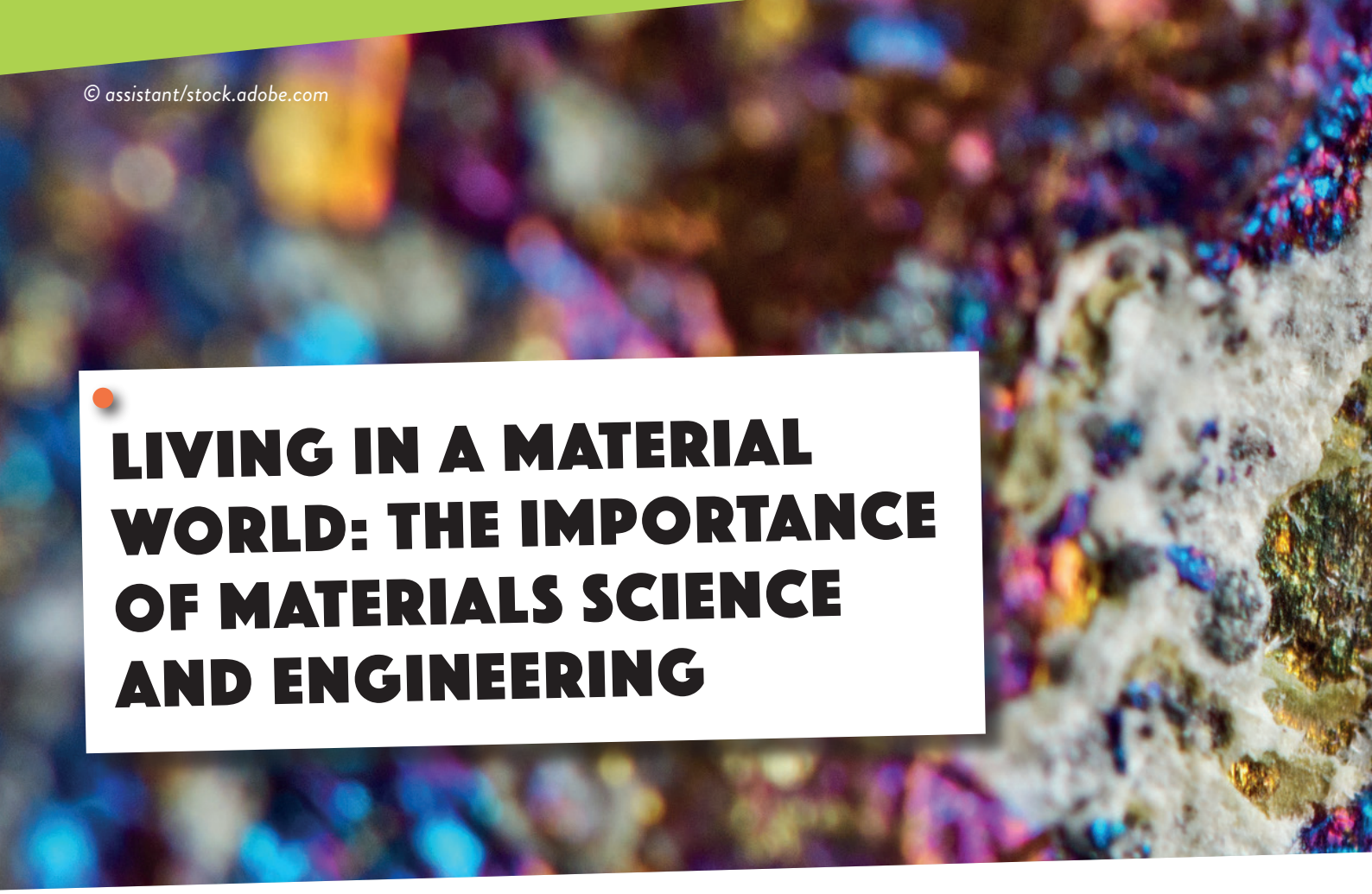

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# LIVING IN A MATERIAL WORLD: THE IMPORTANCE OF MATERIALS SCIENCE AND ENGINEERING

## WHAT IS MATERIALS SCIENCE AND ENGINEERING?

Making things is a very human trait, and one that has been crucial in building the world around us. Materials Science and Engineering (MSE) is the field that deals with the science of making, characterising and testing all types of materials. "MSE has one fundamental tenet at its very centre: the relationship between the structure of a material and its properties," says Dr Ilija Rašović from the University of Birmingham, UK. "This covers anything you make things out of and is true across a huge range of scales, from the atomic level through to civil engineering structures."

Most materials we use can be categorised into one of three categories – metals, ceramics or polymers. "However, many materials nowadays are composites, which may comprise more than one of these," says Dr Fiona Hatton from Loughborough University, UK. "And, as research advances, we are making new materials that might not fall into these traditional categories, such as graphene."

While making materials is an important aspect of MSE, it is only useful if it is accompanied by testing them to understand their properties. "MSE helps us understand how materials behave and how to control their behaviours," says Dr Chris Hamlett, Discover Materials National Outreach Officer. "This allows the development of new materials and also provides new ways in which we can use existing materials."

## PROPERTIES AND PROCESSES

Materials scientists and engineers are interested in properties that affect how a material behaves and, therefore, how it can be used. "The mechanical properties of a material describe how it behaves in response to a force," explains Chris. "Testing these properties answers questions about the material. How bendy is it? How easily is it stretched? How hard is it?" To discover these properties, scientists 'test materials to destruction' – they deliberately break the material and record the force needed to achieve this. A material's chemical properties are equally important. "Its chemical properties define how it reacts to different environments, which is important when thinking about processes such as corrosion," says Chris.

The construction of a material can also significantly affect its properties. "If you manufacture something with a new processing method, it may have a different grain structure and therefore different mechanical properties, which can affect whether or not you can use it for the same application," says Fiona. This highlights the intersection between different 'traditional' fields of science in MSE. Expertise in physics and chemistry is needed to explore material properties, while engineering skills are needed to manufacture and test materials.

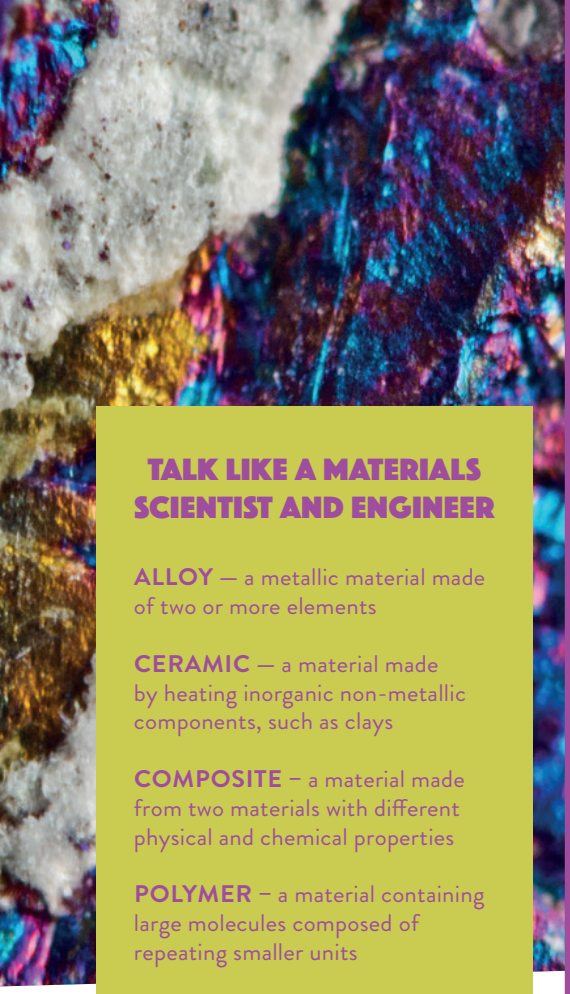
## STRUCTURE AND SCALE

MSE considers how materials behave at every scale. Materials scientists and engineers are interested in the microstructure of materials, as the arrangement of individual atoms and molecules will have a huge influence on the macroscale properties of materials, such as their ability to conduct electricity or heat. "The microstructure of a material affects its physical behaviour," explains Chris. "Careful control of a material's microstructure can lead to some amazing behaviours." One example is shape memory alloys – metals that can be bent, then returned to their original shape by applying heat.

"Once you understand the fundamentals of how structure affects properties, you open up a huge playground in which you, as the materials scientist or engineer, can explore exciting new possibilities for the manipulation of materials to achieve certain ends," says Ilija.

## APPLICATIONS AND ADVANCES

To ensure it has direct value to society, MSE research must always consider the potential applications of different materials, which often involves knowledge of wider



## TALK LIKE A MATERIALS SCIENTIST AND ENGINEER

**ALLOY** — a metallic material made of two or more elements

**CERAMIC** — a material made by heating inorganic non-metallic components, such as clays

**COMPOSITE** – a material made from two materials with different physical and chemical properties

**POLYMER** – a material containing large molecules composed of repeating smaller units

## APPLICATIONS OF MSE IN THE MODERN WORLD

- If concrete was a country, it would be the world's third largest emitter of carbon dioxide! Developing new building materials and new methods of concrete production are therefore key tasks in reducing global greenhouse gas emissions. This is why materials scientists and engineers at the University of Manchester, UK, have invented concretene, concrete containing graphene, which is significantly stronger than standard concrete, meaning less needs to be used in construction.

- If we want to colonise space, how will we construct homes on the Moon or Mars? Materials scientists and engineers at the European Space Agency think they have found the answer – from concrete made by mixing moondust with astronauts' urine!

- Bamboo is incredible – strong, lightweight, flexible, quick-growing, biodegradable, antibacterial... These are just some of its many useful properties. Bamboo has been used in construction for centuries and is still used to build scaffolding in Hong Kong today. Materials scientists and engineers have been exploring uses for this wonder-material, and you will now find utensils, furniture and flooring made from bamboo, as well as clothes and cricket bats.

- Keeping surfaces and equipment sterile in hospitals is a huge challenge. This is why materials scientists and engineers at Loughborough University, UK, are developing anti-biofilm coatings – materials that are resistant to bacteria. This involves not only controlling the surface chemistry of polymers, but also developing polymers from renewable resources such as plant oils instead of petroleum.

fields. "It is of fundamental importance that a materials scientist or engineer understands the needs of the application area in which they are working," says Ilija. If you are creating materials for medical applications, you will need some knowledge of biology, while if you are designing sports equipment, you will need to understand the specific needs of the participants.

While scientific understanding is key to MSE, it is a field defined by innovation and creative thinking. "Materials scientists and engineers are increasingly seeking inspiration from exquisite structures found in nature that have evolved over the course of billions of years," says Ilija. "Additionally, as with every area of our modern world, computers have revolutionised MSE." Computational MSE is now a huge branch of the field, involving modelling material behaviour and using machine learning to accelerate materials discovery.

As innovation continues and methods for materials research and development become ever-more powerful, the future is looking bright for the field of MSE. "Everything around us is made of something," says Ilija. "At some point, a materials scientist or engineer was involved in developing or characterising the material." How could you contribute to this exciting field?

## PATHWAY FROM SCHOOL TO MATERIALS SCIENCE AND ENGINEERING

- At school, maths, chemistry and physics will be useful subjects for studying MSE at university.

- At university, study materials science and engineering, or a related degree such as metallurgy, aerospace engineering, biomaterials engineering or chemical and materials engineering.

- You can also enter the field of MSE from a non-science background. Studying design and technology, art or fashion could lead to a career in MSE.

## EXPLORE CAREERS IN MATERIALS SCIENCE AND ENGINEERING

- As materials form the basis of almost everything we use in life, a degree in MSE opens a wide range of career opportunities, from 'traditional' manufacturing jobs, to designing and developing new materials for a variety of applications.

- Discover Materials has collated a wealth of resources for those exploring careers in MSE. There is careers advice, videos exploring potential MSE pathways, and examples of the career paths that graduates have followed: **www.discovermaterials.co.uk/resource/careers-in-materials-science-and-engineering**

- The Institute of Materials, Minerals and Mining provides resources for students and teachers, including information about careers in the field: **www.iom3.org/careers-learning/schools-outreach.html**

- The Henry Royce Institute runs materials-related events and outreach activities across the UK: **www.royce.ac.uk/outreach**

*A scanning electron microscope image of cuttlefish bone. The structure gives the bones great stiffness yet light weight and inspired the design for the corrugated cardboard used to make postal boxes*
*© Mark Coleman, Discover Materials*

# MEET SOME MATERIALS SCIENTISTS AND ENGINEERS

## DINA FOUAD

*PhD Student, EPSRC CDT in Topological Design, School of Metallurgy and Materials, University of Birmingham, UK*

***Post-16 subjects studied:*** *Maths, Physics, Business Administration*

**I'm passionate about the discoveries that take place in materials science.** I call myself a 'materials astronaut' because I feel like I am exploring the planet of materials, and I love it! The discovery or improvement of materials has the power to change our lives and have a real positive impact on the world.

**Everything in life is made of a material.** Understanding materials is key to understanding the world. It is integrated in design, manufacturing, research, innovation, development – everything. Working in MSE means there's the possibility of being the inventor of the next big thing!

**My current research involves examining the microstructure** of 3D-printed bone-like structures for medical implants, to swap worn-out joints with titanium replacements. This has been a real highlight of my MSE career so far.

**In the future, I would love to teach materials science and explore more of it.** My astronaut journey on the planet of materials continues.

**Titanium is my favourite material.** It's strong, tough and relatively light compared to steel – a tough cookie, like me!

**"I CALL MYSELF A 'MATERIALS ASTRONAUT' BECAUSE I FEEL LIKE I AM EXPLORING THE PLANET OF MATERIALS, AND I LOVE IT!"**

## EBRIMA SALLAH

*PhD Student, Materials Science and Engineering, Swansea University, UK*

***Post-16 subjects studied:*** *Maths, Biology, Chemistry, Sociology*

**I came across my industry-based MSE doctoral programme** while looking for opportunities for further professional development. It enthused my interest in the science of materials and engineering and is allowing me to gain both academic and practical industrial experience.

**MSE is key to solving the world's major problems.** It will help us get cleaner forms of energy, discover how to effectively use waste to work towards a circular economy, and find better ways to source materials and manufacture products with lower carbon emissions. The field of MSE has good opportunities for developing lifelong skills that can be applied to address our planet's biggest issues.

**My current research involves finding efficient experimental methods for industry** to conduct failure analysis and monitor the health of a highly heat-resistant ceramic material. These materials are heavily relied upon by metal-making industries to contain molten metal. It's important that they're not only safe from failure, but also that they maintain the temperature of molten metal to save energy.

**A highlight for my career was the publication in a high-impact scientific journal** of a failure analysis that I hope can be adopted by industries to save them time and money. I've had opportunities to develop non-destructive test methods for failure analysis, using sound waves and lasers.

**I hope to make STEM more accessible for all** by taking part in outreach programmes throughout my career. I have designed and delivered STEM-based workshops related to my research at local schools, and I enjoy running activities during science festivals.

**Ceramics are my favourite type of material.** They have a wide range of applications, from electronics (resistors) to military defences (armoured vests) to aircraft (jet engines). And, of course, they are highly useful in the kitchen (plates and mugs) and bathroom (tiles and bathtubs).

## JESSICA TJANDRA

*PhD Student, Department of Materials, Imperial College London, UK*

***Post-16 subjects studied:*** *Physics, Chemistry, Maths, Economics*

**I chose MSE through a process of elimination** – I knew I wanted to study engineering but wasn't sure which type. I loved physics, chemistry and mathematics equally, but most engineering courses only focus on two out of the three. MSE is truly a mix of all three!

**Materials are literally everywhere.** Believe it or not, all engineering branches rely on MSE. Electronic devices are only what they are today with the development of ever-smaller transistors, modern buildings rely on composites developed through MSE, and aeroplanes use engineering alloys and ceramic coatings to fly efficiently.

**My current research looks at the corrosion behaviour of 3D-printed titanium alloys for bone implants.** Once these implants are in the body, they're exposed to mechanical and chemical stresses through the weight of the body, friction and wear at the joints, and the chemical and thermal conditions of the body. I mimic these conditions in the lab to see how implants behave and degrade over time.

**I love sharing how cool MSE is with people!** I have been involved in many outreach activities, working with children as young as five through to adults. Getting young people excited about MSE, and STEM in general, has been really rewarding. I feel I learn at least as much as the target audience through these activities.

**As a final year undergraduate, I conducted a research project with Rolls-Royce.** I got to see compressor and turbine blades that are used in Rolls-Royce engines, meet experts in the field of MSE, and see how the results of my research directly impacted the development of new engines.

**Titanium is a great material.** It's much lighter than steel but just as strong. With these properties, it gets used a lot in the aerospace industry, but also makes a great material for replacing our bones and joints. It is largely resistant to corrosion and, unlike most metals, doesn't conduct much heat.

## DR LEAH-NANI ALCONCEL

*Lecturer, School of Metallurgy and Materials, University of Birmingham, UK*

***Post-16 subjects studied:*** *Chemistry, Physics, Maths*

**Neither my undergraduate degree nor PhD were in MSE, but in chemical physics.** However, MSE has been a key part of my postdoctoral career. As Product Assurance Manager for a magnetometer used on spacecraft, I was responsible for assessing the material and mechanical properties of every component of the instrument. It was time-consuming work, but fascinating.

**MSE underpins so many other fields.** For instance, it's a crucial part of spacecraft engineering. Measuring and understanding material performance under the extreme conditions found in space determines whether or not a spacecraft will survive its mission.

**I'm interested in space-based dataset management and archiving,** space payload instrument development and inclusive STEM teaching. I enjoy building and testing space hardware with my students.

**The coolest thing I've done in my career is drive the Cassini spacecraft around Saturn!** More directly related to MSE, I am proud to have won a Royal Academy of Engineering Ingenious Award, which allowed me to work with an artist to develop photography workshops to inspire students to study MSE.

**In the future, I would love to build our space engineering capabilities** at the University of Birmingham to the point where we can test new materials in space through regular satellite launches.

**I'm a big fan of aluminium.** Though the process of extracting it is expensive and unpleasant, it's incredibly cost-effective to recycle. It's also light, can easily be combined with other metals to produce space-worthy alloys and is great at shielding sensitive electronics from radiation.

## DISCOVER MATERIALS

Though they work on different topics and are spread out across the UK, all the researchers in this article are part of the Discover Materials network. Discover Materials acts as a hub for students, teachers and parents to explore the world of Materials Science and Engineering. You can find resources about the applications of MSE in our daily lives, activities to do at home or in the classroom, and information about careers in the field. The researchers featured on this page are Discover Materials ambassadors, who deliver workshops in schools and offer support for teachers. To learn more, visit: **www.discovermaterials.co.uk**