scattering scanning near field optical microscopy (s-SNOM). In this work, we discuss general aspects of SNOM technique, and demonstrate its suitability to evaluate the near-field optical response of gold-based antenna-waveguide metasurfaces, *via* cross-polarised and transmission s-SNOM techniques (Fig. 1), at different frequencies in the mid-IR range, and with different polarisation directions. The experimental results are compared with numerical simulations.

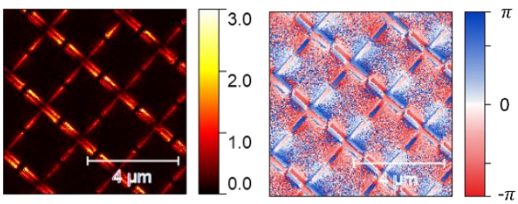


Fig. 1. Typical amplitude and phase maps of Au cut-waveguide/antenna metasurface obtained under normal illumination, transmission s-SNOM, at λ = 5.6 µm resonance wavelength.

References

[1] A. Davoyan and H. Atwater, Optica 5, p 608–611 (2018).
[2] B. Jin et al., Nanoscale 13, p 19903-19914 (2021).
[3] T. Santiago-Cruz et al., Nano Lett. 21, p 4423-4429 (2021).

Designing materials and metamaterial structures for orthopaedic implants

Oosterbeek, R. N.[1]

[1] Department of Engineering Science, University of Oxford, Oxford OX1 3PJ, UK

Contact: reece.oosterbeek@eng.ox.ac.uk

The emergence of mechanical metamaterials is a promising development for improving treatment of musculoskeletal conditions, which affect nearly a third of the UK population. These applications pose particular challenges for material properties. To minimise stress shielding for optimal bone health and regeneration, the modulus should match that of natural bone, however this can be difficult to achieve without reducing the overall strength to inadequate levels.

The performance of a material over the implant lifetime is crucial to consider even for non-bioresorbable implants, and here the microstructure and surface morphology can be severely detrimental to the fatigue lifetime. Here I present several methods for improving the performance of mechanical metamaterials for orthopaedic implants, including design of a new double network metamaterial, and application of heat treatment [1] and surface treatment [2] to metamaterial lattices.

These challenges can be even more complex for bioresorbable materials, whose properties can change significantly during degradation. Ongoing work aims to develop bioresorbable mechanical metamaterials, and fabrication methods for these, such that site-specific control of the microstructure can be achieved. Metamaterial architectures are being specifically designed with degradation in mind, to generate prototype bioresorbable mechanical metamaterials for medical implant devices.

References

[1] S. Ghouse, R.N. Oosterbeek, A.T. Mehmood, F. Vecchiato, D. Dye, and J.R.T. Jeffers. "Vacuum heat treatments of titanium porous structures." Additive Manufacturing 47 (2021).

[2] R.N. Oosterbeek, G. Sirbu, S. Hansal, K. Nai, and J.R.T. Jeffers. "Effect of hirtisation on the roughness and fatigue performance of porous titanium lattice structures." arXiv preprint arXiv:2304.06621 (2023).

Dielectric Metasurfaces for Visible Light

[1] Faculty of Engineering, University of Nottingham, Nottingham, NG7 2LD, UK

Contact: Mitchell.Kenney@Nottingham.ac.uk

Metamaterials are intelligently designed optical components constructed using nanostructures such as dielectrics or metals, which can exhibit novel and unique properties not found in nature. In general, metamaterials are 3D, but most works in recent years focus on their 2D variants termed metasurfaces. These are ultrathin yet efficient devices that could potentially be used to replace a myriad of conventional optical components, which rely on bulky glasses or crystals.

The Kenney Lab at the University of Nottingham is part of the Optics & Photonics group, which is a vibrant and multidisciplinary cohort of experts in optics, sensing, life sciences, and biomedical imaging. The main focus of the Kenney Lab's work focusses upon the design and fabrication of real-world applicable metasurfaces made from high refractive index and low loss dielectric materials [1], particularly Silicon Nitride. All fabrication is done on campus, with dedicated cleanrooms for patterning, material deposition and etching. Our main focus is using these metasurfaces for visible light – due to obvious applications in imaging and sensing; because of the complexity of making dielectric nanostructures with high aspect ratio, we are one of the few groups in the UK with the capability and expertise to achieve this.

Using our expertise in dielectric metamaterials, our focus lies in the development of new and exciting imaging techniques alongside novel metasurfaces. One such technology that we are working towards is *Light Field Imaging* [2] which relies on arrays of metalenses in conjunction with an image sensor to computationally reconstruct the scene in 2.5D, with post-capture focus, parallax, and depth-of-field being possible *with only a single image.* Other fields of research are wide-angle imaging and sensing, polarimetry and High Dynamic Range (HDR) contrast using polarised metasurfaces, optical-bench-on-a-chip, and aberration correction. These can be applied to numerous sectors, such as life sciences, biomedical imaging, defence and security, fibre-based imaging, novel physics, and augmented reality.

References

[1] M. Kenney et al, SPIE Optical Metrology, 110570C (2019)

[2] R. J. Lin al., Nature Nanotechnology, 14, p227 -231 (2019).

Disordered metasurfaces for passive display

Liu, C.[1], Mao, P. [2], Han, M. [2], Palmer, R. E. [3], Zhang, S. [4], Maier, S. A. [5]

[1] Centre for Metamaterials Research and Innovation, University of Exeter, Exeter EX4 4QL, UK
[2]National Laboratory of Solid State Microstructures and Collaborative Innovation Centre of Advanced Microstructures, Nanjing University, Nanjing, China

[3] Nanomaterials Lab, Department of Mechanical Engineering, Swansea University, Bay Campus, Fabian Way, Swansea, SA1 8EN, UK
[4] Department of Physics, University of Hong Kong, Hong Kong, China
[5]School of Physics and Astronomy, Monash University, Clayton, Victoria 3800, Australia

Contact: c.c.liu@exeter.ac.uk

PROBLEM: Passive display without consuming any power is desirable for a sustainable future. Photonic structures can produce vivid colours with unparalleled resolution and stability compared to dyes. However, the cost of structures with feature sizes below optical wavelength significantly limits the practical applications.

SOLUTION: Taking recent advances in fundamental physics, we proposed and realised a metasurface composed of plasmonic nanoparticles with disorder but excellent performance. With a judicious design, the disorder (fabrication imperfection in shape and position) can improve colour purity [1]. Meanwhile, the disorder even offers opportunities to use cheaper materials (copper and aluminium) instead of noble metals with good plasmonic response (such as gold and silver) [2]. Combined with a lithography-free fabrication, the solution may shed light on large-scale colouration.

WHY USE A METAMATIERAL: Metamaterial can achieve optical properties never exist in NATURE. Utilising this platform, we can turn gold/silver/Copper into different vivid colours while keeping its chemical properties, driving the colour extremely stable compared to dyes we use daily.

References

[1] Mao, P., et al. Manipulating disordered plasmonic systems by external cavity with transition from broadband absorption to reconfigurable reflection. Nat Commun 11, 1538 (2020).

[2] Mao, P., Liu, C., Niu, Y. "Disorder-Induced Material-Insensitive Optical Response in Plasmonic Nanostructures: Vibrant Structural Colors from Noble Metals." Advanced Materials 33.23, 2007623 (2021).

Enhancing optical devices through controlled light scattering

Khumar, B..[1], Wynne, L. C.[1], Alhamdan, I.[1], Das, A.[1], Schulz, S.A..[1]

[1] SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16922, UK

Contact: Sebastian Schulz

Within the nanophotonics group we engineer the scattering of light in photonic systems to enhance light matter interactions, resolution of metrology devices and holographic displays operating across a wide wavelength range.In this poster we will highlight some key results, showcasing multiple applications.

Multiple scattering in aperiodic and controllably disordered optical systems is used to enhance the resolution and throughput of spectrometer devices [1], while nanoresonators are employed for high resolution displacement sensing [2,3]. Scattering from regular periodic resonator arrays is used to enhance light matter interactions in metasurfaces incorporating epsilon-near-zero metasurfaces [4,5], as well as generating shape-multiplexed holographic images [6].

References

[1] B. Kumar and S. A. Schulz, Emerging Applications in Silicon Photonic III , 12334, 18-21 (2022).
[2] A. Bag et al., Nature Communications 11, 2915 (2020).
[3] P. Beck et al., APL Photonics 8, 046113 (2023).
[4] M. Z. Alam et al Nature Photonics 12, 79 (2018).
[5] L.C. Wynne et al. Photonics and Nanosctructures – Fundamentals and Applications 42, 100844 (2020).
[6] J. Xiao et al., Advanced Materials Technologies 2202006 (2023).

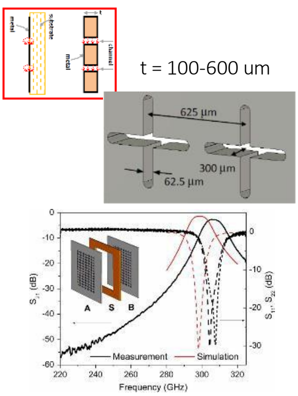
Exploring new manufacturing technologies for millimetre- wave and sub-terahertz metamaterials

Wang, Y.[1], Dimov, S.[2], Attallah, M.[3]

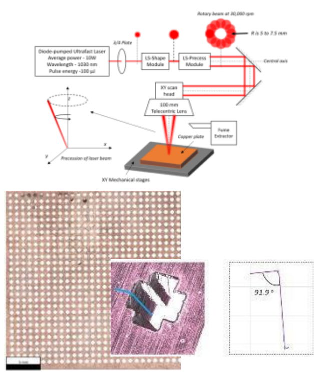
[1] Emerging Device Technology (EDT) Lab, School of Engineering, University of Birmingham, Birmingham B15 2TT, UK
[2]Advanced Manufacturing Technology Centre, School of Engineering, University of Birmingham, Birmingham B15 2TT, UK
[3]Advanced Materials and Processing Lab (AMPLab), School of Metallurgy and Materials, University of Birmingham, Birmingham B15 2TT, UK

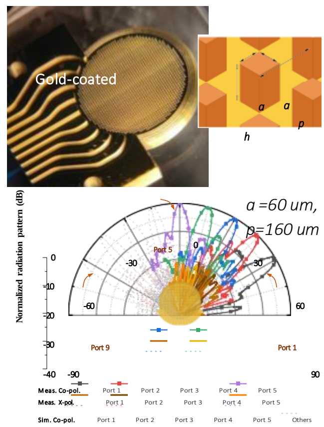
Contact: y.wang.1@bham.ac.uk

We have explored new manufacturing techniques for millimetre-wave and sub-terahertz metamaterials. These include: (1) the cleanroom-based bulk micromachining; (2) the femto-second laser micro processing; and (3) the high-precision 3D printing technique. The first two have been demonstrated on a THICK metal mesh filter free of substrate for its high quality-factor. The third one has been demonstrated on a metallic surface-wave Luneburg lens multi-beam antenna. All work in the 300 - 500 GHz range and could potentially be scaled up or down. The work is primarily to address the manufacture challenge in three-dimensional (either true 3D or thick planar structures) metamaterials.



Bulk micromachining [1]


fs-laser micro process [2]



High-precision 3D printing [3]

References

[1] Y. Wang, et al., “Micromachined Thick Mesh Filters for Millimeter-Wave and Terahertz Applications”, IEEE Trans. THz Sci. Techn., vol. 4(2), pp. 247-253, Mar. 2014.

[2] H. Le, et al., 'Laser precession machining of cross-shaped terahertz bandpass filters', Optics and Lasers in Engineering, vol. 149, 106790, 2022.

[3] B. Nie, et al., "A 3D-Printed Sub-terahertz Metallic Surface-wave Luneburg Lens Multi-beam Antenna," IEEE Trans. THz Sci. Techn., Feb. 2023.

Head Injury Mitigation of an Elastomeric Honeycomb Helmet: A Computational Investigation

Rhosslyn Adams[1], Shwe Soe[2] and Peter Theobald[1]

[1] School of Engineering, Cardiff University, Cardiff, UK
[2] School of Engineering, University of the West of England, Bristol, UK

Contact: shwe.soe@uwe.ac.uk

Contemporary materials used in the traditional helmet liner has limited capabilities to absorb multi-directional impact forces that contributes to the cause of Traumatic brain injury (TBI) which is the most severe form of head injury that can arise from accidents within sports, crashes, or blasts, leading ultimately to disability or death.

We offer the novel route of optimising elastomeric metamaterial using advanced computational tools and additively manufacture to mitigate the risk of head injuries [1].

The greater geometric freedom offered by additively manufacturable metamaterial hold a notable advantage over stochastic cellular structures with tailorable mechanical properties representing a viable route to improving helmet liner performance [2].

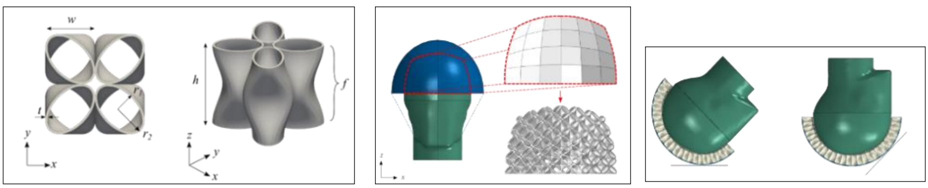


Fig (1) Metamaterial precisely conformed to the shape of the head and under impact

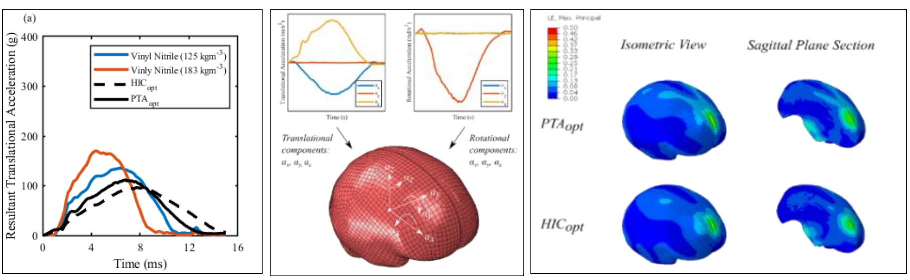


Fig (2) Experimental data, Finite Element head model and strain distribution in head

References

[1] A. Rhoss et al., Materials and Design, 213, 110368 (2022).
[2] S. Soe et al., Additive Manufacturing, 39, 101885 (2021).

Implantable Patch Antenna Based on Elliptic Spiral Split Rings

Alrawashdeh, R. [1] and Zhou, J.[2]
[1] Department of Electrical Engineering, Mutah University, Alkarak 61710, Jordan
[1] Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool L69 3GJ, UK

Contact: zhouj@liverpool.ac.uk

Implantable antennas have a major role in tele-healthcare applications. However, they normally have weak radiation as the human body absorbs most of their radiation. One of the suggested techniques to boost the antenna radiation is to increase its near magnetic field and decrease its near electric field. Metamaterial antennas based on split rings have shown good capabilities in controlling electromagnetic fields and thus have improved radiation and overall performance [1]. The size of such an antenna can be miniaturised as well. In this work, a small patch antenna based on elliptic spiral split rings, as shown Fig. 1, is designed and proposed for implantable applications.

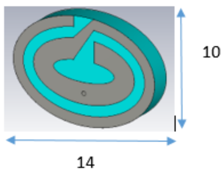


Fig. 1. The proposed antenna structure (dimensions: mm).

The antenna is simulated in a simplified body model of muscle. It works with S11< -10 dB for the 401-406 MHz and 433-434 MHz bands, as shown in Fig. 2, which are specified for implantable applications. The antenna's realized gain has increased by up to 2 when the split rings are spiralled with each other. This is because the spiral structure with the rings optimizes the antenna performance providing the required miniaturization effect and strengthening the near magnetic field at the same time.

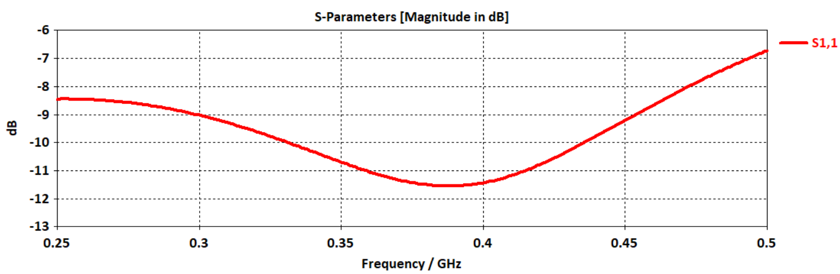


Fig. 2. The reflection coefficient S1,1 (dB) of the proposed antenna.

References

[1] A. Altarawneh and R. Alrawashdeh, "A Multilayer Implantable Patch Antenna Based on Spiral Split Rings," 2022 International Workshop on Antenna Technology (iWAT), Dublin, Ireland, 2022, pp. 37-40

Lithium-Ion Battery degradation characterisation using metamaterial's enhanced ultrasonic signatures

Bashir, I.[1], Maher, A. [1]

[1] Smart Energy, Power Conversion and Control research group
[1] School of Computing, Engineering and Digital Technologies, Teesside University, Middlesbrough TS13BX, UK

Contact: i.bashir@tees.ac.uk

For accurate battery monitoring, synergistic examination across various length and time scales, also the utilisation of a variety of experimental approaches, is required to fully comprehend the causes and effects of LiB degradation. Several techniques were used such as EIS, X-rays, CT-scans, etc. Although these methods allow a mechanistic understanding of battery degradation and provide all the signatures of degradation. However, all these techniques requiring invasive and expensive experimental procedures. Therefore, ultrasonic battery measurement methods have recently been applied and demonstrated an effective way in battery monitoring. It works by sending an ultrasonic pulse to the battery and then listening for the echoes. The current ultrasonic methods treat the battery as a bulk media, making it unable to link ultrasonic waves propagation to degradation mechanisms.

Recently, the characterisation of individual degradation phenomena using metamaterials enhanced ultrasonic signatures is being carried out. This is challenging but identifying the signature and co-relating with the degradation process is a leap forward step for the development of an intelligent onboard monitoring system. This pilot study intends to demonstrate the feasibility for the characterisation of ultrasonic signature related to degradation events and development of wave propagation modelling through heterogenous media. Finite Element Modelling (FEM) is being used to create a Physics-based Model (PM) of the batteries to study the ultrasonic wave propagation through heterogenous media. The focus is mainly to study the two most critical degradation phenomena i.e., Solid Electrolyte Interface layer growth and Particle Cracking using metamaterials enhanced ultrasonic signatures.

Manufacturing and mechanical properties of open cell auxetic polyurethane foam

Zhang, Q.[1], Yu, X.[1], Ji, W.[1], Scarpa, F.[1]

[1] Bristol Composites Institute, University of Bristol, Bristol BS8 1TR, UK

Contact: qicheng.zhang@bristol.ac.uk and f.scarpa@bristol.ac.uk

Porous materials and foams for applications ranging from apparel to protective equipment need to combine resilience, energy absorption, adaptability to shape and relative low-cost. Auxetic polyurethane (PU) foam combine the advantages of the auxetic deformation and the use of commercially available PU foam material, thus leading to multifunctional properties such as indentation resistance, synclastic behavior and high energy absorption. Those properties are critical to make auxetic foams. part of the answer for innovative applications ranging from personal protective equipment, noise reduction, cushioning and aircraft seats.

We describe a simplified procedure to manufacture auxetic PU foam via a single direction thermoforming compression process applied to conventional open cell foam samples[1]. The foams are then characterized via a series of mechanical tests (compression, tension, shear, indentation to vibration and impact) using different custom designed rigs. A multi-scale finite element simulation method based on µ-CT scanned 3D models and skeletonization algorithm[2], plus a dynamic poroelastic model have also been developed for the design of these porous metamaterials[3,4]. Compared to other viscoelastic and readily available commercial foams for packaging and apparel, these auxetic foams show increased anisotropic stiffness distribution[2], negative Poisson's ratio for confront and indentation, and efficiency under impact loads[5] similar to those of EPS foams used in protective head gear.

References

[3] Q. Zhang et al., *Materials & Design*. 211, p 110139-110155 (2021).

[4] Q. Zhang et al. *Composites Part B: Engineering*. 237, p 109849-109862 (2022).

[5] Q. Zhang et al. *Mechanical Systems and Signal Processing*. 179, p 109375-109395 (2022).

[6] Q. Zhang et al. *Nonlinear Dynamics*. 2022, p 1-27 (2022).

[7] Q. Zhang et al. *International Journal of Impact Engineering*. 163, p 104176-104192 (2022).

Mathematical theory for periodic approximations of quasiperiodic metamaterials

Davies, B.[1], Morini, L.[2], Craster, R.V.[1]

[1] Department of Mathematics, Imperial College London, London SW7 2AZ, UK
[2] School of Engineering, Cardiff University, Cardiff CF24 3AA, UK

Contact: bryn.davies@imperial.ac.uk

Quasiperiodic metamaterials show significant potential (such as large spectral gaps and appealing robustness) but are underutilised in applications, partly due to the lack of efficient modelling techniques. The aim of our work is to develop concise and computationally efficient methods for predicting the transmission spectra of quasiperiodic metamaterials.

The most common approach for predicting transmission gaps in quasiperiodic metamaterials, without relying on very large numerical simulations, is to approximate the material by a periodic version of itself. A large section is taken as the unit cell, known as a *supercell*, to which standard Floquet-Bloch techniques can be applied. Understanding how to relate the spectrum of the periodic approximant (which is generally a countable set of continuous Bloch bands) to the Cantor-like, fractal spectrum of the quasiperiodic metamaterial is a challenging problem.

As a demonstrative example, we study a class of one-dimensional quasiperiodic metamaterials with structures arranged according to generalised Fibonacci tiling rules. One of their characteristic features is that the main band gaps are preserved as the size of the periodic approximant increases. This was observed by [1] and named *super band gaps*. We have proved their existence in the sense that there are frequencies which will be in the band gaps of any sufficiently large periodic approximant [2].

This gives rigorous justification for the use of supercell approximations, which is an efficient method to predict the main spectral gaps in a quasiperiodic metamaterial. This facilitates their use in applications, such as the design of waveguides [3], enlarging the metamaterial design space beyond periodic structures.

References

[3] L. Morini and M. Gei, J. Mech. Phys. Solids 119, 83–103, (2018).
[4] B. Davies and L. Morini, preprint arXiv:2302.10063, (2023).
[5] R.V. Craster and B. Davies, Wave Motion 115, 103068, (2022).

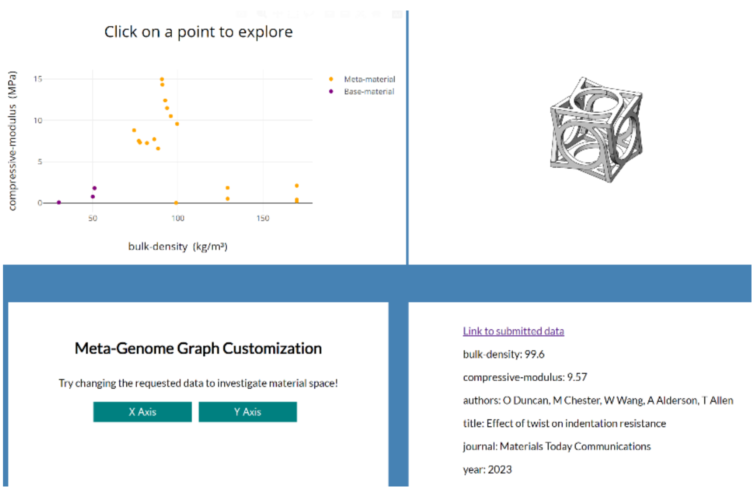
MetaGenome - Metamaterials community shared database with developed material topologies and associated properties

Szyniszewski, S.[1], Earnshaw J. [1], Byers, J. [1], Duncan, O.[2] Kaczmarczyk, L.[3], Scarpa, F.[4]

[1] Department of Engineering, University of Durham, Durham, DH1 3LE, UK
[2] Department of Mechanical Engineering, Manchester Metropolitan University, Manchester, UK
[3] Department of Civil Engineering, University of Glasgow, Glasgow, UK
[4] Department of Mechanical Engineering, University of Glasgow, Bristol, UK

Contact: stefan.t.szyniszewski@durham.ac.uk

Meta-genome aims to create an open research commons for the community of Metamaterials researchers, such that they can deposit the critical properties of their materials such that industrial users and other academic groups can find them. Publishing open-access datasets is now a requirement of the funding bodies and a general expectation from the scientific community. Nevertheless, the data is usually deposited in various formats into various institutional repositories and ad hoc data formats and properties. STL files for 3D printing or simulation input decks are generally unavailable. Here, we aim to create open research commons where the data can be deposited quickly, using standard formats, such that one can search for recent results by prescribing property range or desired properties.



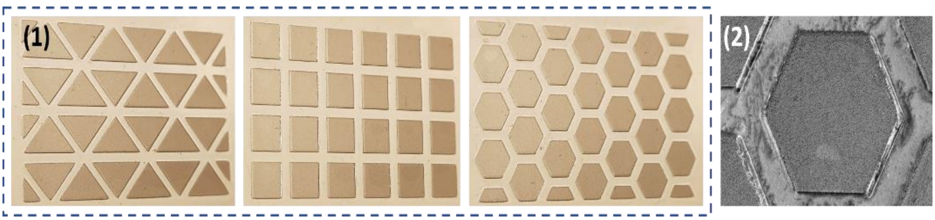
Metamaterial for tuneable compressive response in prosthetic liners

Khan, S.[1], Vijjapu, M. T. [2], Kosel, J.[3]

[1, 2, 3] Sensor Applications, Silicon Austria Labs GmbH, 9524 Villach, Austria

Contact: Sherjeel.Khan@silicon-austria.com

Prosthetics have reformed the lives of leg amputees, but pressure-related problems (discomfort and skin breakdown) are still a significant concern. The prosthetic socket, where the residual limb sits, is a critical interface between the residual limb and the prosthesis. A liner (cushioning material) is worn over the residual limb to reduce movement and chafing between the skin and the socket. For optimal wearing comfort, bony areas of the stump ideally require soft liner material while areas of the stump with soft tissue need a stiffer material [1]. We have proposed a unique approach to create versatile liners using metamaterials that can have variable local stiffness adapted to patient needs. Here, varied stiffness was achieved by varying the shape of the unit cells. Our design also allows integration of a pressure sensor in each unit cell to monitor the forces experienced by the patients in real time. Fig. 1 shows the three designs with unit cells in the shape of a triangle, square, and hexagon fabricated using screen printing of a suitable liner material (i.e., PDMS). The transparent areas are PDMS walls, and the grey areas are silver metal on the substrate. The stiffness of the metamaterial was linked to the shape of the unit cell. Fig. 2 shows the walled structure of the metamaterial. Besides being an additive manufacturing method, screen printing offers a unique advantage in that the PDMS walls intrinsically form a draft angle of 35°- 45° that allowed us to achieve lower stiffness compared to the bulk material [2]. Thus, we achieved higher compliance (softer than bulk material) with adjustable design variables (linked to the unit cell) to alter the compressive response of the (meta)material.



References

[1] S. Henao et al., Scientific Reports 10, 4985 (2020).

[2] N. Brown et al., Journal of Biomechanical Engineering 143(5), 051001 (2021).

Metasurface enabled multifunctional microscopy.

Ansari, M. A.[1], Intaravanne, Y. [1,2], Ahmed, H.[1], Bileckaja, N.[3], Yin, H.[3], Chen, X.[1]

[1] Institute of Photonics and Quantum Sciences, School of Engineering and Physical Sciences, Heriot-Watt University, EdinburghEH14 4AS, U.K.

[2] National Electronics and Computer Technology Center, National Science and Technology Development Agency, 112 Thailand Science Park, Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani12120, Thailand.

[3] Biomedical Engineering Division, James Watt School of Engineering, University of Glasgow, GlasgowG12 8QQ, U.K.

Contact: Muhammad Afnan Ansari

Edge and polarimetric imaging play an essential role in the enhancement of target detection and recognition performance. However, an imaging system with such multiple functionalities tend to be bulky and expensive because of the substantial footprint of their benchtop-based electronic and optical components. Here, we propose a multifunctional 3-in-1 microscope based on an ultrathin metasurface device which can concurrently perform polarimetric, edge and microscope imaging to visualize the multiple facets of transparent biological samples in real-time as shown in Figure 1 [1].
We experimentally demonstrate the capability of the proposed 3-in-1 metasurface-based microscope with various samples. Using the proposed device, the edge imaging enabled reliable and fast cell detection. The polarimetric imaging acquired the complete polarization information. This is used to resolve microstructures and the anisotropic information, for example, their orientation and ordering. Edge and polarimetric information are complementary to that obtained through traditional microscopy imaging, allowing the visualization of multiple facets of the target samples in real-time.

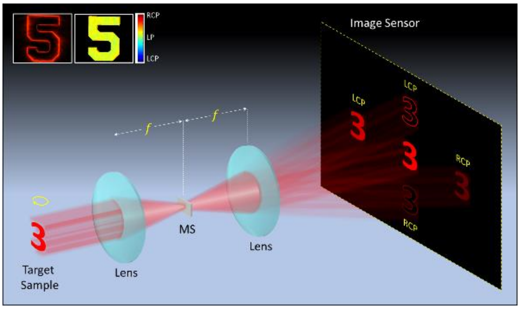


Figure 1. Metasurface enabled multifunctional microscopy.

References

[1] Y. Intaravanne, M. A. Ansari et al., Metasurface-Enabled 3-in-1 Microscopy. Vol 10, p 544–551 (2023).

Microstructurally controlled lattices for functionally graded performance

Freeman, F.[1], Goodall, A. [1], Todd, I.[1]

[1] Department of Materials Science & Engineering, University of Sheffield, Sheffield, S1 3JD

Contact: f.freeman@sheffield.ac.uk

Manufacturers need highly engineered materials capable of meeting stringent performance requirements while being easily recyclable for ongoing sustainability. Metamaterials move beyond traditional material properties, combining spatial control of functional behaviour with an active response to an external stimulus, fitting performance to need in a manner analogous with natural materials like bone and bamboo. My research is focussed on exploiting solid-state phase transformation to engineer microstructurally-graded metamaterials within the material composition envelope [1]. This enables agile design, allowing simultaneous adjustment of microstructure and component geometry, while maximising sustainability by retaining material value for end-of-life recycling. This is demonstrated on microstructurally-graded steels, using build parameters to selectively suppress and trigger the phase transformation from weak, ductile austenite to strong, brittle martensite [2]. I am now developing metamaterial steel lattices for energy absorption, enabling preferred load directions to be activated on impact to direct damage away from the substrate.

References

[1] F. Freeman et al., Influence of solidification cell structure on the martensitic transformation in additively manufactured steels, Additive Manufacturing. 30 100917 2019

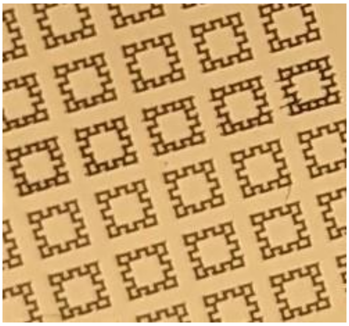
[2] F. Freeman et al., Exploiting thermal strain to achieve an in-situ magnetically graded material, Materials & Design. 161 14–21 2019

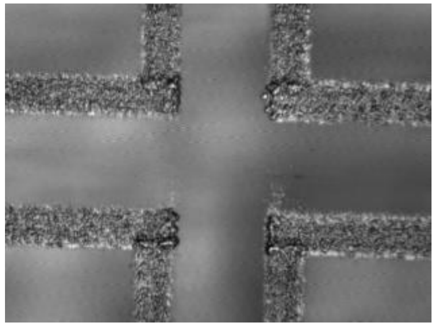
Microwave Metamaterials – Not just a PCB

Henthorn, S., Ford, K. L.

Department of Electronic and Electrical Engineering, University of Sheffield, Sheffield, S1 4ET, UK

Contact: s.henthorn@sheffield.ac.uk





When thinking of microwave metamaterials, we usually picture printed circuit board technology. Here, we show samples of metamaterials fabricated in a variety of ways, enabling flexible and conformal behaviour. This includes aerosol jet printed (AJP) metasurfaces – a "spray-on" technology which can produce conductive patterns at μm precision onto conformal surfaces; knitted and woven fabric metamaterials, which allow scalable manufacturing using commercial machines and looms, as well as enabling wearable, conformal and lightweight designs; and electronically reconfigurable materials.

The samples are for a range of applications, including transmitters for wireless communications, which can modulate information onto a radio carrier wave at transmit power and frequency; mmWave reflectarrays, for producing narrow beams of radiation to help overcome high pathloss at mmWave frequencies; and radar scattering materials for stealth.

Nano-opto-mechanical Metamaterials: Parametric Frequency Mixing, Frequency Combs and Photonic Time Crystals

Liu, T.[1], Li, J.[1, 2], Ou, J.-Y.[1], MacDonald, K. F.[1], Zheludev, N. I.[1, 2]

[1] Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, Southampton, SO17 1BJ, UK

[2] Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore 637371

Contact: Tongjun.Liu@soton.ac.uk

We demonstrate that photonic metamaterial systems in which structural mechanical resonances at ~MHz frequencies are strongly coupled to near-IR optical resonances offer an ideal, highly adaptable platform for the realization and exploitation of parametric effects at μW/μm^2 intensities (e.g. frequency mixing and comb generation) and, moreover, that such structures can be driven to a state possessing all key features of a continuous 'time crystal' - an eagerly-sought new state of matter with properties that are periodic in time, rather than in space. These phenomena, and the simplicity and control achievable in the nano-opto-mechanical metamaterial platform, open a path for the study of time-varying photonic media, classical many-body states in the strongly correlated regime, and for applications in all-optical modulation, frequency conversion, metrology and timing.

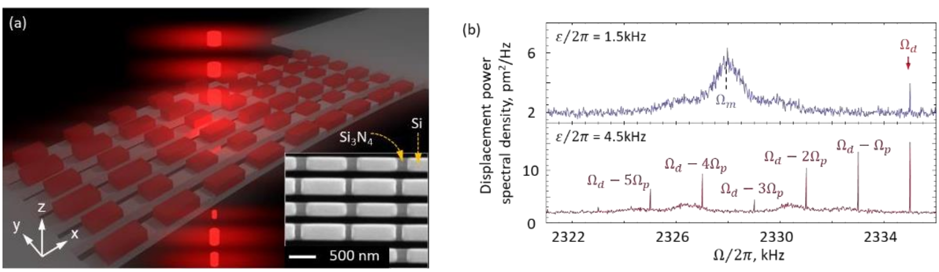


Fig 1 (a) Artistic impression of a metamaterial array of silicon-on-silicon-nitride nanowire oscillators. The inset SEM image shows a portion of the experimental sample. (b) Phononic frequency comb generation: signal at the optical driving frequency Ω_d increases with parametric pumping strength ε as a result of parametric gain, and a series of 'teeth' appear at frequencies $\Omega_d \pm N\Omega_p$.

Numerical investigation of Poisson's ratio and the influence of re-entrant Auxetic unit cell arrangement

Vance, A.[1]

School of Engineering, Faculty of Science and Engineering, University of Wolverhampton, Telford Campus, Telford TF2 9NT, United Kingdom

Contact: a.vance@wlv.ac.uk

The problem

An ageing worldwide population presents a global healthcare challenge like none before. Increased prevalence of arthritic conditions will heighten the requirement for surgical intervention at many anatomic weight-bearing sites, [1–3]. Whilst total hip arthroplasty (THA) is considered a successful and cost-effective intervention method to address osteoarthritis of the hip, current techniques do not fully address the flexural loading scenario. This design inadequacy leads to aseptic loosening remaining a primary attributable factor of total hip arthroplasty revision surgery, [1–7].

Metamaterials, more specifically the unusual negative Poisson's ratio (v) that Auxetic structures exhibit, present the opportunity to enhance bone-implant interaction, [5–9]. This research investigates the use of numerical modelling methods to evaluate v for Re-entrant bow-tie unit cell arrangements.

Findings

The lateral displacement was investigated with varying unit cell configurations between 1x1 and 10x10. It has been revealed that v varies dependent on lateral displacement data acquisition strategy and unit-cell configuration, Figure 2. It is shown to be appropriate to deploy the 5x5 arrangement and to avoid single unit cell configurations.

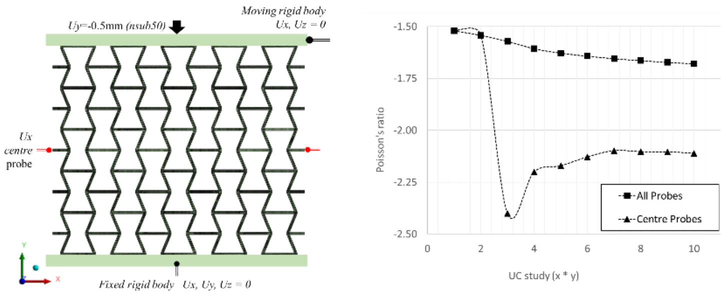


Figure 2 – 5x5 configuration example and resultant Poisson's ratio values

Future works

Based on the findings presented in these works, future investigations are considering the relation of lateral to longitudinal strain of three-dimensional Auxetic geometries and the optimisation of additively manufactured load bearing implants.

References [1-7] Please contact the author. *Page limited exceeded.*

Optical Metasurfaces: building blocks of tomorrow's technologies

Rahmani, M.*, Xu, L., Ying, C.

[1] Department/Entity, University, City & Postcode, Country

Contact: mohsen.rahmani@ntu.ac.uk

Light-matter interactions can be highly controlled via nanoscale structures, hundreds of times thinner than human hair. A single-layer of designed and engineered subwavelength nanostructures, so-called metasurfaces, can resonantly couple to the incident light and manipulate the light's behaviour on demand. Metasurfaces can reproduce the functions of bulk optics and, on occasions, can offer new functionalities that are not possible with conventional diffractive optics. In this showcase, I will demonstrate the research activities of the newly formed Advanced Optics and Photonics Group at Nottingham Trent University on light-matter interaction with metasurfaces [1-3]. I will discuss the group activities on employing metallic, dielectric and semiconductor metasurfaces to control the light intensity, frequency and propagation direction. I will demonstrate how metasurfaces can lead to several exciting applications, including flat optics [1], near-infrared imaging [2], and ultra-sensitive biochemical sensing [3].

References

[1] K. Zanganeh Kamali, et al., Electrically programmable solid-state metasurfaces via flash localised heating", Light: Science and Application 12, 40 (2023).
[2] Zheng, Ze, et al., Third-harmonic generation and imaging with resonant Si membrane metasurface, Opto-Electronic Advances, Opto-Electron Adv 2023, 220174 (2023).
[3] Yousefi, et al., Optical Monitoring of In Situ Iron Loading into Single, Native Ferritin Proteins, Nano Letters, ASAP https://doi.org/10.1021/acs.nanolett.3c00042 (2023).

Plasmonic metasurfaces as cross-reactive artificial taste buds

Clark, A.W.[1]

[1] James Watt School of Engineering, University of Glasgow, Glasgow, UK

Contact: Alasdair.clark@glasgow.ac.uk

Currently, the beverage industry relies on large and expensive analytical tools for quality control that are not suitable for real-time, in-line monitoring. Alternatively, human tasters can be trained to recognize impurities within batches of product, but they are prone to giving inconsistent scores due to the nature of human taste. Therefore, there is a need for real-time sensory tools that can be deployed within production facilities for quality control, ideally providing "taste" scores similar to those of human testers.

We have developed a novel array of metasurfaces that, when combined, act as an artificial tastebud device. Composed of millions of plasmonic nanostructures, each about 100nm x 100nm in size, the optical response of each metasurafce is highly dependent on the refractive index of any surrounding liquid, shifting the apparent colour of the metasurface.

Through specific chemical surface modification of the plasmonic nanostructures we can segregate the molecular components of sample liquids, ensuring that each differently-modified metasurface probes a different family of components within the liquid.

By comparing the resonance shifts from each array we generate a unique statistical score for each mixture; a score we can link to flavour profiles experienced by human tasters.

We are now working with commercial partners to bring a bench top product to market, for applications in beverage production, counterfeit detection, and water quality monitoring.

Plasmonic nanorod metamaterials for sensing and catalysis

Roth, D.J.[1], Zaleska, A. [1], Zayats, A.V.[1]

[1] Department of Physics and London Centre for Nanotechnology, King's College London, London WC2R 2LS, UK

Contact: diane.roth@kcl.ac.uk

Our technology is based on optical metamaterials comprised of subwavelength metallic nanorods. Their unique electromagnetic properties arise from their material composition and geometric structure and are highly tuneable throughout the visible and near-infrared spectral range. The metamaterial is fabricated using a self-assembly technique achieving large area at a low cost compared to usual nanofabrication techniques. We will be demonstrating the metamaterial's capabilities for several applications, including:

- High sensitivity all-optical hydrogen sensing [1]. On interaction with low (subexplosive) concentrations of hydrogen gas, large changes to the metamaterial's optical response are induced, visible to the naked eye. This all-optical detection method guarantees a spark-free sensor, which can be remotely interrogated optically.
- Oxygen sensing and local chemical reactions [2]. Extending on the sensor above, we demonstrate a compact, electrically-driven plasmonic metamaterial device, based on highly reactive nanoscale tunnel junctions, which simultaneously operates as a light source and a sensor.
- Photocatalysis. Taking advantage of an increased reactive surface area and tailored optical properties, a copper nanorod metamaterial is used as a highly-efficient photocatalyst for the plasmon-driven catalytic conversion of CO_2.

References

[1] M.E. Nasir et al., Advanced Materials 26, p 3532–3537 (2014).

[2] P. Wang et al., Nature nanotechnology, p 159–164 (2018).

Position Nano-metrology with Topologically Structured Light

Rhea T. Sam[1], Jun-Yu Ou[1], Kevin F. MacDonald[1], and Nikolay I. Zheludev[1,2]

[1]Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, UK
[2]Centre for Disruptive Photonic Technologies, TPI, SPMS, Nanyang Technological University, Singapore

Contact: rts1v21@soton.ac.uk

We present a novel single-shot, real-time optical ruler for detecting nanometric displacements as small as λ/400, enabled by a Pancharatnam-Berry phase metasurface and a polarization-sensitive camera.

The optical ruler generates a complex electromagnetic field with subwavelength singularities that serve as marks on a deeply subwavelength scale, allowing for high-resolution lateral displacement measurements between two platforms - one supporting a laser source, polarization-optics and metasurface: the other, imaging optics and a camera. Our implementation overcomes limitations of previous designs by capturing diffraction patterns for four different polarization states simultaneously, eliminating the need for moving parts and reducing measurement uncertainties.

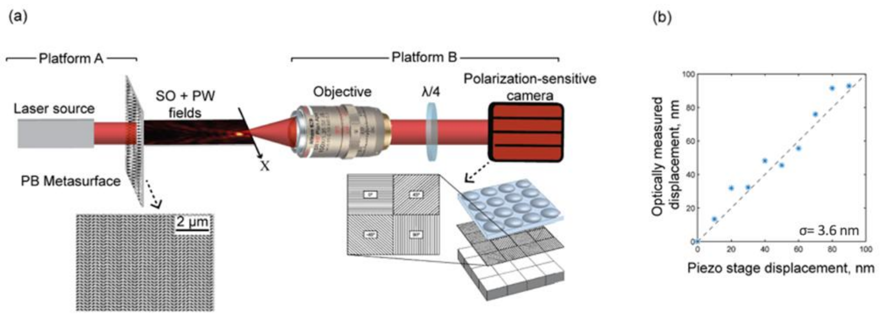


Fig. 1 (a) Schematic showing key components of the arrangement for measurement of nanometric displacement between the two platforms, *A* and *B*, in the *x* direction. (b) Optical ruler measurement of piezoelectrically-controlled displacement between platforms A and B.

The key component is a polarization-sensitive camera (Fig. 1a) with pixelated sensitivity to four linear polarization states (0°, 45°, 90°, and 135°). With an operating wavelength of λ = 642 nm and magnification of 550×, we achieve a measurement precision of 3.6 nm. Our optical ruler offers a robust, real-time solution for nanometric displacement measurement in a range of applications.

Scalable and Multifunctional Sensors by Inkjet Printed Graphene Network

Wang, F.[1], Heaton, C.[1], Gosling, J.[2], Im, J.[1], Austin, J.[1], Cottam, N.[2], Fromhold, T.M.[2], Makarovsky, O.[2], Wildman, R.[1], Hague, R.[1], Tuck, C.[1], Turyanska, L.[1]

[1] Faculty of Engineering, University of Nottingham, Nottingham NG7 2RD, UK
[2] School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, UK

Contact: F.Wang@nottingham.ac.uk

As a novel layered 2D material, graphene has induced a boom in the field of sensor research around the world due to its advantages in mechanical, thermal, and electrical properties.[1] However, the need for high quality mass production, large area fabrication and the homogeneous deposition on various substrates poses a great challenge. We employ inkjet printing as an advanced and convenient fabrication method for achieving comparative effectiveness and multi-material vertical stacking.[2] A scalable fully inkjet-printed graphene multifunctional sensor matrix which integrated humidity, thermal, and pressure sensors was fabricated using two layers of graphene arrays separated by a dielectric layer. The integration of all three sensors into a matrix required that each sensor provide output responses to a specific stimulus without being interfered by other stimuli. The bottom graphene layer can sense the temperature change and the top graphene layer were as the humidity sensing arrays. The dielectric layer sandwiched between two graphene arrays acted as an active layer for the capacitive pressure sensors. The responses have been modelled by inter-flake tunnelling of the printed graphene network.[3] Further functionality can be integrated by bringing in additional layers, such as detecting hazardous chemicals and gases. [4] Such multifunctional sensors can be fabricated on flexible substrates such as fabrics and have wide applications in environment monitoring and healthcare devices.

References

[1] Nag A, Mitra A, Mukhopadhyay S C. Graphene and its sensor-based applications: A review[J]. Sensors and Actuators A: Physical, 2018, 270: 177-194.

[2] Wang F, Gosling J H, Trindade G F, et al. Inter-flake quantum transport of electrons and holes in inkjet-printed graphene devices[J]. Advanced Functional Materials, 2021, 31(5): 2007478.

[3] Gosling J H, Makarovsky O, Wang F, et al. Universal mobility characteristics of graphene originating from charge scattering by ionised impurities[J]. Communications Physics, 2021, 4(1): 30.

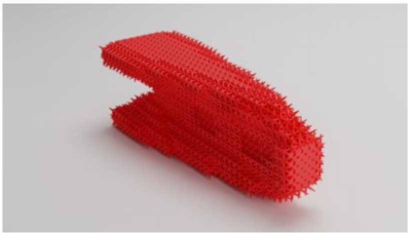
[4] Huang, Le, et al. "Multifunctional graphene sensors for magnetic and hydrogen detection." ACS applied materials & interfaces 7.18 (2015): 9581-9588.

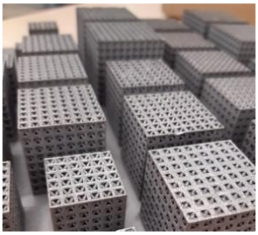
Structural Metamaterial Optimization

Ryan Murphy[1], Dilaksan Thillaithevan[1], Rob Hewson[1], Matthew Santer[1]

[1] Department of Aeronautics, Imperial College London, London, UK
Contact: r.murphy17@ic.ac.uk, d.thillaithevan17@ic.ac.uk, rhewson@ic.ac.uk, msanter@ic.ac.uk

Multiscale structural optimization exploits the complex material response derived by metamaterials to design optimal structures with targeted material properties. We have developed a flexible three-dimensional multiscale optimization framework in which local microstructure properties are tailored by the optimizer to design structures with desirable macroscale properties [1]. Initially demonstrated using classical compliance-based structural optimization problems, this framework has since been extended to include frequency [2], stress [3] and manufacturing constraints [4] as well as considerations for manufacturing uncertainty [5] and thermo-structural [6] problems.





We have validated our work through single-scale finite element analysis and experimental testing. Our work has significant application across many fields. We have many industrial collaborations across the aerospace sector — particularly for lightweighting and frequency control — and as part of the EPSRC OncoEng (oncoeng.org) Programme Grant, current research is focused on the design of a highly nonlinear, deployable structural implant for the treatment of bone metastases.

References

[1] Imediegwu, C., Murphy, R., Hewson, R., and Santer, M., "Multiscale structural optimization towards three-dimensional printable structures," Struct Multidisc Optim, 2019. https://doi.org/10.1007/s00158-019-02220-y

[2] Nightingale, M., Hewson, R. & Santer, M. Multiscale optimisation of resonant frequencies for lattice-based additive manufactured structures. Struct Multidisc Optim 63, 1187–1201 (2021). https://doi.org/10.1007/s00158-020-02752-8

[3] Thillaithevan, D., Bruce, P. & Santer, M. Stress-constrained optimization using graded lattice microstructures. Struct Multidisc Optim 63, 721–740 (2021). https://doi.org/10.1007/s00158-020-02723-z

[4] Murphy, R., Hewson, R., Santer, M. In-loop additive manufacturing constraints for open-walled microstructures. Additive Manufacturing 48 (2021). https://doi.org/10.1016/j.addma.2021.102385

[5] Thillaithevan, D., Bruce, P. & Santer, M. Modelling material uncertainties using random irregularities in lattice based multiscale optimization. AIAA SciTech Forum (2022). https://doi.org/10.2514/6.2022-0634

[6] Imediegwu, C., Murphy, R., Hewson, R. et al. Multiscale thermal and thermo-structural optimization of three-dimensional lattice structures. Struct Multidisc Optim 65, 13 (2022). https://doi.org/10.1007/s00158-021-03087-8

Structurally reconfigurable and reusable metamaterials

Pope, S. A.[1], Claeyssens, F. [2], Khan, M. A. [1]

[1] Department of Automatic Control and Systems Engineering, University of Sheffield, Sheffield S1 3JD, UK
[2] Department of Materials Science and Engineering, University of Sheffield, Sheffield S1 3JD, UK

Contact: s.a.pope@sheffield.ac.uk

The majority of products manufactured today have a form fixed at manufacture. This makes them inherently inflexible to changes in user/environment demand and difficult to recycle at the end of their useful life. In contrast, most engineers know the benefits of digital reconfigurable architectures from childhood (e.g. LEGO ® studded bricks). They allow a product to be manufactured from a finite set of building blocks and then readily modified or de-constructed using an "inverse" process without generating unnecessary waste. Metamaterials inherently support the concept of a digitally reconfigurable architecture through the concept of the meta-atom.

We are developing a manufacturing process which uses non-contact techniques to repeatedly organise, assemble and disassemble building blocks to produce a material/device that can be considered as more than a sum of its parts. In other words, a Star Trek style replicator assembling discrete LEGO-like blocks of material. It will lead to a future transformation in the manufacture of structural and adaptable metamaterials.

Metamaterials manufactured with this approach can be readily tuned until a desired performance is achieved, reconfigured to meet a change in user/environmental demand, disassembled and blocks reused with minimal waste and repaired by replacing blocks.

Two photon polymerisation for metamaterials application

Im, J.[1], Liu, Y.[1], Hu, Q.[1], Trindade, G.[2], Parmenter, C.[3], Fay, M.[3], Wildman, R.[1], Hague, R.[1], Turyanska, L.[1], Tuck, C.[1]

[1] Centre for Additive Manufacturing, University of Nottingham, Nottingham NG7 2RD, UK
[2] National Physical Laboratory, Teddington TW11 0LW, UK
[3] Nanoscale and Microscale Research Centre, University of Nottingham, Nottingham NG7 2RD, UK

Contact: Jisun.Im@nottingham.ac.uk

A femtosecond laser-induced two photon polymerisation (2PP) is a high-resolution additive manufacturing technology that allows for the creation of highly precise and complex microstructures with submicron resolution. This technology has revolutionised the creation of micro- and nano-scale structures, leading to the emergence of new products and technologies. However, the limited availability of functional materials, especially metal nanoparticles that are suitable for use in this process, hinders the technology's full exploitation. Here we propose three complementary strategies for the integration of metal nanoparticles with 2PP processes to fabricate nanoparticle-polymer composites and metal nanoparticle-decorated surface patterns in microscale, which opens up the path for metamaterials application. We demonstrate the photonic metamaterials fabricated by two photon polymerisation for applications in sensors, such as surface enhanced Raman spectroscopy, and split ring resonators.

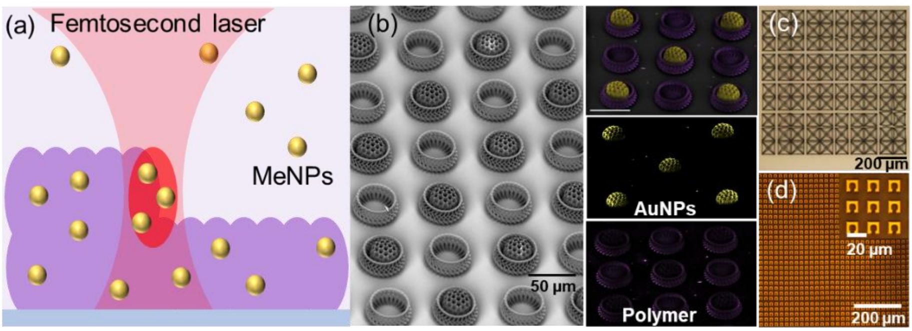


Figure 1. (a) Schematic diagram for integration of metal nanoparticles (MeNPs) with 2PP process, (b) SEM image (left) of 3D microstructures and ToF-SIMS mapping image (right) of a multimaterial structure for selective surface decoration of NPs [1], (c) an array of octahedral structure and (d) gold coated spilt ring resonators.

References

[1] J. Im et al., Advanced Functional Materials, p2211920 (2023).

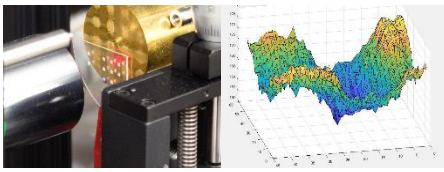
Ultracompact metasurface based instrumentation for manufacturing applications

D. Townend, J.H.-T. Chan, J. Kendrick, P. Yang, J. Williamson, D. Tang, N. Sharma, A.J. Henning, H .Martin, F. Gao, P. Scott, X. Jiang.

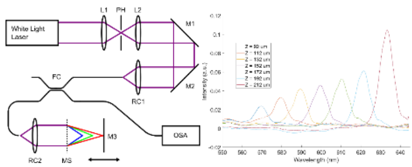
[1] Centre for Precision Technologies, University of Huddersfield

Contact: a.henning@hud.ac.uk

Manufacturing is moving towards the use of smart and autonomous processes to improve the outcome of manufacturing processes and reduce scrappage. However, in order to do this sensors need to be applied in a manner to allow sufficient feedback to be gained to control the processes. Optical sensors would seem ideal for this task, but their size and weight prohibit their application in many desirable applications. While efforts have been made to produce lightweight and compact optical instruments, the use of traditional refractive elements in their construction imposes a limit to the progress that is being made. By switching to metasurfaces to manipulate the light this barrier is overcome and a step-change in the size of instruments can be realised. Here we demonstrate several of our successes in creating metasurfaces for just such applications.



A picture of a metasurface element that carries out all of the optical manipulations needed to realise a confocal microscope is pictured on the left, and the resulting measurement of the diamond turned brass surface is pictured on the right [1].



A schematic of a chromatic confocal sensor realised using a metasurface is shown on the left, with the changing spectral response as the location of the mirror (M3) changes, shown on the right [2].

The illustrations above show our success in creating metasurfaces that carry out all the optical manipulations to realise a confocal instrument [1] (diagram on the left), and a chromatic confocal sensor [2] (shown on the right), but we are also looking to reduce instrument size through the use of metasurface spectrometers [3], and implement other instruments based on metasurfaces that realise techniques such as focus variation.

References

[1] “Metasurface Confocal – Enabling a Shift in Optical Instrumentation”, D.J. Townend, J. Williamson, D. Tang, N. Sharma, A.J. Henning, H. Martin, X. Jiang, to be presented at CLEO Europe 26 – 30 June 2023

[2] “An ultra-compact metasurface-based chromatic confocal sensor”, J.H.T. Chan, D. Tang, J. Williamson, H. Martin, A.J. Henning, X. Jiang, accepted for publication in CIRP Annals - Manufacturing Technology 2023

[3] “Towards miniaturised instrumentation realised via metasurfaces” J. G. Kendrick, A. J. Henning, H. Martin, J. Williamson, D. Tang, N. Sharma, X. Jiang. EUSPEN 23rd International Conference & Exhibition 12th – 16th June 2023, Copenhagen, Denmark

Visualising acoustic fields with liquid crystals

Trushkevych, O.[1], Billson, D.R [1], Hutchins, D.A [1], Turvey, M[2], Edwards, R.S. [2]

[1] School of Engineering, University of Warwick, Coventry, CV4 7AL,UK
[2] Physics Department, University of Warwick, Coventry, CV4 7AL,UK

Contact: o.trushkevych@warwick.ac.uk

Visualisation of acoustic fields may give feedback for designing and manufacturing of acoustic metamaterials. The gold standard for measuring acoustic fields and vibration is scanning laser vibrometry, but this method is not currently used for acoustic metamaterials research possibly because it can be slow due to point-by-point scanning, and can only measure displacement of a sample surface.

We have developed large area (tens of cm^2) low-cost passive sensors that can provide visual information about ultrasound energy (displacement of a vibrating surface, wavefront in fluid). The spatial resolution is at least mm. Such sensors are based on thermochromic liquid crystals (TLC) [1], they work in ultrasound range but may be extended to the audible range. The sensors can be paint-on or sheets, and we believe they may be able to visualise evanescent waves. We have demonstrated visualisation of resonant patterns of flexural transducer vibrating at high vibrational modes and standing Lamb waves on a plate, and edge resonances on a plate (Figure 1).

We are working on further developing these sensors, and applying them to metamaterials characterisation seems promising.

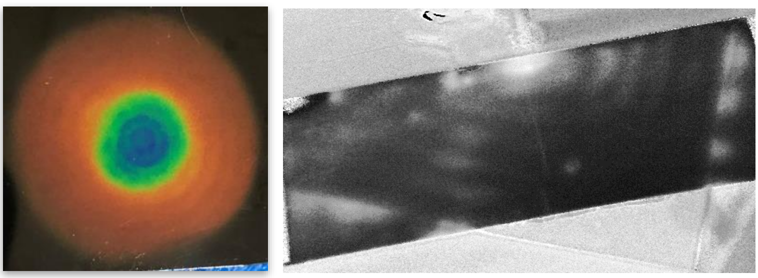


Figure 1. Visualisation of vibration using TLC sensors (a) high vibrational mode of a flexural transducer at 2.66 MHz; (b) visualisation of standing Lamb waves on a perspex plate, processed extracting hue for better visibility.

References

[1] UK Patent Application GB2112813.7 - Acoustic field visualisation

Wetting of auxetic metamaterials.

McHale, G.[1], Armstrong, S.[1], Mandhani, S.[2], Meyari, M.[1], Wells, G.[1], Ledesma-Aguilar, R.[1], Semprebon, C.[3], Carter, E.[2], Alderson, A.[2]

[1] Wetting, Interfacial Science & Engineering Lab, Institute for Multiscale Thermofluids, The University of Edinburgh, Edinburgh EH9 3FB, UK

[2] Materials & Engineering Research Institute, Sheffield Hallam University, Sheffield S1 1WB, UK

[3] Smart Materials & Surfaces Lab, Faculty of Engineering & Environment, Northumbria University, Newcastle upon Tyne NE1 8ST, UK

Contact: A.Alderson@shu.ac.uk

Auxetic metamaterials become wider when stretched lengthwise. This unusual expansion response is typically achieved by creating additional space in the lattices whilst maintaining constant solid area. This allows new types of strain-responsive superhydrophobic materials. Here we analytically model the unique wetting properties caused by strain-dependent changes in the Cassie-Baxter solid surface fraction and Wenzel roughness in an auxetic metamaterial. We then illustrate these ideas by constructing experimental models illustrating the relationship between different states of strain and superhydrophobicity as the lattice structure transitions from an auxetic to a conventional (positive Poisson's ratio) one.

Acknowledgement. The financial support of the UK Engineering & Physical Sciences Research Council (EPSRC) is gratefully acknowledged (EP/T025190/1 and EP/T025158/1).

Wireless Charging with High Flexibility and Reliability

Zhou, J.[1], Zhuang, Y. [1] and Chen, X.[1]

[1] Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, L69 3GJ, UK

Contact: jiafneg.zhou@liverpool.ac.uk

Wireless power transmission has been intensively researched for more than 15 years up to now, but the technology has not been widely adopted for wireless charging yet. Currently, there are mainly two ways to implement wireless charging: inductive coupling and resonant coupling.

For traditional inductive wireless charging, such as the Qi standard, while the charging efficiency can be >90%, the distance between the transmitter and receiver is very short, usually in the mm range. This requirement greatly limits its suitability for wireless charging. A receiver needs to be aligned with a transmitter with mm accuracy.

With more recent resonant charging, the range can be increased. Resonant coupling is a form of inductive coupling. By using resonance, power can be transferred at greater distances. The misalignment can be up to a few cm. For a few commercially available devices, the receiver should be aligned with the transmitter typically within a range of 2 cm. Optimization software is needed to adjust the system to improve efficiency.

Fig. 3 Wireless Charging of a Mobile Phone

We will show that, by using metasurface-based design methods, we can significantly improve the flexibility and reliability of resonance-based wireless charging. The key advantage of this patented technology is the great tolerance of misalignment without the need for any active or dynamic control [1]. It will be demonstrated that, as shown in Fig. 3, the charging system can achieve above 70% efficiency when a 7 cm × 7 cm receiver is misaligned by ±6cm on a 20 cm × 20 cm transmitter.

Reference

[1] Y. Zhuang, … and J. Zhou, "Range-Adaptive Wireless Power Transfer Based on Differential Coupling Using Multiple Bidirectional Coils," in IEEE Transactions on Industrial Electronics, vol. 67, no. 9, pp. 7519-7528, Sept. 2020.

Zero-Index photonics

Ferrera, M. [1], Jaffray, W. [1]

[1] Institute of Photonics and Quantum Sciences, Heriot-Watt University, SUPA, Edinburgh EH14 4AS, UK

Contact: M.Ferrera@hw.ac.uk

The problem: The holy grail of ultra-fast signal processing would be a material fully compatible with standard semiconductor processes, and exhibiting strong and energetically efficient optical nonlinearities (see Fig.1).

The solution: In recent years, the optics and photonics communities have shown renewed interest in transparent conducting oxides (TCOs), which have been used for over two decades in photovoltaic and communication technologies [1].

TCOs stand out among other ENZ systems due to their ability to have an extremely small real index around their ENZ wavelength, leading to a slow-light effect that enhances material nonlinear properties. This is the foundation for the emerging field of near-zero-index photonics [2].

Why using our materials: Research in conductive oxide nonlinear optics has grown rapidly, with numerous experiments showcasing remarkable effects like unitary index change, bandwidth-large frequency shift, and efficient ultra-low-power frequency conversion [3].

Our work develops around TCOs' foreseeable role in future all-optical integrated systems

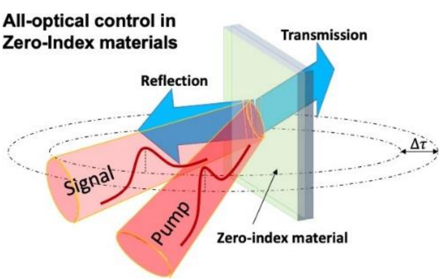


Fig.1 – Ultra-fast optical modulation via pump/probe scheme in zero-index thin films

References

[1] W. Jaffray et al., Advances in Optics and Photonics 14, 2, 148-208 (2022).
[2] J. B. Khurgin et al., Optica 7 (3), 226-231 (2020)
[3] W. Jaffray et al., Nature Communications 13, 3536 (2022).

3D Printed RF Devices

Wolfson School of Mechanical, Electrical, and Manufacturing Engineering, Loughborough University, Loughborough, UK

Contact: Will Whittow

The Wireless Communications Research Group at Loughborough consists of 5 academics, 4 PDRAs, and several Doctoral Researchers. Our expertise lies in antenna and metasurface design, RF, materials, and propagation. We have antenna and measurement capabilities up to 67 GHz. We also have extensive dielectric characterization capability as well as 3D printing facilities.

Our group is currently working on several exciting projects focusing on 5G/6G communications, intelligent reflective surfaces, 3D-printed anisotropic materials, beam-steering antennas for satellite communications, etc. Some interesting videos showing our facilities and past projects, along with > 100 journal papers can be freely accessed by scanning the QR code below.

COLLABORATION OFFERS

Heriot-Watt University: Institute of Photonics and Quantum Sciences

Experimental Nanophotonics Group

Contact: Muhammad Afnan Ansari

Our Experimental Nanophotonics Group at Heriot-Watt University is dedicated to the fundamental physics of metasurface and its application in ultrathin optical devices for imaging, display and information processing. Our main research interests include metalenses, holograms, optical vortex beams and polarization detection.

The ultrathin nature and unusual functionalities have enabled the discovery of new phenomena and the development of novel prototype devices for future technologies. To explore the commercial applications of novel nanodevices and integrated optical systems, we have built connection with industry, including STMicroelectronics, Renishaw and Holoxica.

Keywords: Metasurfaces, Nanophotonics, Flat-optics

Imperial College London: Centre for Advanced Structural Ceramics

Contact: Florian Bouville, f.bouville@imperial.ac.uk

My group is part of the Centre for Advanced Structural Ceramics at Imperial College London. We are looking at processing, microstructure and structural properties for advanced ceramics. My group activities at the moment focuses on developing new processes, either by modifying traditional techniques or using high resolution additive manufacturing (Digital Light Printing) techniques, to obtain tougher ceramics.

The microstructure targeted can be inspired from natural, geological, or from other design principles depending on the focused properties (fracture toughness, impact resistance, functional properties). With the CASC, we have access to extensive processing tools (wet/dry processing, robocasting, light based printing), sintering tools (atmosphere control furnaced, hot press, SPS, high vacuum furnaces), and structural characterisation with a focus on fracture testing (toughness measurement with in-situ capabilities, either optical or SEM/TEM based supported by FEM).

We also benefit from a newly opened electron microscopy center with cryogenic and environmental capabilities. We are looking for new industrial problems and applications to leverage these processing capabilities. There are multiple ways to work with us, starting from collaborative preliminary work to test new ideas to direct access to our equipments or integrating our company consortia for cheaper price and proposition of UG/PG projects.

Imperial College London: Materials

PKPetrov's TFDM Group

Contact: Peter Petrov, p.petrov@imperial.ac.uk

Dr Peter K Petrov is a Principal Research Scientist at the Department of Materials at Imperial College London and the Royce Institute Technology platform lead for Thin films device materials (TFDM).

Dr Petrov has more than 25 years of experience in the development of functional oxide and nitride thin film materials, and the fabrication of microwave, plasmonic and light-manipulating devices for communication, energy harvesting and biosensing.

He leads an enthusiastic team of 2 PDRA, 2 RA, 3 PhD and 3 MSc students working on the development of alternative plasmonic materials, novel device fabrication using photo and e-beam lithography complemented with reactive ion etching (ICP-RIE), and characterization of their surface, structure and electrical properties (dc – 53 GHz) under external magnetic, electrical and optical bias.

The Petrov's TFDM Group's ongoing research work includes the development of Robust manufacturable antimicrobial surfaces enabled by superhard plasmon-enhanced photocatalytic materials, Nano-enclosures for stable vaccine formulations and bio-sensing devices.

We are open to collaboration and can offer expertise in thin film materials deposition, characterisation and nano-scale device manufacturing as well as the training and access to equipment for thereof via the Royce Institute.

Keywords: thin film deposition, device fabrication, on-chip MW measurements

Imperial College London: Solid State Physics

Physics

Contact: Rupert Oulton, r.oulton@imperial.ac.uk

Our team explores the control of light matter interactions through the use of metamaterials and plasmonics.

While we focus on the use of metals, which provide optical confinement at length scales limited only by nano fabrication technology, we also work with dielectric materials, where low loss is important.

Our team explores linear and nonlinear light matter interactions, including fluorescence enhancement, laser physics, Raman spectroscopy and nonlinear wave mixing from harmonic generation to four wave mixing and high harmonic generation.

Keywords: Light-Matter Interactions, Applications, Photocatalysis, Magnetism, Raman Spectroscopy, Ultrafast Pulse Characterisation

Imperial College London: Structural Metamaterials Group

Aeronautics

Contact: Matthew Santer, m.santer@imperial.ac.uk

We use optimization and other advanced multi-physics numerical techniques to design structural metamaterial architures which can respond to multiple stimuli — loading, displacement, temperature, etc. — in a targeted way.

We have many collaborations applying our technology within the aerospace industry and in wider fields including spinal implants.

We are always happy to discuss working together on new projects and incorporate new physics into our framework.

Keywords: Metasurfaces, Nanophotonics, Flat-optics

King's College London: Nano Optics - Photonics & Nanotechnology

Contact: Diane Roth, diane.roth@kcl.ac.uk; Anatoly Zayats, a.zayats@kcl.ac.uk

The research in the Nano Optics group at King's College London involves the development and applications of advanced photonic technologies and of novel nanomaterials to address modern challenges in photonic and quantum technologies, new nanostructured materials, sensing, imaging and clean energy.

The group adopts an interdisciplinary approach to provide leading-edge research in optical, mechanical and structural properties of nanostructures and nanoparticles.

The current research interests are in the areas of nanophotonics, plasmonics, optical metamaterials and metasurfaces, electromagnetic field topology and optical spin-orbit coupling effects, complex beams (vortices, radial beams, …), nonlinear and ultrafast optics and spectroscopy, hot-electrons and associated photochemistry, near-field optics and scanning probe microscopy, and optical properties of surfaces, thin films, semiconductors and low-dimensional structures.

We combine expertise in nanofabrication, laser science, advanced imaging techniques and numerical modelling.

As a member of the London Centre for Nanotechnology, our shared facilities and equipment are available to external researchers to book and use.

We can also host mid-/long-term internships from both academia and industry.

If you are interested in working with us and discuss potential projects of mutual interests, please get in touch with Prof. Anatoly Zayats or Dr. Diane Roth.

Loughborough: Wireless Communications Research Group

Wolfson School of Mechanical, Electrical, and Manufacturing Engineering, Loughborough University, Loughborough, UK

Contact: Will Whittow

The Wireless Communications Research Group at Loughborough consists of 5 academics, 4 PDRAs, and several Doctoral Researchers. Our expertise lies in antenna and metasurface design, RF, materials, and propagation. We have antenna and measurement capabilities up to 67 GHz. We also have extensive dielectric characterization capability as well as 3D printing facilities.

Our group is currently working on several exciting projects focusing on 5G/6G communications, intelligent reflective surfaces, 3D-printed anisotropic materials, beam-steering antennas for satellite communications, etc. Some interesting videos showing our facilities and past projects, along with > 100 journal papers can be freely accessed by scanning the QR code below.

Manchester Metropolitan University: Sports Engineering

Contact: Thomas Allen, t.allen@mmu.ac.uk

We are mechanical engineers based at Manchester Metropolitan University. We work on mechanical metamaterials, including modelling and experiments.

We are looking for academic and industry partners to help us in our mission to showcase the benefits metamaterials can bring to health and sport.

If you would like to work with us, please come and speak to us.

We offer expertise and facilities in 3D printing, auxetic foam, shear thickening materials, materials characterisation, including impact testing, high-speed photography and computer aided engineering.

Keywords: Sport, mechanical, foam, 3D printing, impact

MBDA UK

Emerging Technologies

Contact: Matt Rayner, matt.rayner@mbda.co.uk

MBDA is a leading manufacturer of missile systems, producing complex weapons to suit the needs of all three armed forces.

We are looking for collaboration and partnerships with innovative SMEs and researchers, across a wide variety of fields, but particularly photonic metamaterials, active and microwave metamaterials.

All topics included in the Metamaterials for Space day are relevant and of interest, as well as imaging metamaterials, and routes to commercialisation.

Keywords: Defence, collaborative partnership, active metamaterials, microwave metamaterials, photonic metamaterials, space, vibration, temperature

National Physical Laboratory: Quantum technologies

Contact: Mayela Romero-Gómez, mayela.romero@npl.co.uk

In the quantum materials group at NPL, we specialise in the characterisation of structured materials, in the nano and micro scale with our wide range of probe-imaging techniques, which allows us to study fundamental physical properties such as electric, magnetic, and thermal responses at the nanoscale, in addition to photocurrent and optical near-field, in spectral ranges varying from the visible to near and mid-infrared.

We are looking to establish collaborations with academia and industry, to support the development of new-generation devices based on novel materials, such as plasmonic/dielectric metamaterials and metasurfaces, for applications in quantum technologies, energy, and sensors.

NPL offers access to our facilities through different programs, such as Measurement for Quantum (M4Q), Measurement for business (M4B) and Measurement for Innovation (M4I), and we can partner with academia through the UK National Quantum Technologies Programme, specifically, through the Quantum Technology Hubs.

Keywords: Quantum Materials, nano-probe characterisation, sub-diffraction imaging

Nottingham Trent University: Smart Materials

Engineering

Contact: Mahdi Bodaghi, mahdi.bodaghi@ntu.ac.uk

The UK Metamaterials Network Conference allows me to showcase the developing expertise and facilities I have got in the 4D Materials and Printing Lab at Nottingham Trent University.

I will Introduce our recent sustainable metamaterials achievements that may have a high impact on the UK metamaterials and beyond. I aim to disseminate our research results and hear new ideas and directions in the field of active metamaterials, modelling and advanced manufacturing.

The main function of our presence at the Conference will be focusing on pathways to maximise research impact at an industrial level and generating new ideas and brainstorming to shape the future of metamaterials for a better world.

This opportunity will grow my network and lab visibility and these dissemination and brainstorming mechanisms will serve to develop links with new partners, and it is anticipated that new ideas may rise that will lead to novel grant proposals, funding applications and new collaborations.

Networking, collaboration, exchange program, and internationalisation are current challenges, and this Conference will address all of them.

Keywords: Smart Materials and Structures; Modelling; Metamaterials; Soft Robotics; 3D and 4D Printing Technologies

Pepsico

Metamaterials to enhance food, beverage and packaging for new consumer experiences

Contact: John Bows, john.bows@pepsico.com

PepsiCo is one of the world's leading food and beverage companies, with its products enjoyed by consumers more than 1 bn times a day. Net revenue was $86bn in 2022 driven by brands like SodaStream, Pepsi, Doritos, Walkers, Quaker and Mountain Dew.

Metamaterials have been identified by PepsiCo R&D as an early stage technology that has the capacity to enhance food, beverage and packaging to create new consumer innovation, experiences and business benefits.

Opportunity spaces include, but are not limited to:

- Wearable devices for health & wellness monitoring (e.g. hydration)
- Frequency selective microwave heating (domestic, food service)
- Evanescent reusable devices / single-use packaging for crisping / browning food in microwave ovens
- Colour without dyes (e.g. removal of artificial compounds like of azo dyes)
- Communicate state of food / beverages (in production, during use or after use, food security / authenticity / adulteration)
- Improve biodegradability of packaging (e.g. after exposure to an external field)
- Enabling delivery of customised consumer experiences in packaging e.g. maintain temperature, reshape for a new use,
- Temporary or permanent coating structures applied to processing equipment e.g. to enhance CIP, change surface functionality, reduce fouling, improve flow, enhance heat or energy transfer.

We are looking to partner to prototypes for proof-of-principle testing (food-safe as appropriate) inc. computer simulations, as well as economical routes to scale.

PepsiCo can engage through academic partnerships (e.g. UKRI funding, PhDs, post-docs), pre-competitive consortia, direct funding, in-kind contributions, access to PepsiCo R&D facilities (e.g. pilot lines, experimental, computational, sensory and analytical) and via our Open Innovation portal **https://pepsico.yet2.com/**.

Queen's University Belfast: Advanced Composites Research Group

School of Mechanical and Aerospace Engineering

Contact: Zafer Kazanci, z.kazanci@qub.ac.uk

The Advanced Composites Research Group brings together a multidisciplinary team of researchers, focusing on the science and engineering of composite materials and structures.

Our research covers advanced computational modelling, conventional and additive manufacturing of composite structures and also encompasses mechanical metamaterials and their responses under severe loading conditions such as blast and impact.

We offer state-of-the-art computational tools for virtual testing, optimised design, damage prediction, crashworthiness and process modelling of composite metamaterials.

Keywords: composites, mechanical metamaterials, additive manufacturing, crashworthiness, blast/impact loading

Rheon Labs

Product Group

Contact: Olga Kravchenko, olga.kravchenko@rheonlabs.com

RHEON™ technology has been uniquely developed to control kinetic energy. It is a technology solutions house solving sports engineering challenges with strain rate sensitive metamaterials.

As Head of Design I am responsible for developing computational methods and design solutions that are driven by objective and subjective data.

We are open for collaborations on grants, co-branding and development.

If you are interested in hearing more feel free to contact me.

Keywords: Mechanical metamaterials technology, industry, data driven design

Sheffield Hallam University: Auxetic Materials

Materials and Engineering Research Institute

Contact: Andrew Alderson, A.Alderson@shu.ac.uk

What we do

We undertake world-leading research and consultancy into materials and structures possessing negative mechanical properties – with a major focus on negative Poisson's ratio (auxetic) response – materials which get thicker when stretched lengthwise and thinner when compressed. We employ a range of modelling and experimental techniques to understand how and why natural auxetic materials occur, and to develop man-made auxetics from the nanoscale to the macroscale based on a variety of internal material architecture and deformation mechanism combinations. Working closely with colleagues within and external to the university we move auxetic technology to commercial application through improved material performance in sectors including sporting goods, health and wellbeing, transport and defence.

We offer expertise in the following

- Auxetic materials in composite, textile, cellular solid and polymer forms
- Materials fabrication
- Quasi-static and dynamic mechanical properties testing
- Modelling and simulation
- Microstructural characterisation

What we are looking for

Collaborations and partners to develop underpinning fundamental science for mechanical metamaterials, and to apply research towards commercial applications.

How to work with us

Depending on the nature of the research we work with partners through direct and match funded research and consultancy activity, or on grant-funded projects via government funding bodies and research councils. Contact Prof Alderson in the first instance.

Keywords: Mechanical metamaterials; Auxetic materials

Silicon Austria Labs GmbH: Sensor Systems

Printed and Flexible Electronics

Contact: Sherjeel Khan, sherjeel.khan@silicon-austria.com

Our group is part of the research institute "Silicon Austria Labs" based in Austria. We develop innovative and sustainable sensing solution for different industries. Our team uses the basis of state-of-the-art technologies to work on different sensors that collect information from the environment, inspired by all five senses.

From the multitude of sensors, it is important to find the optimum combination in order to use it, with the help of intelligent algorithms and recent developments, to expand the heterogeneous integration of smart sensor systems for various applications.

We have know-how in all aspects of the printed electronics innovation process from conception to design, simulation, materials, fabrication, integration and testing.

We merge these competencies with the latest technologies to realize integrated systems fully enabled through customized software and hardware solutions.

Our aim is to create devices and processes that can be efficiently translated to products and smoothly integrated into systems and specific applications.

Scientists from various fields work in our interdisciplinary team to be able to tackle a broad range of challenges.

Keywords: Printed electronics; smart sensors; sustainable materials

Teesside University: Smart Energy, Power Conversion and Control

Department of Engineering

Contact: Imran Bashir, i.bashir@tees.ac.uk

What we do

At Teesside University, a newly established Acoustic research group working in Low frequency acoustic sensors, Acoustic metamaterials, Water leakage detection using acoustics, Ultrasonic monitoring of batteries to study degradation and advanced signal processing techniques. We have anechoic chamber, full setup for acoustic testing, COMSOL and Battery monitoring testing facility. We have expertise in both experimental acoustics and simulations such as FEM, BEM and analytical modelling. We are part of Prestigious Net-Zero centre and looking for applications using acoustics metamaterial for Hydrogen monitoring.

What we are looking for

We are looking for (i) collaboration, sharing resources and expertise (ii) Metamaterial manufacturing facility (iii) Acoustic sensor fabrication facility (iv) wave propagation modelling in complex heterogenous medium and (v) expertise in ultrasonic testing.

How to work with us

Collaboration: Funding bids, Research papers and sharing resources such as expertise and lab equipment. Early career academics in acoustics are actively looking to collaborate with universities and industry. Acoustic Metamaterials science have been well understood, looking to collaborate to these for different acoustic applications. The research group is looking to expand through collaboration and research. The team is flexible and have support from the school to expand and show its impact.

Keywords: Low frequency acoustic sensors, Acoustic metamaterials, Water leakage detection, Ultrasonic monitoring, battery degradation, advanced signal processing

TWI Ltd: Materials, Performance and Integrity Group

Contact: Melissa Riley, melissa.riley@twi.co.uk

TWI is a world leading RTO with expertise in welding, joining and structural integrity. We have been active in surface engineering and coatings research for >30 years. We offer a wide range of processes applicable for manufacturing metasurfaces. Current activities active include development of a diverse range of functional coatings, including EMI and lightning strike protection applications, SurFlow™ data transmission through composites, as well as leading the development of novel metasurface manufacturing methods for wind turbine applications funded by DSTL.

Facilities include large scale mechanised surface preparation and coating facilities, composite manufacturing, laser processing, additive manufacturing and inspection capabilities, combined with extensive materials and surface characterisation, analysis and functional testing.

TWI has strong links to academic research to support technologies at TRL1-3, alongside manufacturing process and procedure developments to take technologies to TRL4 and above. Technologies can be demonstrated on representative components within our large scale facilities, supported by offline programming/simulation and multiple inspection capabilities for process validation and quality assurance. TWI's membership base & links with wider industry supply chains enable rapid technology transfer to end users.

For further information please contact melissa.riley@twi.co.uk

University of Bath: Theoretical Physics

Physics

Contact: Anton Souslov, A.Souslov@bath.ac.uk

We are a theoretical physics research lab at the University of Bath. We are interested in modelling the mechanics of soft materials and designing new states of matter. Our interests include active mechanical materials, topological metamaterials, and the intersection of metamaterials and fibre optics. We design mechanical metamaterials with novel properties and functionalities using patterns on scales from nanometers to the macroscopic.

We are looking for collaborations across theory, experiments, and industry. We are especially enthusiastic about finding new industrial problems that can be solved via metamaterial design.

Keywords: Soft matter, active matter, mechanical metamaterials

University of Birmingham: Emerging Device Technology Group

Electronic, Electrical and Systems Engineering

Contact: Yi Wang, y.wang.1@bham.ac.uk

First of all, I am NOT from the Birmingham Metamaterial groups. My Emerging Device Technology (EDT) group specialises in the application of new materials and new manufacture techniques in high frequency devices and sensors from microwave to terahertz frequency.

Examples of recent work include: liquid alloy based programmable / reconfigurable microwave devices; bulk micromachined mm-wave and THz micro-coax and waveguide devices; and 3D printed microwave and sub-terahertz devices.

We are looking for opportunities to apply our manufacture capabilities to metamaterials as well as new ideas and potential collaboration on two specific areas. One is the use of liquid materials (liquid metal in particular) in active metamaterials, and the other is about Auxetic materials.

Auxetic materials are primarily used in acoustic and mechanical community.

We are looking for experts (especially in the area of design and modelling) in this area to collaborate with.

We are open for all forms of collaboration, academic or commercial.

Keywords: Advanced manufacturing techniques; Liquid materials; Auxetic materials

University of Bristol: BASElab

Biological Sciences

Contact: Marc Holderied, marc.holderied@bristol.ac.uk

Prof Holderied's lab at the University of Bristol is finding biological inspiration for acoustic applications.

Specifically, his work on acoustic camouflage has lead to the discovery of an ultrasound-absorbing stealth cloak, which is ultrathin and broadband, that moth have evolved on their wings as a defence against detection by bat biosonar.

We have translated this functionality into the human hearing range and our prototypes substantially outperform traditional sound absorbers.

We are pursuing commercialisation and are looking to talk to potential users of thinner and lighter sound absorber metamaterials.

Keywords: University of Bristol; bio-inspired sound absorber metamaterials

University of Bristol: Metamaterials and Metacomposites group

Bristol Composites Institute

Contact: Qicheng Zhang, qicheng.zhang@bristol.ac.uk;

Fabrizio Scarpa, f.scarpa@bristol.ac.uk

What we do

We have over 20 years of experience in designing, manufacturing, and testing mechanical metamaterials for shape morphing, adaptive structures and energy absorption related to vibration and impact loading. We also develop mechanical metamaterials using biobased, synthetic-biology oriented and low-cost components to generate sustainable architected materials solutions.

What we are looking for

We are looking for expertise related to PCB and flexible electronics printing technologies to further increase the multifunctional aspects of our mechanical metamaterials for applications related to communications and general EMC.

How to work with us

Contact Professor Fabrizio Scarpa (f.scarpa@bristol.ac.uk) and/or Dr Qicheng Zhang (qicheng.zhang@bristol.ac.uk)

Keywords: Mechanical metamaterial, Metacomposites, energy absorption, sustainable architected material

University of Cambridge: Complex Additive Materials

Department of Engineering

Contact: Miaomiao Zou, mz467@cam.ac.uk

We used shear-stiffening materials and 3D printing technology for the new generation of impact-resistance sports devices. We are looking for more suitable application scenarios of this design and material.

We are professional in 3D printing, and we would like to cooperate with mechanical-expert groups and would like to learn more about how impact resistance is needed in real life.

Keywords: Impact resistance protection

University of Cambridge: Physics

Contact: Calum Williams, cw507@cam.ac.uk

To understand and dynamically control the light-matter interaction in photonic nanostructures, and to build transformative imaging and sensing devices that make use of this understanding.

I am starting my research group at the University of Exeter (Dept. of Physics) in Sept 2023, and very interested in expanding my research horizons with new collaborations (both academic and industrial).

Keywords: Metamaterials; Nanophotonics; Imaging; Sensing; Biomedical; Nanofabrication

University of Cranfield: Mechanical Engineering

Contact: Mostafa Ranjbar, Mostafa.Ranjbar@cranfield.ac.uk

We are working on vibroacoustic, Auxetic and Mechanical metamaterials. We develop novel structures for noise and vibration controls, energy harvesting, Phononic and underwater applications.

We have a long term experience in commercialisation of vibroacoustic metamaterials for railway, Aerospace and submarines. We welcome any industrial or academic cooperation, consultation and project funding.

Keywords: Auxetics, sandwich panels, mechanical metamaterials, design optimization, Aerospace, railway, vibroacoustics, submarine, energy harvesting

University of Durham: MetaMaterials for Extreme Loads

Engineering

Contact: Stefan Szyniszewski, stefan.t.szyniszewski@durham.ac.uk

We are a group of academics centred around the University of Durham, Metropolitan Manchester University, the University of Glasgow, the University of Bristol and UCL.

We have a broad range of expertise in modelling multiphysical systems, databases and data curation and developing cloud-based solutions for a broader academic and industrial community.

Our industrial engagement centres around mechanical metamaterials for the sports, nuclear, and defence sectors.

We are keen to broaden our perspective and expand our group with new viewpoints and fields of Metamaterial science.

Keywords: modelling, AI, machine learning, extreme physics

University of Edinburgh: Mechanics and Geometry of Advanced Structures Laboratory (MEGA SLab)

School of Engineering

Contact: Marcelo Dias, marcelo.dias@ed.ac.uk

The Mechanics and Geometry of Advanced Structures Laboratory (MEGA SLab) is based at the School of Engineering in the University of Edinburgh.

MEGA SLab's research interests lie within a broad range of topics in theoretical structural mechanics and soft condensed matter, and materials modelling.

Our main focus is to understand how mechanical properties, that an elastic body acquires, arise from a careful design of its internal geometry in addition to its material composition.

These questions are relevant to topics such as shape formation in nature, biomechanics, mechanics of materials and structures, controlled design and functionality of thin plates and shells.

Keywords: Applied mechanics, Soft matter physics, Modelling

University of Exeter: Acoustic and Electromagnetic Metamaterials

Physics

Contact: Alastair Hibbins, a.p.hibbins@exeter.ac.uk

Within the Physics department at the University of Exeter we investigate both metamaterials designed to control acoustic & elastic waves, and electromagnetic metamaterials operating at frequencies from radio waves to visible light. Our work spans from exploration of the fundamental physics governing these structures all the way to developing prototypes for their use in industrial settings.

In our research into acoustics we design, simulate, and experimentally characterise acoustic and elastic metamaterials, considering both airborne and underwater sound. We focus on unearthing new wave-control phenomena for applications in sound/vibration isolation, sensing, noise control, and energy harvesting.

In the field of electromagnetics we examine photonic materials through combing metamaterials with dyes, 2D materials, or biological/bio-inspired materials in order to create ultra-sensitive detectors, extreme long-range energy transport and ultra-thin optical components. At longer wavelengths, we develop THz and mm-waves metamaterials for advanced imaging techniques with applications in Medicine. In the microwave regime we develop metamaterials for antennas on both flat and planar surfaces, reflectarrays, and directional scatterers.

We work with academics and industry to create new ways to fabricate metamaterials and design and test prototypes for their application in the field.

Keywords: 2D materials, biological/bio-inspired materials, detectors, energy transport, THz and mm-waves metamaterials, imaging, antennas, reflectarrays, directional scatterers.

University of Exeter: High Frequency Metrology of Materials

Physics

Contact: Rob J Hicken, r.j.hicken@exeter.ac.uk

Our primary focus is high frequency (MHz-THz) metrology of materials using a combination of electrical and ultrafast optical measurement techniques. We apply these methods principally, but not exclusively, to magnetic materials and operate the EPSRC-funded Exeter Time Resolved Magnetism (EXTREMAG) facility for the benefit of the UK magnetism and spintronics community, with access via a one page proposal document.

While the most immediate applications of nanostructured magnetic materials are found in data storage technology, recent discoveries within antiferromagnetic spintronics and all-optical manipulation of magnetism present new opportunities in THz wireless applications and optical telecommunications.

We are particularly interested in partnering with colleagues from different fields to extend the reach of technology based upon magnetic materials.

Keywords: spintronics, metrology, MHz, THz

University of Exeter: Photonic Metamaterials

Engineering

Contact: Changxu Liu, c.c.liu@exeter.ac.uk

My group is working on the fields including metamaterials, plasmonics, nanotechnology, and nanophotonics, with particular focus on innovative aspects of wave interaction in disordered and hybrid systems.

As a theoretical/numerical group, we collaborate extensively with experimental group, either proposing idea to realise or building models to explain experimental results.

Keywords: nanophotonics, disordered photonics, energy harvesting

University of Exeter: PhotMat

Physics

Contact: William Wardley, w.wardley@exeter.ac.uk

Traditionally, making molecules with new properties, e.g. dyes of different colours, has been the province of chemistry, new properties are based on making new molecules.

Our approach is fundamentally different, we use light to alter the way molecules interact with each other, something that can lead to radical changes in their properties, without changing their chemical composition. We use two related techniques known as strong coupling and weak coupling.

Keywords: Strong coupling' 'nanophotonics'

University of Exeter: Solar Energy and Biomimicry

Renewable Energy

Contact: Katie Shanks, k.shanks2@exeter.ac.uk

We develop various solar energy technology aimed at improving performance and integration. This includes: perovskites, dye sensitized solar cells, solar concentrators, hydrogen generation, biomimicry, nanomaterials fabrication, energy efficient/management smart glazing and life cycle analysis.

We are looking for experts in photonic metamaterials and thermal management metamaterials, and 3D printable metamaterials.

Keywords: Solar energy: nanomaterials; photoelectrolysis, third generation solar cells, perovskites

University of Glasgow: Nanophotonics

James Watt School of Engineering

Contact: Alasdair Clark, Alasdair.clark@glasgow.ac.uk

What we do

Nanophotonic and plasmonic device engineering; molecular nano patterning; and DNA origami. Our application areas include bio and chemical sensors (including artificial taste buds), engineered surfaces for single-molecule studies, structural colour for security printing, and metasurfaces for data comms.

What we are looking for: Multi-disciplinary partners with problems in sensing, fabrication, single-molecule measurements, and optical component creation.

How to work with us

Email Alasdair.clark@glasgow.ac.uk, or find me at the conference.

Keywords: plasmonics; nano photonics; optical metasurfaces; structural colour; sensors; artificial taste buds; DNA origami

University of Huddersfield: Centre for Precision Technologies, Optical Metrology

Computing and Engineering

Contact: Andrew Henning, a.henning@hud.ac.uk

One of the focusses of the optical metrology group within the Centre for Precision Technologies at the University of Huddersfield is the development of ultra-compact optical metrology systems for manufacturing exploiting nanotechnology, with a specific focus on the use of metamaterials to achieve this aim.

These will allow the proliferation of sensor networks, allowing manufacturing processes to be improved, making them more efficient, reducing waste and improving the lifetime of manufactured elements.

We are always interested in hearing from groups that would benefit from our expertise in metrology to aid with measurement problems they are having, or who believe they have novel materials/techniques that would aid our sensor design and instrument development.

Keywords: Metrology, Instrument development, manufacturing

University of Liverpool: High Frequency Research Group

Electrical Engineering and Electronics

Contact: Jiafeng Zhou, jiafeng.zhou@liverpool.ac.uk

We can carry out the design of metamaterial-based devices for wireless communications, energy harvesting and wireless charging.

Keywords: Microwave, RF, wireless power transfer, wireless charging, frequency selective surface, amplifiers, antennas, filters

University of Nottingham: Centre for Additive Manufacturing

Contact: Jisun Im, Chris Tuck, Richard Haque

Jisun.Im@nottingham.ac.uk

The Centre for Additive Manufacturing (CfAM) at the University of Nottingham is a world-leading centre in Additive Manufacturing (AM) that houses unique portfolio developmental AM processes (i.e., bespoke multi-material ink jetting system, liquid metal-jetting system and volumetric 3D printing) and commercially available systems including SLA, SLS, FDM, inkjet, extrusion bioprinter, projection microSLA and multi-photon lithography system. The core research at the CfAM is to establish a fundamental platform of pioneering research activity on the underpinning processes, materials and computational methods necessary for the successful execution and implementation of AM as a viable manufacturing tool. Over the years, the Centre has made significant strides in exploring the potential of AM for the creation of metamaterials, such as electromagnetic, optical and acoustic applications. We place great value on partnerships and collaboration with both academics and commercial enterprises across the world. We believe that by working together, we can develop functional materials and explore manufacturing and scale-up technologies for metamaterials, ultimately leading to a more sustainable and innovative future. We welcome the opportunity for collaboration and partnerships to drive the research, development and applications of metamaterials to new heights.

Keywords: Additive Manufacturing

University of Nottingham: Optics and Photonics

EEE

Contact: Mitchell Kenney, mitchell.kenney@nottingham.ac.uk

Our group currently develops and fabricates novel visible wavelength metamaterials, with a particular focus towards healthcare, life-sciences, and computational imaging. All of the metamaterials are made in-house by our group at Nottingham University, using bespoke designs and models.

We are looking for keen collaborators who work in computational imaging and life-sciences to help find more applications for the visible metamaterials, particularly arrays of lenses which are useful for 3D imaging applications.

Contacting me at Mitchell.Kenney@nottingham.ac.uk, I am happy to have a chat.

Keywords: metamaterials; metasurfaces; metalenses; 3D imaging; visible

University of Oxford: Biodegradable mechanical metamaterials

Department of Engineering Science

Contact: Reece Oosterbeek, reece.oosterbeek@eng.ox.ac.uk

Dr Oosterbeek is initiating a new research group at the University of Oxford, to develop biodegradable mechanical metamaterials for medical implant applications.

This firstly involves development of new manufacturing methods for biodegradable materials, aiming to achieve site-specific control over the microstructure of polymers and polymer composites during additive manufacturing using polymer powder bed fusion.

This also involves development of new metamaterial architectures specifically designed to influence the degradation behaviour of these materials, and the evolution of mechanical properties during degradation.

These material and structure developments will then be used to design and fabricate new metamaterial-based implant devices, targeted at specific applications such as orthopaedic fixation devices.

I am looking for collaborations across a range of areas, including new polymers and composites for metamaterial fabrication, modelling of the mechanical and degradation properties of new structures, and biologically relevant testing of prototype materials and devices.

To get in touch please email reece.oosterbeek@eng.ox.ac.uk

Keywords: mechanical metamaterials, medical implant, bioresorbable implants, polymer AM, polymer microstructure, composites

University of Sheffield: Active and reconfigurable metamaterials lab

Automatic Control and Systems Engineering

Contact: Simon Pope, s.a.pope@sheffield.ac.uk

What we do: We specialise in active metamaterials (pure active, reconfigurable, 4D, tuneable, adaptive, and programmable), mainly in the mechanical and acoustic domains, but also in the electromagnetic and thermal domains. We work on the design, modelling, simulation analysis and implementation of active metamaterials (including machine learning approaches).

We cover both theoretical and experimental work, including new manufacturing approaches, such as for structurally reconfigurable metamaterials. Our facilities include a lab for prototyping active mechanical metamaterials and new manufacturing approaches for reconfigurable metamaterials.

What we are looking for: People in research and industry, who are interested in the application of “active” metamaterials and new approaches for the manufacture of reconfigurable metamaterials.

We are looking for people who can manufacture and test active metamaterials that we can embed actuation, sensing and control into, across any of the physical domains.

How to work with us: We have an interdisciplinary background in control and systems and its application to a range of physical systems across mechanical and electrical domains.

We are open to collaboration on projects and proposals with people working in a wide range of areas.

We can provide expertise in areas related to active metamaterials, modelling and analysis and can provide experimental facilities for prototyping and test of active mechanical metamaterials.

Keywords: active, mechanical, acoustic, modelling, manufacture, AI

University of Sheffield: Alloys and Manufacturing

Materials Science & Engineering

Contact: Felicity Freeman, f.freeman@sheffield.ac.uk

Led by Prof. Iain Todd at the University of Sheffield, we primarily work on the development of new alloys and the development of new processes to enable engineering structures to be manufactured from them.

Understanding the mechanisms driving the evolution of microstructure during processing is essential to developing new manufacturing processes that are fit for purpose.

Our manufacturing research is conducted on the near-industrial scale and much of it is focused on detailed investigations of novel manufacturing routes based on the use of alloy powders and is conducted in close collaboration with industry.

Fundamental research on emerging metallic materials concentrates on structural control and the development of new functional and structural properties.

As the lead partner in MAPP (EPSRC Future Manufacturing Hub in Manufacture using Advanced Powder Processes), we are delivering on the promise of powder-based manufacturing to provide low energy, low cost, and low waste high value manufacturing routes and products to secure UK manufacturing productivity and growth.

Keywords: Additive manufacturing; powder processing; process control; functionalisation.

University of Sheffield: Communications Group

Electronic and Electrical Engineering

Contact: Stephen Henthorn, s.henthorn@sheffield.ac.uk

The Communications Group covers almost the whole field of wireless communications from application layer to physical layer, with particular interest in radio waveforms and electromagnetic structures.

Our metamaterials expertise focusses on the microwave domain, producing imaginative solutions in applications including antenna enhancement, communications equipment, wireless security, healthcare and stealth. This includes extensive research into reconfigurable metamaterials, as well as non-standard fabrication approaches including weaving, knitting and printing of electromagnetic materials.

Our measurement facilities include anechoic chambers and an NRL arch, allowing reflection, transmission, radar cross section and pattern measurements from 100 MHz to 10 GHz. Above this, our Group is home to the UKRI National mmWave Facility, taking pattern, transmission and reflection measurements up to 110GHz, including on-wafer measurement of devices. We have also recently obtained EPSRC funding to develop the UKRI National 6G Radio Systems Facility, extending our over-the-air measurement capability to 220 GHz.

These facilities are open to commercial and academic use with specialist technical support. Contact mmwave@sheffield.ac.uk for further information.

We are also always interested in potential collaboration on any of our areas of expertise listed above – for further information on this contact s.henthorn@sheffield.ac.uk

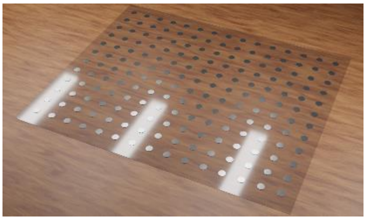
Keywords: Microwave; mmWave; Reconfigurable; Communications; 5G; 6G; Defence; Health

University of Southampton: Acoustic Metamaterials Research

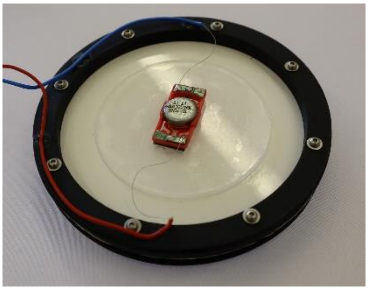
Institute of Sound & Vibration Research

Contact: Felix Langfeldt, F.Langfeldt@soton.ac.uk

What we do



Fundamental and applied research in passive and active acoustic and mechanical metamaterials for noise and vibration control. Analytical and numerical modelling as well as experimental studies, small-scale (e.g. impedance tube) and large-scale (e.g. transmission tests).



Key research areas:

- Membrane- and plate-type acoustic metamaterials
- Partitions with embedded acoustic metamaterials
- Active acoustic and mechanical metamaterials

What we can offer

The ISVR offers state-of-the-art testing facilities for noise and vibration control testing and aeroacoustic measurements as well as world-leading experts covering all areas of sound and vibration.

What we are looking for

- Opportunities to collaborate with other academic institutions and/or industrial partners in national and international research projects
- Industrially funded PhD projects
- In-situ validation of acoustic metamaterial designs
- New challenges and applications for acoustic metamaterials

University of Southampton: Nanomechanics & Nanophotonics Group

School of Physics and Astronomy

Contact: Bruce(Jun-Yu) Ou, bruce.ou@soton.ac.uk

Nanomechanics & Nanophotonics research group is run by Dr Bruce (Jun-Yu) Ou, an expert in nano-optomechanical metamaterials, AI-assisted optical metrology and semiconductor nanofabrication.

We are working in two mainstreams 1. Metalenses for imaging and metrology applications. 2. Nano-optomechanical metamaterials for controlling photons interacting with phonons and sensing on a chip.

We can design and fabricate metalenses from visible to mid and long -infrared wavelengths. We also can measure picometre scale displacement with electrons and photons.

We are more than happy to discuss any applications of metalenses and nano-optomechanical metamaterials with interested people.

Keywords: metalens, optomechanics, nanofabrication

University of Southampton: Nanophotonics & Metamaterials

Optoelectronics Reserach Centre

Contact: Kevin MacDonald, kfm@orc.soton.ac.uk

We are an experimental nanophotonics and photonic metamaterials research group. Our current research interests and activities, supported by major grants from UK, European and US funding agencies, range from: fundamental electrodynamics – study of the generation, propagation and interaction with matter of toroidal and topologically structured light; through the development and demonstration of novel functionalities enabled by nano/opto-mechanically reconfigurable metamaterials; to new concepts of optical imaging, metrology and photonic device functionality at the sub-nanometre scale.

Our website: www.nanophotonics.org.uk

We are always open to discussing opportunities for academic and industrial collaboration – please contact Prof Kevin MacDonald (kfm@orc.soton.ac.uk).

Keywords: Photonics; Nanomechanics; Optomechanics; Metrology

University of St Andrews: Nanophotonics

School of Physics and Astronomy

Contact: Sebastian Schulz

What we do

We are specialised in the design and fabrication of nanophotonic structures, including but not limited to metasurfaces, photonic crystals, waveguides and plasmonic systems.

What we can offer

Design and modelling: a range of techniques including plane wave expansion methods, finite difference and finite element methods and home build codes.

Fabrication: lithography (UV and electron beam), dry and wet etching, material deposition (sputtering, ALD, evaporation).

Characterisation: linear and nonlinear characterisation (CW) or metasurfaces and waveguide systems

What we are looking for

We mostly look for collaborators with application or challenge-driven needs for the design and fabrication of new devices. We are looking for new active materials to include in our devices.

We are looking for theory and modelling collaborators that are interested in developing new simulation approaches and novel device classes.

Keywords: Nanophotonics, photonics crystals, nonlinear optics, plasmonics, sensing, communications, fabrication, modelling

University of Sussex: AURORA

Engineering and Informatics

Contact: Gianluca Memoli, g.memoli@sussex.ac.uk

As a team we design sound and noise management solutions inspired by light technologies. This includes the academics, who work on immersive experiences and HCI, and the ctart-up, Metasonixx, who focuses on noise management indoor. –

We are looking for places were to run pilots. –

You can get in touch with g.memoli@sussex.ac.uk for the academic side and with g.memoli@metasonixx.co.uk for the commercial side.

Keywords: acoustic metamaterials, sound delivery, noise cancellation

University of the West of England: RSP Digital Manufacturing Group

School of Engineering

Contact: Shwe Soe, shwe.soe@uwe.ac.uk

What we do: Our group has been actively working on the development of additively manufactured helmet liners for head injury mitigation in sport. The novelty of our work lies on the use of elastomeric metamaterials that can offer superior energy absorption than contemporary materials. We achieved this by developing a complete digital manufacturing workflow from the data acquisition of head shape to the manufacture and testing of the complete helmet liner that precisely fit to the user's head. In our research journey we have optimised the relevant AM process parameters, evaluated thin wall manufacturability, developed the custom jigs to experiment the material performance, translated the material data into constitutive models, used advanced FEA technique to optimise the metamaterials, manufactured the complete helmet liners and tested to the exact standards of interest.

What we are looking for: We are looking for the research collaboration with end users such as manufacturers of helmet or PPE and sport governing bodies in different fields.

How to work with us: Using the state-of-the-art facilities equipped at our research institutes we can offer short-term and long-term projects that suit to the customers requirement.

Keywords: Additive Manufacturing, 3D Printing, Metamaterial, Helmet, Head Injury, Sport

University of Warwick: Advanced Imaging and Measurement (AIM) lab

Engineering

Contact: Richard Watson, r.watson.2@warwick.ac.uk

The lab undertakes non-destructive testing, imaging and measurement research with both ultrasonic and thermal processes.

Development of metamaterials for biomedical imaging has shown imaging resolution below the wavelength limit. Research in metamaterial production techniques was also undertaken previously.

Extension to this existing expertise is ongoing with application of active fluids to control the metamaterial fluid interaction now beginning.

We would like to work with people with new ideas or challenges to try and solve in acoustic metamaterials and to develop active metamaterials.

We would like to develop collaborations with other research groups and develop collaboration with industry.

Please approach me to discuss ideas and potential interactions.

Keywords: Acoustic metamaterials, Active metamaterials, Active fluids, Imaging, Metamaterial production.

University of Warwick: Ceramics Group

Warwick Manufacturing Group

Contact: Claire Dancer, c.dancer@warwick.ac.uk

The Ceramics Group at WMG, University of Warwick works primarily on developing new and low energy processing routes for ceramic materials, in combination with polymeric and/or metallic materials where necessary.

Our focus is on formative routes for metamaterial and similar structures. We have access to a huge range of materials characterisation equipment through the Warwick Analytical Sciences Centre (WASC) and WMG's own facilities.

We are looking for collaborations with metamaterial designers/modellers, with groups with demonstrator devices which require scale-up to demonstrate industrial viability, and with groups able to test functional properties e.g. acoustic, microwave, particularly at device level.

We collaborate with academic groups through joint projects, and with industry through joint projects or via one of our funding schemes, which include SME support, High Value Manufacturing Catapult projects, and direct contract R&D including service characterisation route through WASC.

Contact c.dancer@warwick.ac.uk for further information and links to services.

Keywords: manufacturing; characterisation; ceramics; materials; metamaterials

University of Warwick: Electronic Materials and Interfaces

School of Engineering

Contact: Nicholas Grant, nicholas.e.grant@warwick.ac.uk

What we do: My group focuses on developing thin dielectric and conductive films for electronic devices, with specific expertise in silicon photovoltaics. We use atomic layer deposition to achieve conformal coatings ranging from 0.5 nm to >50nm. We can easily grow graded films without subjecting the sample to ambient conditions (e.g. metallic to dielectric), thereby enabling clean interfaces within the graded film stack.

What we are looking for: How to utilise the preciseness and versatility of ALD grown thin films in the context of metamaterials.

How to work with us: We are open to new collaborations and research ideas, especially in the area of metamaterial applications, so please do get in touch if there is a need for ALD or precise control of thin film layers.

Keywords: silicon photovoltaics, thin dielectric films, conformal coating

University of Warwick: Ultrasound and Vibration

School of Engineering

Contact: Oksana Trushkevych, o.trushkevych@warwick.ac.uk

What we do: I am a new assistant professor building own group and working with Ultrasound groups in School of Engineering and Physics department at Warwick University; I work in several research areas, all of which are related to the Metamaterials theme.

One strand is on large area visualisation of ultrasound and vibration using liquid crystal based sensors.

Another strand is on magnetostrictive materials for applications in non-destructive testing and transducer development, and also in a broader research context including active metamaterials.

I also have 10 years of experience working in photonics, liquid crystals, liquid crystal based nanocomposites and nanomaterials (carbon nanotubes, graphene). My interest in metamaterials started from photonic crystals and optical metamaterials and the idea they can be made tuneable by introducing liquid crystals into the structures. I am also interested in composite materials, methods of their characterisation and in using self assembly for manufacturing periodic structures.

What we are looking for: Applications of ultrasound visualisation techniques as we believe they may be suitable for visualising evanescent acoustic fields.

Looking for ways how my research interests can be allied in the field of metamaterials

How to work with us: Get in touch: o.trushkevych@warwick.ac.uk!

Keywords: acoustic field visualisation, magnetostriction (active metamaterials), nanocomposites, liquid crystals

University of Wolverhampton: Additive Manufacturing of Functional Materials

Faculty of Science and Engineering

Contact: Aaron Vance, a.vance@wlv.ac.uk

The research activities of the group are supported by a range of interdisciplinary academic specialists, post-docs, research technicians and PhD students.

The group works closely with business, other research institutions, AMT/8 Additive manufacturing BSI standards development committee, and other policymakers to translate the research for improving industrial competitiveness, societal benefits, commercial use, spinoff companies and better products.

Through active collaboration with both academic and commercial enterprises, the AMFM group has realised new opportunities that go beyond the current state of the art.

The core research carried by group is focussed on the investigating the underpinning processes, materials, and computational methods for multifunctional additive manufacturing for the development of fully functional materials and systems.

Enquiries should be sent for the attention of Aaron Vance a.vance@wlv.ac.uk

Keywords: Additive-manufacturing, material-development, LBPF, Functional-materials

World Rugby

Contact: Marc Douglas, info@worldrugby.org

World Rugby is the law making and regulatory body for the sport of rugby union worldwide.

We are looking to identify ways to promote player welfare and to make the sport more accessible to people of all backgrounds across the globe.

We are always eager to hear from people working on projects that might help us achieve our goals at info@worldrugby.org.

Delegate contact details

Higher Education Institutions

Name	Organisation	Email
Aaron Vance	University of Wolverhampton	a.vance@wlv.ac.uk
Akram Alomainy	Queen Mary University of London	a.alomainy@qmul.ac.uk
Alasdair Clark	University of Glasgow	Alasdair.clark@glasgow.ac.uk
Alastair Hibbins	University of Exeter	a.p.hibbins@exeter.ac.uk
Alex Powell	University of Exeter	a.w.powell@exeter.ac.uk
Alf Smith	Warwick University	alfred.w.smith@warwick.ac.uk
Amir A. Zadpoor	Delft University of Technology	a.a.zadpoor@tudelft.nl
Anastasiia Zaleska	King's College London	anastasiia.zaleska@kcl.ac.uk
Anatoly Zayats	King's College London	a.zayats@kcl.ac.uk
Andrea Di Falco	University of St Andrews	adf10@st-andrews.ac.uk
Andrew Alderson	Sheffield Hallam University	A.Alderson@shu.ac.uk
Andrew Henning	University of Huddersfield	a.henning@hud.ac.uk
Anton Souslov	University of Bath	A.Souslov@bath.ac.uk
Bruce(Jun-Yu) Ou	University of Southampton	bruce.ou@soton.ac.uk
Bryn Davies	Imperial College London	bryn.davies@imperial.ac.uk
Calum Williams	University of Cambridge	cw507@cam.ac.uk
Changxu Liu	University of Exeter	c.c.liu@exeter.ac.uk
Chris Stevens	University of Oxford	chris.stevens@eng.ox.ac.uk
Christopher Tuck		
Claire Dancer	University of Warwick	c.dancer@warwick.ac.uk
David Newman	UK Metamaterials Network	D.Newman4@exeter.ac.uk
Dawei Tang	University of Huddersfield	d.tang@hud.ac.uk
Deborah Greaves	University of Plymouth	deborah.greaves@plymouth.ac.uk
Diane Roth	King's College London	diane.roth@kcl.ac.uk
Dilaksan Thillaithevan	Imperial College London	dt718@ic.ac.uk
Edmund Linfield		
Fabrizio Scarpa	University of Bristol	f.scarpa@bristol.ac.uk
Feiran Wang	University of Nottingham	f.wang@nottingham.ac.uk
Felicity Freeman	University of Sheffield	f.freeman@sheffield.ac.uk
Felix Langfeldt	University of Southampton	F.Langfeldt@soton.ac.uk
Florian Bouville	Imperial College London	f.bouville@imperial.ac.uk
Frances Tammer	University of Exeter	f.tammer@exeter.ac.uk
Gianluca Memoli	University of Sussex	g.memoli@sussex.ac.uk
Gregory Chaplain	University of Exeter	g.j.chaplain@exeter.ac.uk
Helen Rance	University of Exeter	h.j.rance2@exeter.ac.uk
Iman Dayyani	Cranfield University	
Imran Bashir	Teesside University	i.bashir@tees.ac.uk

Name	Organisation	Email
Iris Nandhakumar	University of Southampton	iris@soton.ac.uk
Jiafeng Zhou	University of Liverpool	jiafeng.zhou@liverpool.ac.uk
Jinyao Zhang	University of Liverpool	Jinyao.zhang@liverpool.ac.uk
Jisun Im	University of Nottingham	jisun.im@nottingham.ac.uk
Joe Shields	University of Exeter	j.shields@exeter.ac.uk
Kai Sun	University of Southampton	k.sun@soton.ac.uk
Karen Pearson	University of Exeter	k.pearson7@exeter.ac.uk
Katie Shanks		k.shanks2@exeter.ac.uk
Kevin MacDonald	University of Southampton	kfm@orc.soton.ac.uk
Mahdi Bodaghi	Nottingham Trent University	mahdi.bodaghi@ntu.ac.uk
Marc Holderied	University of Bristol	marc.holderied@bristol.ac.uk
Marcello Ferrera	Heriot-Watt University	m.ferrera@hw.ac.uk
Marcelo Dias	University of Edinburgh	marcelo.dias@ed.ac.uk
Matthew Santer	Imperial College London	m.santer@imperial.ac.uk
Miaomiao Zou	University of Cambridge	mz467@cam.ac.uk
Mitchell Kenney	University of Nottingham	mitchell.kenney@nottingham.ac.uk
Mohsen Rahmani	Nottingham Trent University	mohsen.rahmani@ntu.ac.uk
Mostafa Ranjbar	University of Cranfield	Mostafa.Ranjbar@cranfield.ac.uk
Muhammad Afnan Ansari	Heriot-Watt University	
Nader Engheta	University of Pennsylvania	engheta@seas.upenn.edu
Nicholas Grant	University of Warwick	nicholas.e.grant@warwick.ac.uk
Oksana Trushkevych	University of Warwick	o.trushkevych@warwick.ac.uk
Olly Duncan	Manchester Metropolitan University	o.duncan@mmu.ac.uk
Otto Muskens	University of Southampton	O.Muskens@soton.ac.uk
Peter Petrov	Imperial College London	p.petrov@imperial.ac.uk
		qammer.abbasi@glasgow.ac.uk
Qicheng Zhang	University of Bristol	qicheng.zhang@bristol.ac.uk
Raphaëlle Haywood	University of Exeter	r.d.haywood@exeter.ac.uk
Reece Oosterbeek	University of Oxford	reece.oosterbeek@eng.ox.ac.uk
Rhea Thankam Sam	University of Southampton	rts1v21@soton.ac.uk
Richard Watson	University of Warwick	r.watson.2@warwick.ac.uk
Rob Hicken	University of Exeter	r.j.hicken@exeter.ac.uk
Rupam Das	University of Exeter	r.k.das@exeter.ac.uk
Rupert Oulton	Imperial College London	r.oulton@imperial.ac.uk
Ryan Murphy	Imperial College London	r.murphy17@imperial.ac.uk
Shwe Soe	University of the West of England	shwe.soe@uwe.ac.uk
Simon Pope	University of Sheffield	s.a.pope@sheffield.ac.uk
Stefan Szyniszewski	University of Durham	stefan.t.szyniszewski@durham.ac.uk
Stephen Henthorn	University of Sheffield	s.henthorn@sheffield.ac.uk

Name	Organisation	Email
Thomas Allen	Manchester Metropolitan University	t.allen@mmu.ac.uk
Tongjun Liu	University of Southampton	Tongjun.Liu@soton.ac.uk
William Wardley	University of Exeter	w.wardley@exeter.ac.uk
Yi Wang	University of Birmingham	y.wang.1@bham.ac.uk
Zafer Kazanci	Queen's University Belfast	z.kazanci@qub.ac.uk

Industry, governmental agencies, other

Name	Organisation	Email
Abdelhalim Azbaid El Ouahabi	Metasonixx Ltd	halim@metasonixx.co.uk
Angela Brown	Department for Science, Innovation and Technology	
Arseny Alexeev	Snap Inc.	aalexeev@snapchat.com
Bruno Reynolds	Oxentia	bruno.reynolds@oxentia.com
Cabrini Cotter-Boston	Department for Science, Innovation and Technology	
Christopher John Reed	MBDA UK	
Gemma Attrill	Dstl	gdrattrill@dstl.gov.uk
Ian Youngs	Dstl	
Jamie Williams	National Physical Laboratory	
Jan Taylor	UKRI - EPSRC	jan.taylor@epsrc.ukri.org
John Bows	PepsiCo	john.bows@pepsico.com
John Kraus	Engineers Without Borders UK	
Joshua Hamilton	QinetiQ	jkhamilton@qinetiq.com
Marc Douglas	World Rugby	marc.douglas@worldrugby.org
Matt Rayner	MBDA UK	matt.rayner@mbda.co.uk
Mauro Augelli	UK Space Agency	Mauro.Augelli@ukspaceagency.gov.uk
Mayela Romero-Gómez	National Physical Laboratory	mayela.romero@npl.co.uk
Melissa Riley	TWI Ltd	melissa.riley@twi.co.uk
Michael Tagima	QinetiQ	mltagima@qinetiq.com
Olga Kravchenko	Rheon Labs	olga.kravchenko@rheonlabs.com
Paul Febvre	Space Applications Catapult	Paul.febvre@sa.catapult.org.uk
Sandy Fisher John	Ploughshare	sandy.fisher.john@ploughshare.co.uk
Sarah Goodchild	Dstl	sagoodchild@dstl.gov.uk
Sean Butterworth	BAE Systems	sean.butterworth@baesystems.com
Sherjeel Khan	Silicon Austria Labs GmbH	sherjeel.khan@silicon-austria.com
Steve Forster	Dstl	
Themos Kallos	Meta Materials Inc	themos.kallos@metamaterial.com

Name	Organisation	Email
Thomas Bassett	MBDA UK	thomas.bassett@mbda-systems.com
Zaffie Cox	EPSRC	

MAKE YOUR OWN METAMATERIAL

Make your own metamaterial

The herringbone tessellation is an auxetic / mechanical metamaterial structure you can make yourself with (origami) paper.

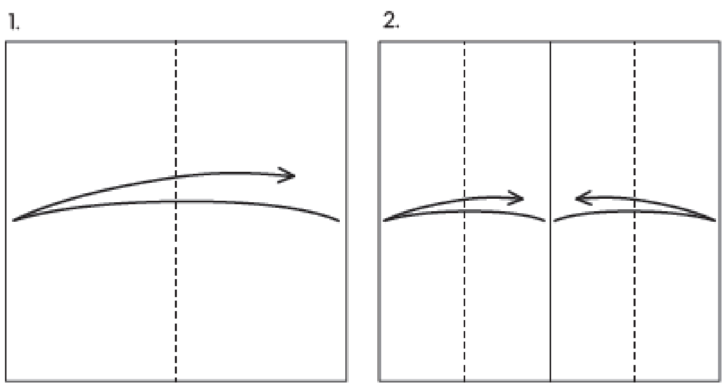
The instructions provided here are publicly available on https://www.origamitessellations.com/2018/01/bauhaus-foundation-course-instructional-booklet/.

Credit: Eric Gjerde.

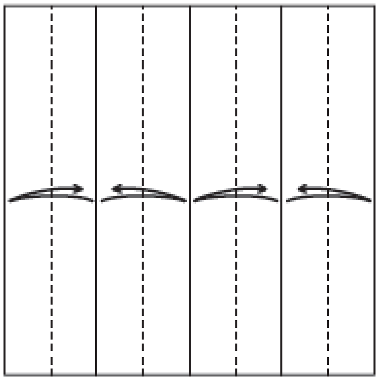
Folding instructions

Dashed line = valley fold, looks like a valley pointing away from you
Solid line = mountain fold, looks like a mountain tip pointing towards you

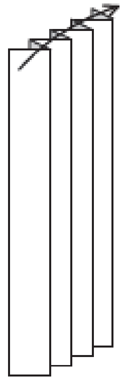
If you are unsure how to fold it, here is also a video with instructions (NB loud music!):
https://youtu.be/LpwfcOXFKtQ



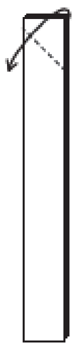
3.



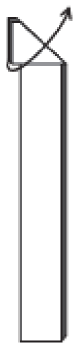
4.



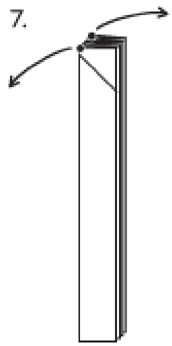
5.



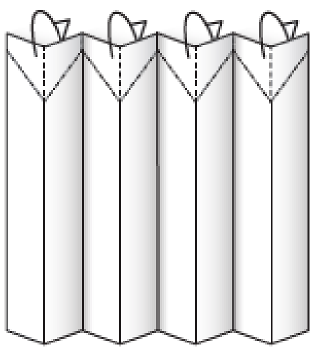
6.



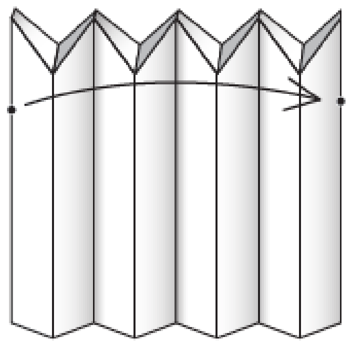
7.



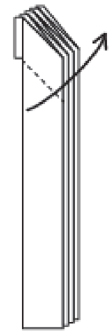
8.



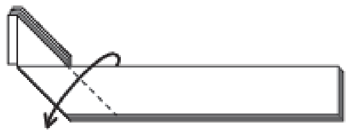
9.



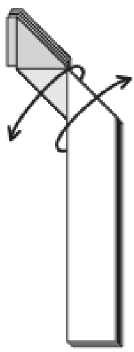
10.



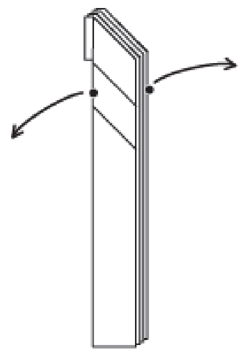
11.



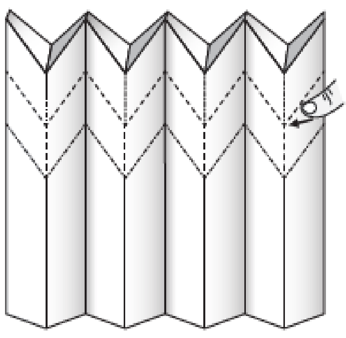
12.



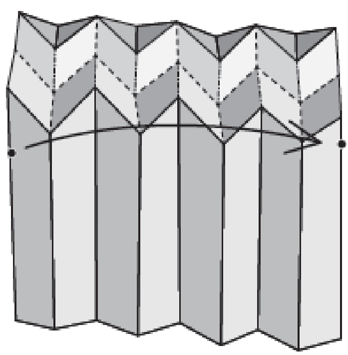
13.



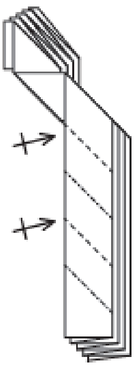
14.



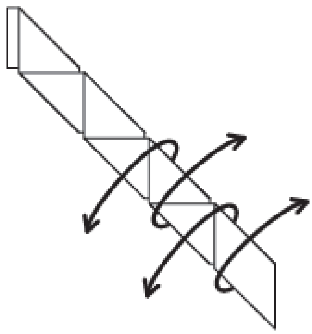
15.



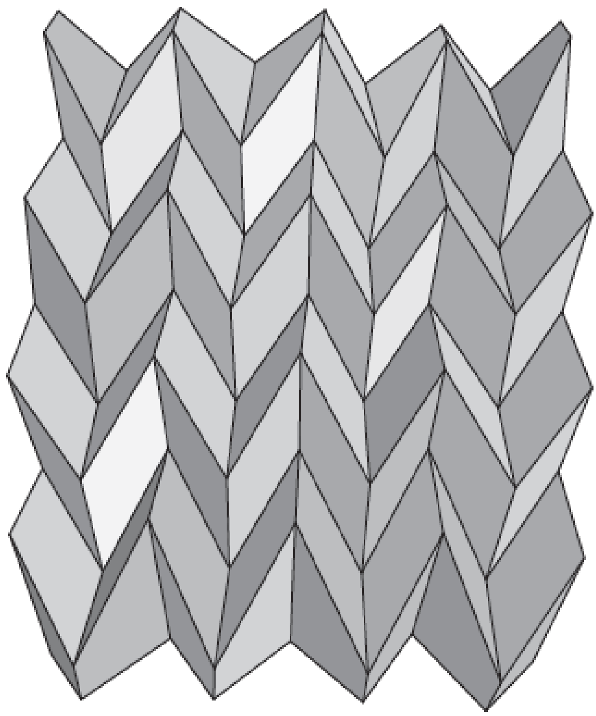
16.



17.



18.



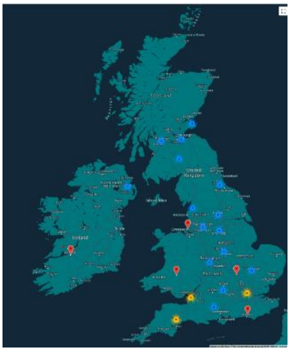
ABOUT THE NETWORK

About the Network

In March 2021, the UK Metamaterials Network started as a jointly funded endeavour between the EPSRC UK Metamaterials Network grant (EP/V002198/1), the UK's Defence and Security Laboratory (Dstl) and the Innovate UK KTN Commercialising Metamaterials Innovation Network. The current funding period lasts from 1 March 2021 to 30 September 2024.

The Network's key objective is to build a vibrant and creative, multidisciplinary community to accelerate novel and innovative metamaterials research and exploitation pathways, while securing and building the UK's sovereign capability and prosperity in this crucial scientific area.

The Network's extensive promotion of the benefits of metamaterials technology (e.g., case studies; promotional material on social media; strategic documents for UKRI; etc.), facilitation of access to metamaterial experts and facilities (through the online database[3]) and closer interactions with end-users at appropriate events (e.g. industry-academia workshops) will help grow external investment in metamaterials research.



As of 1 May 2023, the Network consists of 679 members in the following categories:

- 568 Academia,
- 105 Industry,
- 38 RTO (Research and Technology Organisations),
- 8 Research Council or other funding body,
- 14 Government or policy organisation,
- 32 Other.

The Network funding can be utilised to run conferences, workshops, discussion groups, and other collaboration building events through its Special Interest Groups and Forums, as well as profile raising initiatives and activities to support the talent pipeline development.

Under the EPSRC award T&Cs, the funding cannot be used to fund research activities directly.

The Dstl investment is dedicated to support summer studentships, the annual conference, and in particular the activities of the Wireless and Microwave Metamaterials Special Interest Group.

The KTN contribution sponsored the logo development for the Network.

[3] https://metamaterials.network/expert-database/

Governance structure

The Network is governed on 3 levels:

1. **Management Team**
   - Prof Alastair Hibbins (University of Exeter; Principal Investigator)
   - Dr Claire Dancer (University of Warwick, Co-Investigator)
   - Dr David Newman (Public Engagement Manager)
   - Dr Helen Rance (Impact and Partnership Development Manager)

2. **Voluntary Leadership Team**

The management team is being supported by a strong group of academics, early career researchers, and industry representatives who are leading to focus areas:

- 7 Special Interest Groups (SIGs)[4], covering the core scientific metamaterials domains:
  - Acoustic Metamaterials
  - Active Metamaterials
  - Manufacturing and Scale Up
  - Mechanical Metamaterials
  - Modelling and AI-Design
  - Photonic Metamaterials
  - Wireless and Microwave Metamaterials

- 3 Forums[4]:
  - Horizon Scanning and Disruptive Concepts
  - Industry
  - Outreach and Education

- 3 Challenge Areas[4]:
  - Metamaterials for Health
  - Metamaterials for Space/Aviation
  - Metamaterials for Sustainability

Honorary members of the Leadership Team are Dr Milo Baraclough, Dstl; Prof Andrea Di Falco, University of St Andrews; Dr Jamie Williams, NPL; Prof Ian Youngs, Dstl.

The members of the Leadership Team dedicate their time voluntarily to drive Network activities forward and build this community.

[4] https://metamaterials.network/focus-areas

3. External Advisory Board

The role of the External Advisory Board (EAB) is to provide advice on strategic direction and activities for the UK Metamaterials Network.

EAB membership:

- **Prof Nader Engheta** (Professor of Electrical and Systems Engineering; University of Pennsylvania, US)
- **Mr Jason Field** (DST Head of S&T Commissioning)
- **Prof Hugh Griffiths** (Chair of the Defence Science Expert Committee; Professor of Radio Frequency Sensor Systems; University College London)
- **Prof Dame Jane Jiang** (Professor of Precision Metrology, University of Huddersfield)
- **Prof Maria Kafesaki** (Assoc. Prof in the Dept. of Materials Science and Technology, University of Crete, Greece)
- **Prof Edmund Linfield** (Director of the Bragg Centre for Materials Research; University of Leeds)
- **Mr Jan Taylor** (EPSRC, Senior Portfolio Manager for Advanced Materials / Physical Sciences)

The EAB members have been appointed with a term time until the end of the Network funding in September 2024. The Board is chaired by Prof Edmund Linfield.

Thank you for joining the
UK Metamaterials Network Conference 2023!

UK
META
MATERIALS
NETWORK

UK METAMATERIALS NETWORK CONFERENCE 2023

One community, one voice.

SPONSORSHIP

The UK Metamaterials Network Conference 2023 is kindly sponsored by the Engineering and Physical Sciences Research Council (EPSRC) and the Defence Science and Technology Laboratory (Dstl).