Government
Office for Science

META-MATERIALS

Advanced materials with engineered structures that give them advantageous properties beyond those of their constituent materials.

CONTEXT

Metamaterials present opportunities across the five Critical Technologies set out in the UK's S&T Framework in 2023. There are distinct opportunities for metamaterials to enable advances in all the critical technologies.

TECHNOLOGY

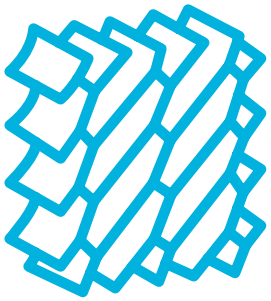
Metamaterials are made up of repetitive sub-structures known as meta-atoms. These are designed, engineered and combined to produce advantageous properties. Most are designed to interact differently with energy that travels in waves, e.g. electromagnetic. Others are designed for enhanced mechanical, structural or thermal properties.

FUTURE THINKING

Metamaterials are increasingly considered important for future network technologies such as 6G. As the diversity of metamaterial technologies in development increases, so do the areas of potential application. For example, managing high temperatures in space applications, compact augmented reality optics, biosensors, anti-microbial materials, or more efficient solar panels and wireless charging.

UK POSITION

The UK produces impactful research, with strength in electromagnetic and acoustic metamaterials. The UK is host to start-ups, SMEs, and large organisations interested in development. The UK files fewer patents than leading nations.



$10.7 BILLION
global market value by 2030 for metamaterials.

1ST & 4TH
1st globally for research impact and quality by FCR 2018-2021. 4th globally for overall research output in 2018-2022.

Reference: iuk-business-connect

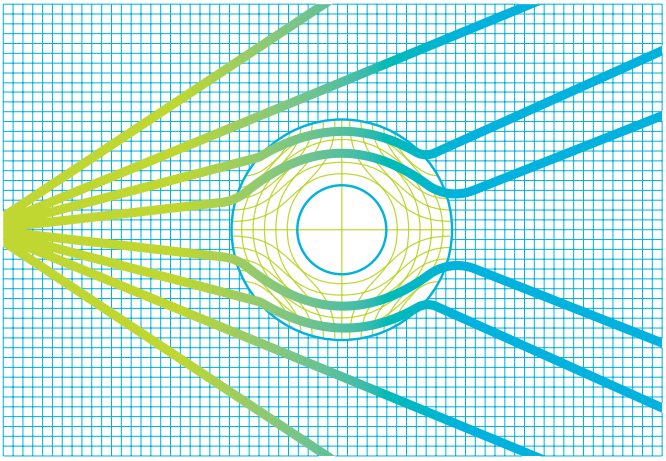
Source: Dimensions

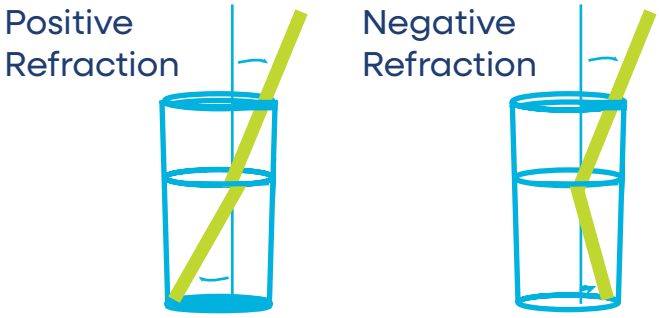
FCR: Field Citation Ratio

APPLICATION MAP

	Transport	Energy & Net-zero	Aerospace & Defence	Future Telecoms	Healthcare	Photonics & Sensing
Deployment	Vibration & Noise Management	Radar-stealthy Wind Turbines	Enhanced Antennas	Wireless Power Transfer Electro-magnetic Shielding	Noise Reduction Performance/ Protective Wearables & Equipment	Filters
Development	Optical Processing - Edge Detection Compact Inconspicuous Antenna LIDAR	Solar Panel Design Passive Thermal & Noise Management	Sensing/ Targeting Space-based Solar Power Terahertz Sources	Reconfigurable intelligent surfaces High Power Efficient Radio-frequency 5G/6G Extreme Bandwidth Antenna	Point of Care Diagnostics Smart Implants, Prosthetics, and Tissue Engineering Health-sensing Wearables	Ultra-thin Lenses Anti-counterfeiting Augmented Reality
Research	Autonomous & Connected Vehicles Wide Field of View Sensing Wireless Charging	Critical Mineral Replacement Cryogenics Efficient Displays/ Signs	Signature Reduction & Management Space Nuclear Reactors & Propulsion Systems Lightweight, Ultra-stiff components	Quantum Communications	Construction Materials Antimicrobial Surfaces Drug Delivery	Single Molecule Chemical Sensing Miniaturised Cameras Quantum Computing Optical Computing

WAVE MANIPULATION CASE STUDY





Negative Refractive Index
As light and sound waves move from one material to another, their velocity changes, altering their path. When entering conventional materials, waves are bent towards the normal – known as positive refraction.

Metamaterials can be engineered to have a negative refractive index, which enables the manipulation of sound or electromagnetic waves. For example, bending incoming waves around an object to create an "invisible" zone. This may enable noise reductions in factories and hospitals or reduce the radar signature of wind turbines.

OPPORTUNITIES

- **Reduced SwaP demands:** For conventional materials, increasing the performance of one parameter e.g., antenna bandwidth, often comes with a trade-off e.g., cost, weight. Metamaterials can reduce size, weight, and power (SWaP) demands of systems, reducing these trade-offs.
- **Future Telecoms:** Increasingly considered important for 6G and satellite communications.
- **Energy Security & Net Zero:** Reduced power consumption through acoustic and thermal management, enabling advances in renewable energy such as solar.
- **Healthcare:** Low-cost biosensors and real-time biomonitoring, point-of-care diagnostics, advanced prosthetics, and noise management in clinical settings.

CHALLENGES

- **Global competition:** Advanced materials are a common priority area for nations pursuing advantage through science and technology. Experts suggested the UK risks losing its competitive edge and ability to secure benefit from metamaterial technologies derived from the UKs leading research.
- **Commercialising UK research:** Experts highlighted gaps in support for translational research, manufacturing skills, and scale-up facilities. To achieve the full potential of metamaterials a coordinated approach between researchers and end users is needed to ensure development considers manufacturing and other commercial requirements.

Please share you views.
Email us at **emtech@go-science.gov.uk**