# Engineering Level 2 - Modern High-Performance Materials

# 1 of 16 – Introduction

Welcome to this session on modern high-performance materials.

By the end of this session, you will be able to:

* Know the definition of a modern material
* Identify the properties of a range of high-performance materials
* Give examples of potential uses for some high-performance materials

# 2 of 16 - Modern high-performance materials

Most products are only as good as the materials they are made from. Because of this, companies often have large research and development budgets and departments who are tasked with refining existing construction materials or even inventing completely new materials from which products can be made.

A modern material is defined as one that has been engineered to have improved properties in some way. This includes more traditional modern materials, such as concrete and steel, and newer materials such as graphene, titanium and metallic foams.

In this session we will look particularly at high performance materials that have useful and exciting applications in engineering.

# 3 of 16 – Titanium

Titanium is a metal, silver in colour with low density and high strength. In fact, it has the highest strength-to-density ratio of any metallic element.

In its unalloyed condition, titanium is as strong as some steels, but less dense. Combining it as an alloy with other metals such as aluminium, iron, molybdenum and manganese makes it even stronger.

The two most useful properties of titanium are its corrosion resistance and high strength-to-density ratio. This makes it a popular choice in the aerospace industry for making parts for aeroplanes and in the automotive industry for making parts of cars. You will also find titanium in sports equipment, bicycle frames and even glasses.

# 4 of 16 – Tungsten

Tungsten is another very useful metallic element. It is found naturally, almost exclusively in chemical compounds.

Tungsten is remarkable for its robustness. It has the highest melting point of all the elements, and it is very dense, being about 19.3 times as dense of water. Despite its positives, tungsten is a brittle and hard material, making it difficult to work. In order to make it more workable, it can be combined with carbon to become tungsten carbide, which is a powder that can be easily formed and when solid has a hardness close to that of diamond.

Learn more about how tungsten carbide is made by watching this [video](https://www.youtube.com/embed/95yS7W66-BI).

Because of its high melting point, tungsten can often be found in places that get very hot, such as the filament of a lightbulb and TIG welding equipment. It is also used as an additive to high-performance steel, and in its carbide form in industrial cutting machinery.

# 5 of 16 – Superalloys

A superalloy, or high-performance alloy, is an alloy that exhibits several key characteristics:

* Excellent mechanical strength
* Resistance to thermal creep deformation
* Good surface stability
* Resistance to corrosion or oxidation

The primary application for such alloys is in turbine engines, both aerospace and marine. They are also used for building equipment in the energy industry, such as nuclear reactors and industrial gas turbines.

Superalloys were originally iron-based and cold wrought prior to the 1940s. In the 1940s, investment casting of cobalt-based alloys significantly raised operating temperatures.

# 6 of 16 – Ceramics

Ceramics are materials that are neither metallic nor organic. They can be crystalline or glassy, and they are typically hard and chemically non-reactive. Depending on their composition, they can be good insulators or conductors. Ceramics include pottery and clay, bricks, tiles, glass and cement.

As ceramics are heat-resistant, they can be used for many tasks for which materials like metal and polymers are unsuitable.

Ceramic materials are used in a wide range of industries, including mining, aerospace, medicine, refinery, food and chemical industries, packaging science, electronics, industrial and transmission electricity and guided light wave transmission. Examples of products with ceramic components include fibre-optic cables, phone touch-screens, sporting equipment, batteries, roads, buildings and computers.

# 7 of 16 - Metallic foam

Metallic foams are broadly similar to any other type of foam, but are made of metal, usually aluminium. They are made by injecting a gas or foaming agent into the molten metal.

Metallic foams are strong but lightweight. A typical metallic foam will have between 75% and 95% of its structure made of pores or spaces which trap gases inside the metal. This allows the material to retain much of the strength of the original metal but without the weight or density of a piece of solid metal the same size.

There are two types of metallic foam:

* Open cell foam, where the pores are connected together
* Closed cell foam, where the pores are individually sealed

Metallic foams are particularly useful in vehicles such as planes and cars, because they absorb shock very effectively in the case of an accident. They are also useful for vibration and sound absorption, and even have use in filtration systems.

# 8 of 16 - Advantages and disadvantages of metallic foam

As with any material, there are advantages and disadvantages to metallic foam.

Advantages:

* Has a high strength-to-weight ratio, particularly when aluminium is used
* Has the ability to absorb large amounts of energy when crushed
* Is non-flammable in most cases
* Allows the transfer of heat energy very easily

Disadvantages:

* High cost means they are only used with advanced technology
* Once crushed they do not spring back to shape like polymer foams, so can only be used once

# 9 of 16 – Kevlar

Kevlar is the registered trademark for a para-aramid synthetic fibre. This high-strength material was first commercially used in the early 1970s as a replacement for steel in racing tyres. Typically, it is spun into ropes or fabric sheets that can be used as such, or as an ingredient in composite material components.

Kevlar has a high tensile strength and is lightweight. It is resistant to chemical corrosion and is extremely tough. It is also non-flammable.

Kevlar is best known for its use in ballistic body armour, but it has other applications too. It is excellent for making protective equipment such as gloves that need to withstand cuts and slashes and is used to make very strong ropes and cables. It is also used in the aerospace and automotive industries because of its high strength-to-weight ratio.

# 10 of 16 – Graphene

Graphene is made of a single layer of carbon joined together in a honeycomb structure. It is the thinnest compound known to exist because it is only one atom thick, so appears invisible to the naked eye.

Although it has so far proved challenging to manufacture large quantities of it because of cost and environmental implications, graphene is of great interest to engineers as is hypothetically one hundred times stronger than steel, incredibly light and an excellent conductor of both heat and electricity.

Graphene has a wide range of potential applications, including in smart technologies, protective shields, healthcare diagnostic equipment and supercapacitors.

Watch this [video](https://youtu.be/fs1-9xRsGCQ) to see some of the exciting applications of graphene that are already being explored.

# 11 of 16 - Future research and development

Engineers will always have a use for materials that are stronger, lighter, better conductors or better insulators than those they already work with. Material scientists all over the world in research and development teams or working within universities are constantly working to improve the materials that the world has available for construction, or to invent entirely new materials.

Research and development never stops, and there will always be a desire to improve product functionality through the materials used to create them and reduce costs of raw materials and manufacture.

# 12 of 16 – Question 1

Indicate if the following statements about titanium are true or false.

1. Titanium has low density.
2. Titanium has low strength.
3. Titanium is not resistant to corrosion.
4. Titanium is gold in colour.

The correct answers are:

1. True
2. False
3. False
4. False

# 13 of 16 – Question 2

Which of these are properties of tungsten?

Choose all that apply.

1. It is very hard
2. It is a yellow-bronze in colour
3. It is brittle
4. It can be combined with carbon to make carbide

The correct answers are A, C and D.

# 14 of 16 – Question 3

Which of the following are key characteristics of superalloys?

Choose all that apply.

1. Excellent mechanical strength
2. Resistance to thermal creep deformation
3. High surface reflection for light
4. Good surface stability
5. Resistance to corrosion or oxidation
6. Low cost to produce

The correct answers are A, B, D and E.

# 15 of 16 – Question 4

Which of the following are examples of ceramics?

1. Iron
2. Glass
3. Brick
4. Aluminium
5. Tungsten carbide
6. Cement

The correct answers are B, C and F.

# 16 of 16 – Conclusion

Well done. You have completed this session on modern high-performance materials.

You should now be able to:

* Know the definition of a modern material
* Identify the properties of a range of high-performance materials
* Give examples of potential uses for some high-performance materials

If you have any questions about anything covered in this session, speak to your tutor for more help.