Smart Materials and the environment

Objectives

In this section you will;

Consider the impact of the material used on the environment

Learn about smart materials

Learn where new materials come from and how they might be used

Key Words

- Aesthetics…..how we respond to the visual appearance of a product
- Smart materials…..materials that are able to react to the user or the environment such as changes in temperature, moisture, pH or electrical and magnetic fields.

Environment

- In recent years we have all been made very aware of environmental issues. Organisations such as the Environment Agency have put plans in place to improve the way we treat the world around us and our quality of life.
- The Environmental Agency's vision is of 'a rich, healthy and diverse environment for present and future generations'.
- There are many factors involved in looking after our environment and working towards that vision. We now think more than ever before about the harmful gases and chemicals we put into the atmosphere, things we throw away and what we can recycle, and using the sun, wind and water to make energy.

- Many designers are now bringing these ideas into their work. They are trying to minimize environmental damage by selecting materials very carefully and considering the importance of reuse and recycling. Where the product has come from and where it ends up are key questions for a healthy environment

Smart Materials

- A **Smart material** is a family of materials whose physical properties change when they are subjected to different environments (such as temperature change or if an electric current is applied). Smart materials are being used, and are continually being developed, for medical, defensive and industrial products

- Tinted glass (photo chromatic glass) is an example of a smart material. The glass darkens when exposed to light from the visible and ultra violet spectrum. These are found in sunglasses and visors.
- Solar panels make use of the Photovoltaic cell which captures the power of the sun. Today many items make use of solar panels as their energy source for example hospital power, weather stations, lighting in remote areas (such as decorative garden lamps), radios,buoys and other instances where power is needed short term.

Thermo Ceramics

- Thermo ceramics make it possible to contain certain metals at high temperatures at which they melt. Mixing ceramics and metal powders together to form ‘cermets’ allows designers to operate machinery at high temperatures that would normally melt normal alloys and steels.

Shape Memory Alloys (smart wire)

- These metals were developed in the 1970's and these alloys can be plastically deformed at certain temperatures. They keep their shape at these temperatures then revert back to their original form. Nickel-titanium and Gold-cadmium alloys are often used in addition to Iron-nickel-cobalt-titanium alloy. The heat is needed to change their shape created by passing electrical currents through it.

How it works

As we know about the two phases occurring in molecular rearrangement, that are Martensite and Austenite. Martensite is the relatively soft and easily deformed phase of shape memory alloys, which exists at lower temperatures. The molecular structure in this phase is twinned as shown in Figure1. Upon deformation this phase takes on the second form shown in Figure2. Austenite, the stronger phase of shape memory alloys, occurs at higher temperatures. The shape of the Austenite structure is cubic. The undeformed Martensite phase is the same size and shape asthe cubic Austenite phase on a macroscopic scale.

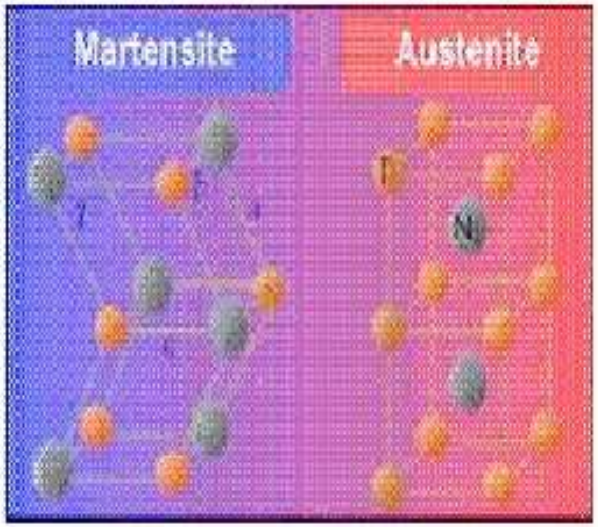


Figure 1. Martensite and austenite phases

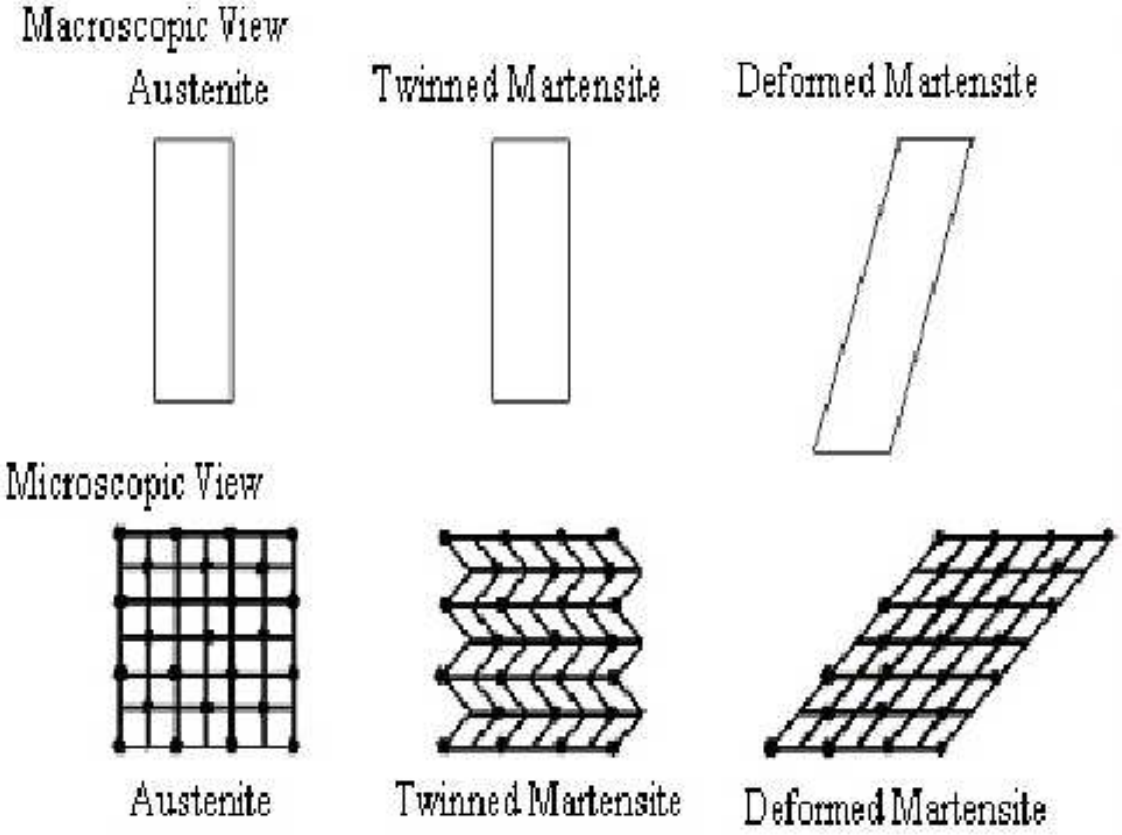
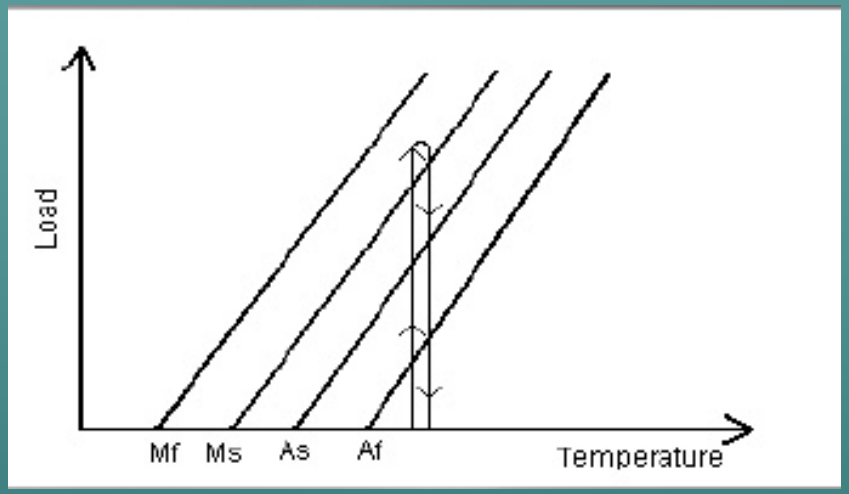


Figure 2: Microscopic and Macroscopic Views of the Two Phases of Shape Memory Alloys

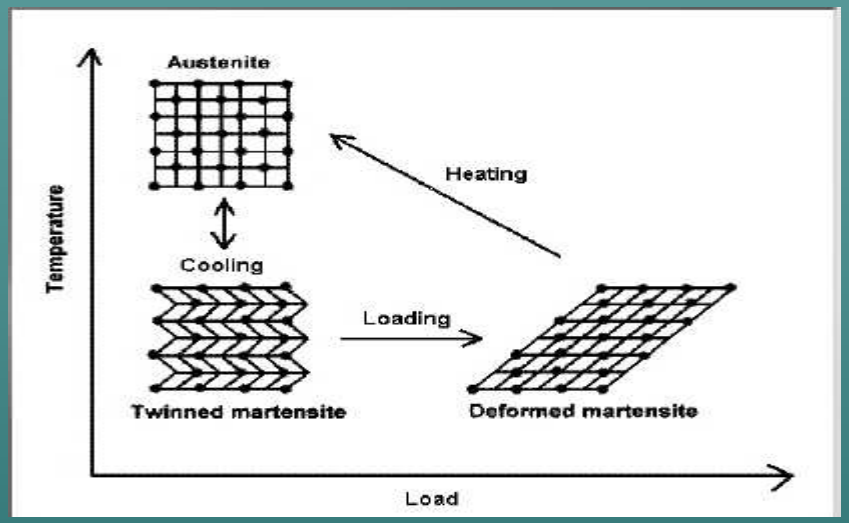
Pseudo-elasticity



Pseudo-elasticity occurs in shape memory alloys when the alloy is completely composed of Austenite. Pseudo-elasticity occurs without a change in temperature. The load on the shape memory alloy is increased until the Austenite becomes transformed into Martensite simply due to the loading, this process is shown in Figure. The loading is absorbed by the softer Martensite, but as soon as the loading is decreased the Martensite begins to transform back to Austenite since the temperature of the wire is still above Af, and the wire springs back to its original shape.

Shape memory effect

The shape memory effect is observed when the temperature of a piece of shape memory alloy is cooled to below the temperature Mf. At this stage the alloy is completely composed of Martensite, which can be easily deformed. After distorting the SMA the original shape can be recovered simply by heating the wire above the temperature Af. The deformed Martensite is now transformed to the cubic Austenite phase, which is configured in the original shape of the wire.



Microscopic Diagram of the Shape Memory Effect

The Martensite transformation is diffusionless, coordinative movement
of atoms from higher symmetry structure (Austenite) to lower symmetry structure (Martensite) upon
cooling.

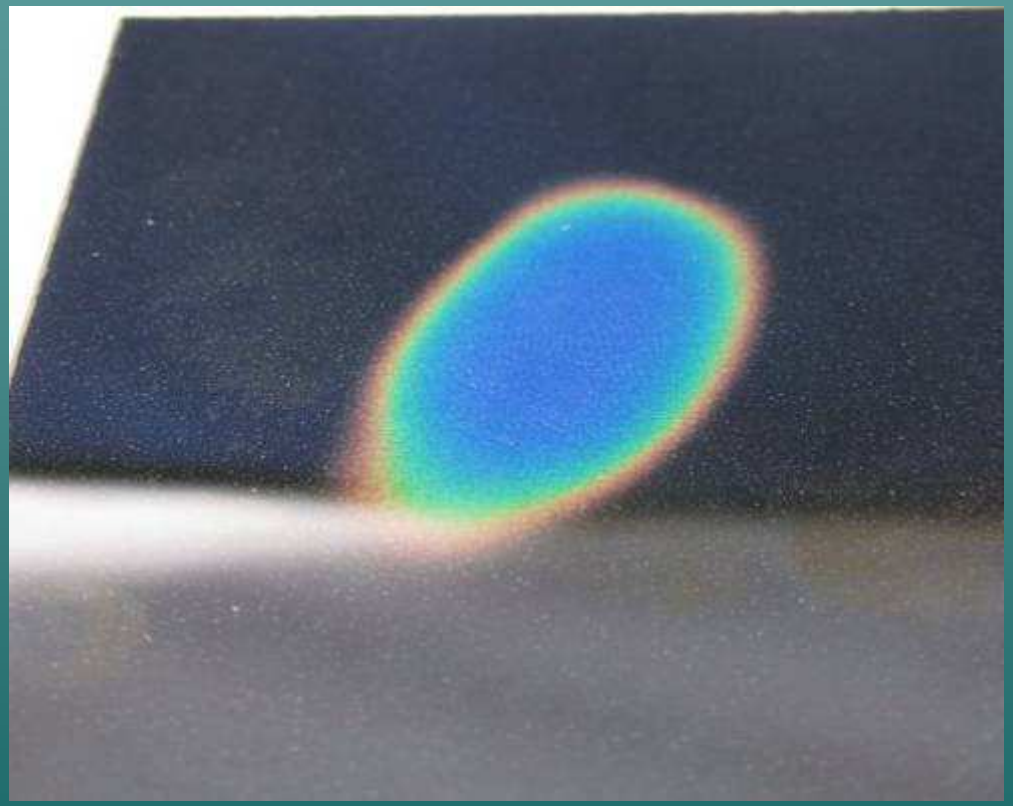
•Polymorph

This is a unique polymer that fuses in hot water and can then be moulded to any form. When solid it has similar properties to nylon

Used to make the moulds for the vacuum formed seat and fuel tank of this motorcycle project

•Thermocolour Sheet

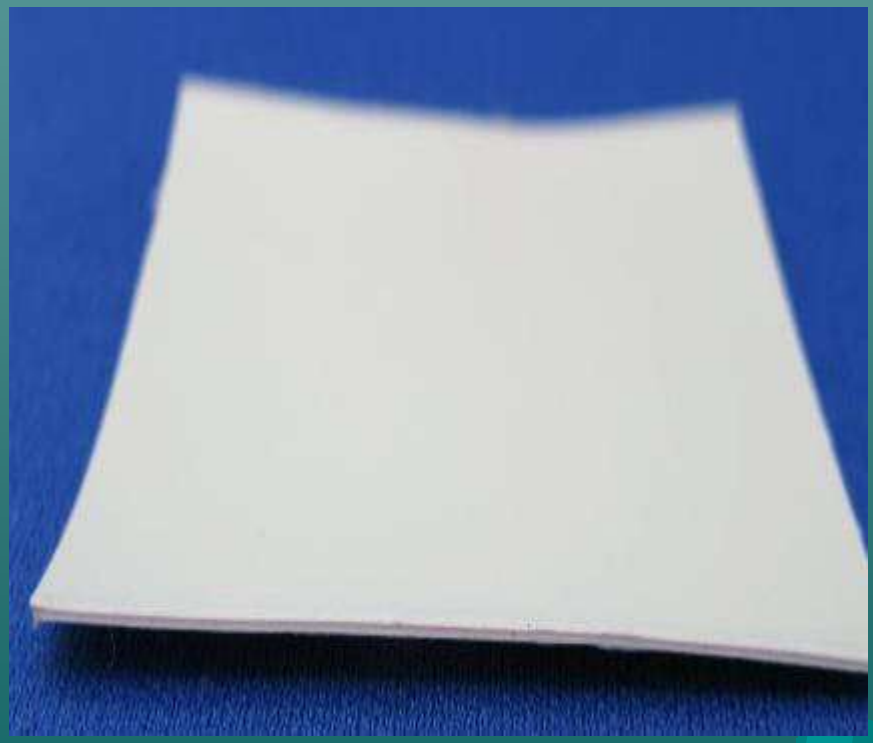
This is a self adhesive sheet whose colour changes according to the temperature. Used for thermometers, heat warning patches and novelty advertising of products



Sheet changing colour according to temp

•Phosphorescent Sheet

This is a sheet that absorbs light energy and re-emits it as white light for up to eight hours. Used extensively for emergency lighting in the event of a power cut

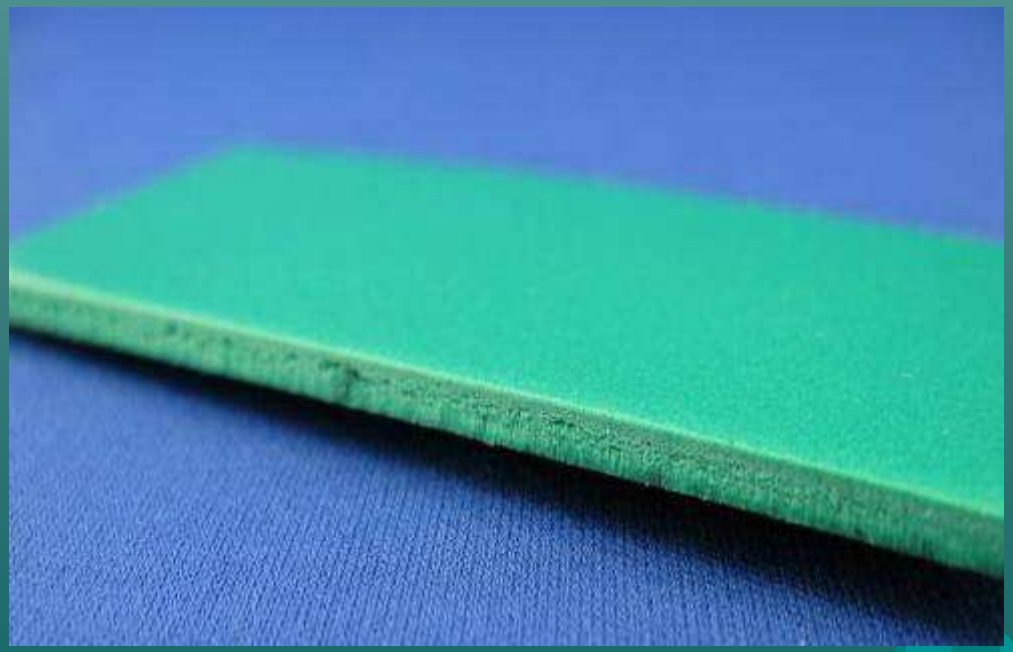


•Magnetic Sheet

This is a flat polymer magnetic sheet as used in fridge magnets. Also available in thin A4 sheets that can be printed on

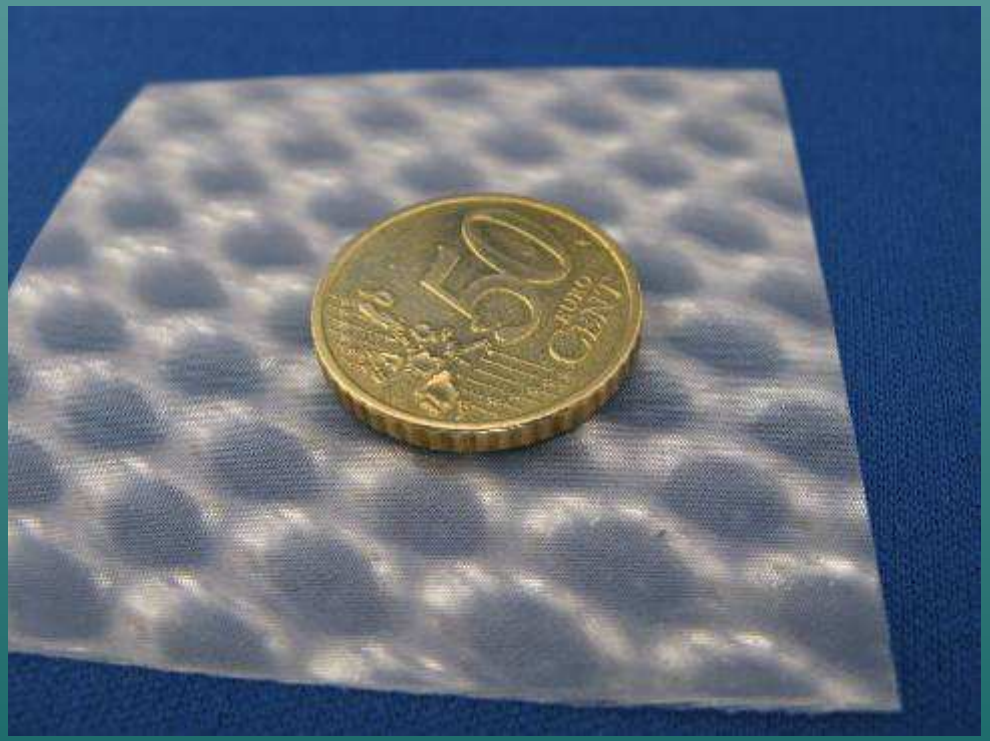
Rigid PVC Foam Plastic

This is a new generation of sheet material used widely for signs and exhibitions. Thermoforms very well. It is widely used for ‘plug and yoke’ mouldings



Lenticular Sheet

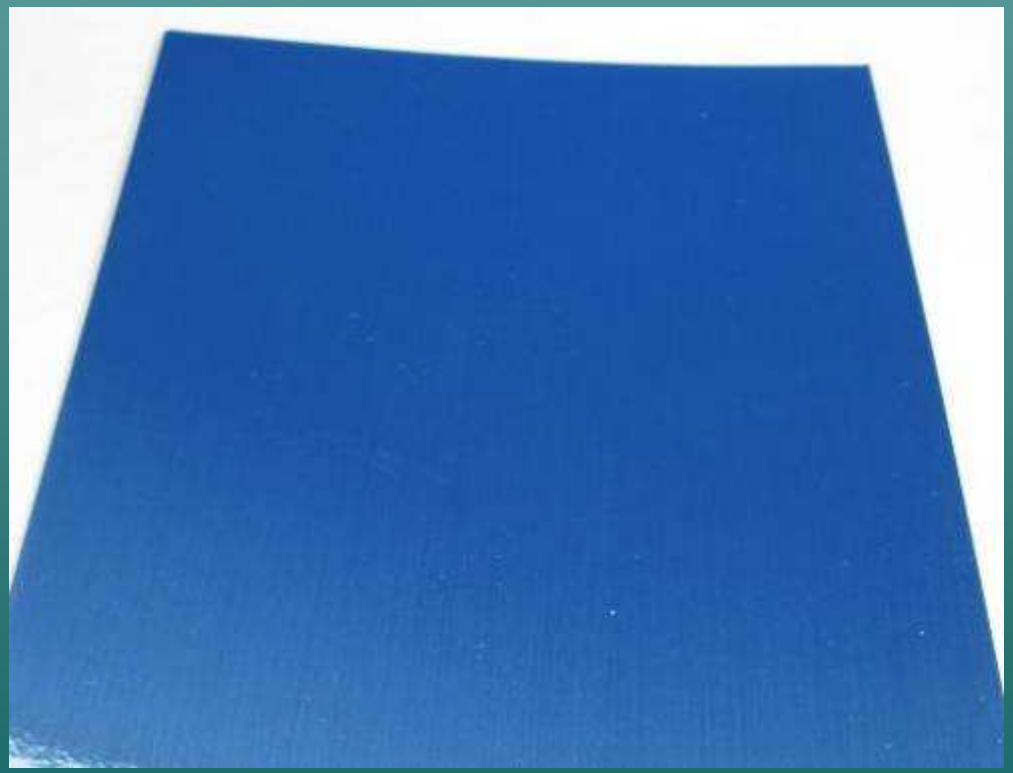
This sheet is about 1mm thick but gives the illusion that it is nearer to 6mm thick. An object placed on the sheet appears to sink below the surface



The camera lens does not capture the effect

Anodised Effect Card

This is almost impossible to tell from the real thing.
Ideal for project mock-ups.
It is relatively cheap and cuts easily with a scissors or craft knife



Galvanised Effect Card

This is almost identical to the real thing. Ideal for project mock-ups. It is relatively cheap and cuts easily with a scissors or craft knife. Used for packaging of top branded goods

Quantum Tunnelling Composite (QTC)

- A QTC in its normal state is a perfect insulator
- When compressed it becomes a perfect conductor
- If only lightly compressed its conductivity is proportional to the pressure applied

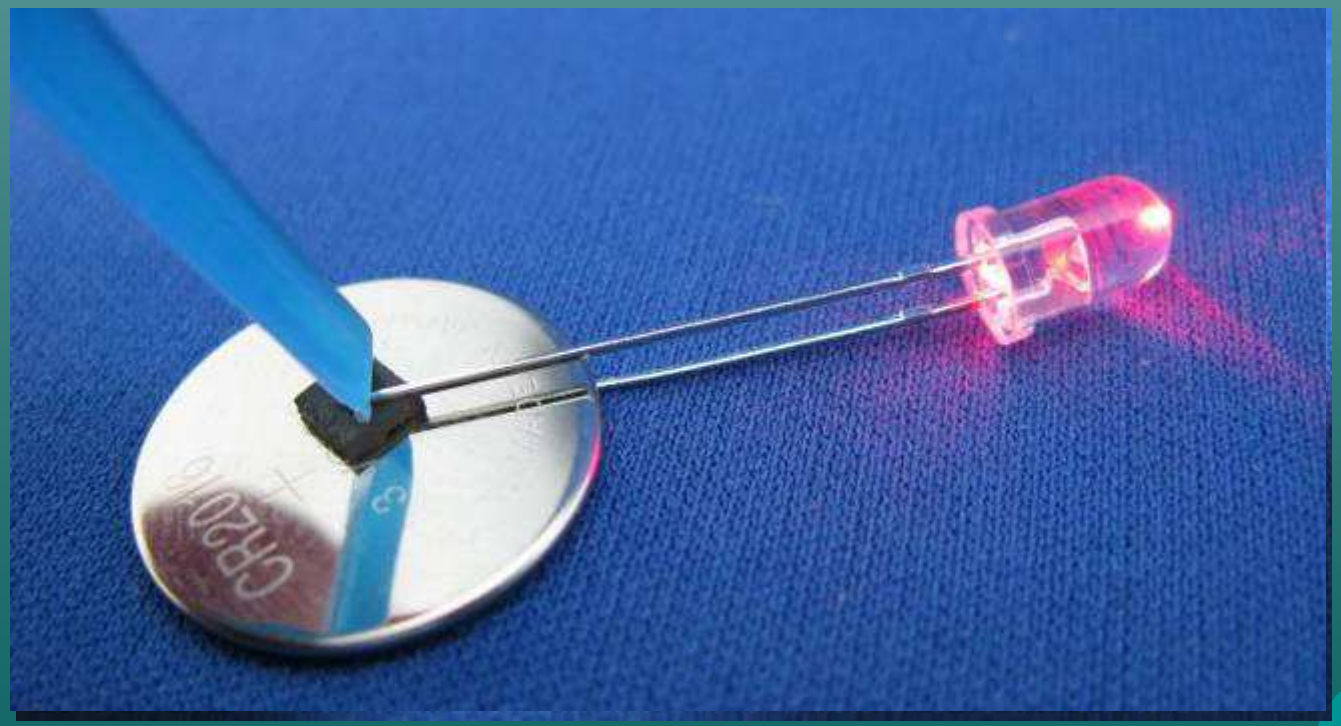
How does it work?

In normal physics an electron cannot pass through an insulation barrier.

In Quantum physics theory a wave of electrons can pass through an insulator – this is what is happening!

Quantum Tunnelling Composite (QTC)

Quantum Tunnelling Composite (QTC)



Light Pressure being applied

SMART MATERIALS IN DENTISTRY:

- Shape memory alloys-NITINOL
- Ceramic Braces
- Smart ceramics
- Smart composites-Amorphous $Ca_3(PO_4)_2$
- Smart fibers-Hollow Core Photonic Fibers (PCF)

"SHAPE MEMORY ALLOYS"

WHAT ARE NITINOL BRACES?

NITINOL is an alloy of nickel and titanium.

It was introduced in the year 1972 to the field of Orthodontics.

This alloy is used as braces to correct dental malformations.

These braces move only 6mm in 6 months-MINIMAL DISCOMFORT.

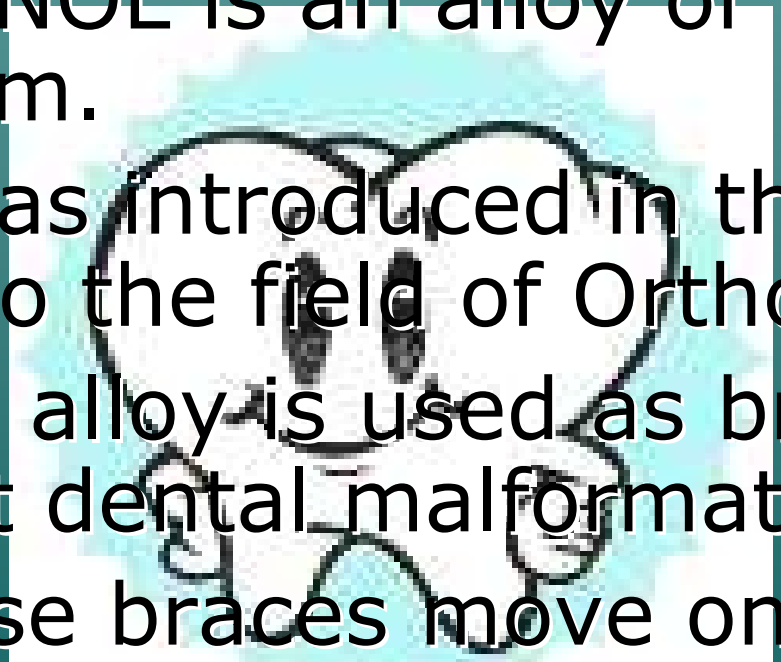
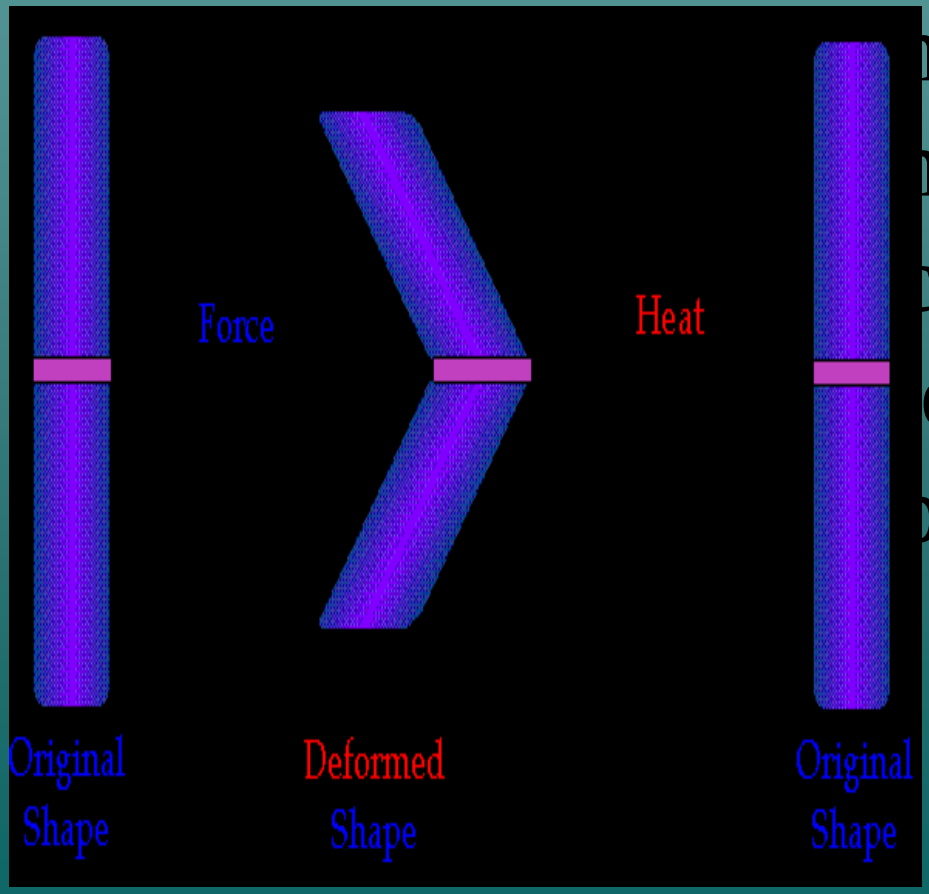


IMAGE OF NITINOL BRACES COMPARED WITH STAINLESS STEEL BRACES.

NITINOL BRACES

ADVANTAGES OF NITINOL BRACES:



- Nitinol braces have high flexibility and high resistance thus creating greater ease to use and increased patient comfort.

WHAT ARE CERAMIC BRACES?

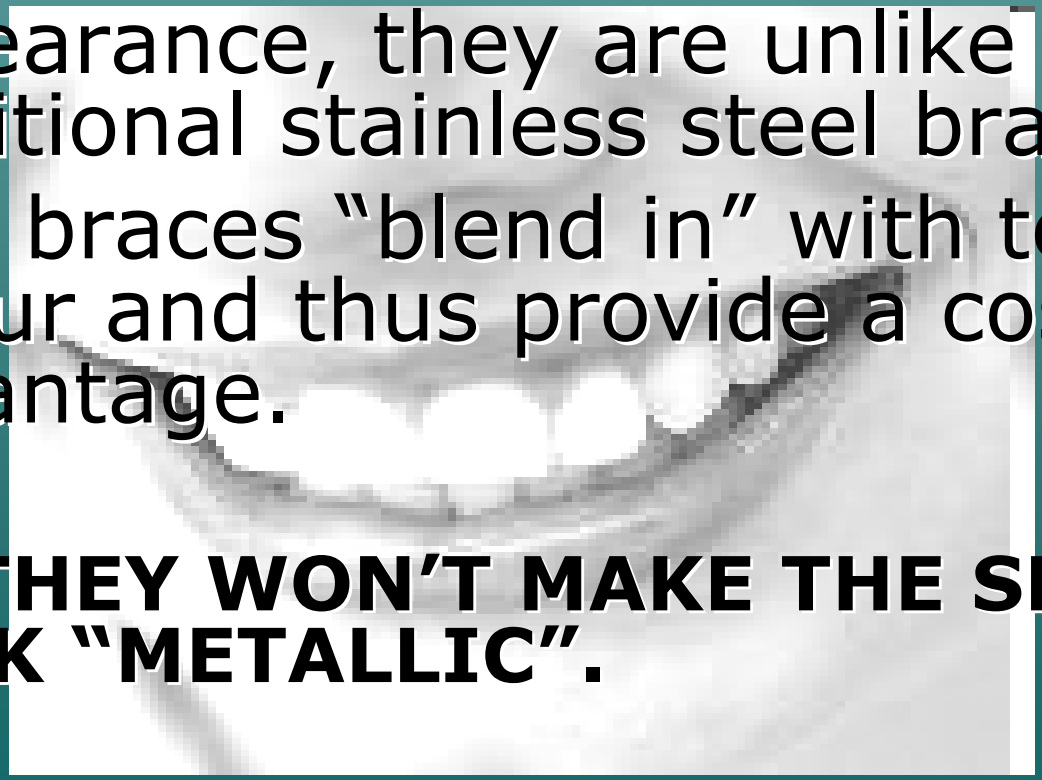
- Ceramic braces are less visible braces that are an alternative to the traditional braces.
- They blend themselves to natural colour of the teeth so that they appear more appealing.
- They are harder than the enamel so they are placed on the upper front teeth.

IMAGE OF CERAMIC BRACES.

CERAMIC BRACES

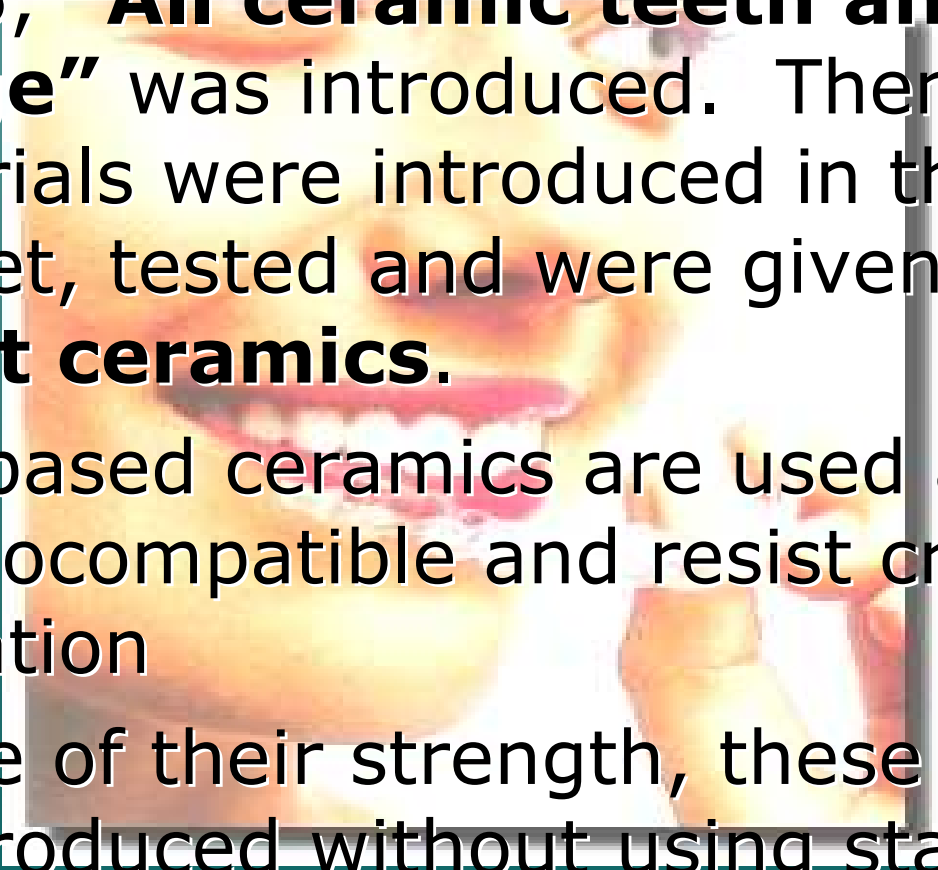
ADVANTAGES OF CERAMIC BRACES:

- As these braces are translucent in appearance, they are unlike traditional stainless steel braces.
- These braces "blend in" with teeth colour and thus provide a cosmetic advantage.



SO THEY WON'T MAKE THE SMILE LOOK "METALLIC".

WHAT ARE SMART CERAMICS?



In 1995, **"All ceramic teeth and bridge"** was introduced. Then these materials were introduced in the market, tested and were given name as **smart ceramics**.

Zircon based ceramics are used as they are biocompatible and resist crack formation

Because of their strength, these ceramics are produced without using stainless steel or metal.

ADVANTAGES OF SMART CERAMICS:

Alumina or any other currently available ceramics do not have high fracture toughness and flexural strength as in the case of zirconia. Ceramic system offers a good solution to all these needs by taking the advantages of these properties namely **strength, toughness, reliability and biocompatibility of zirconium oxide**. As these ceramics are bioresponsive they are said to be smart materials.

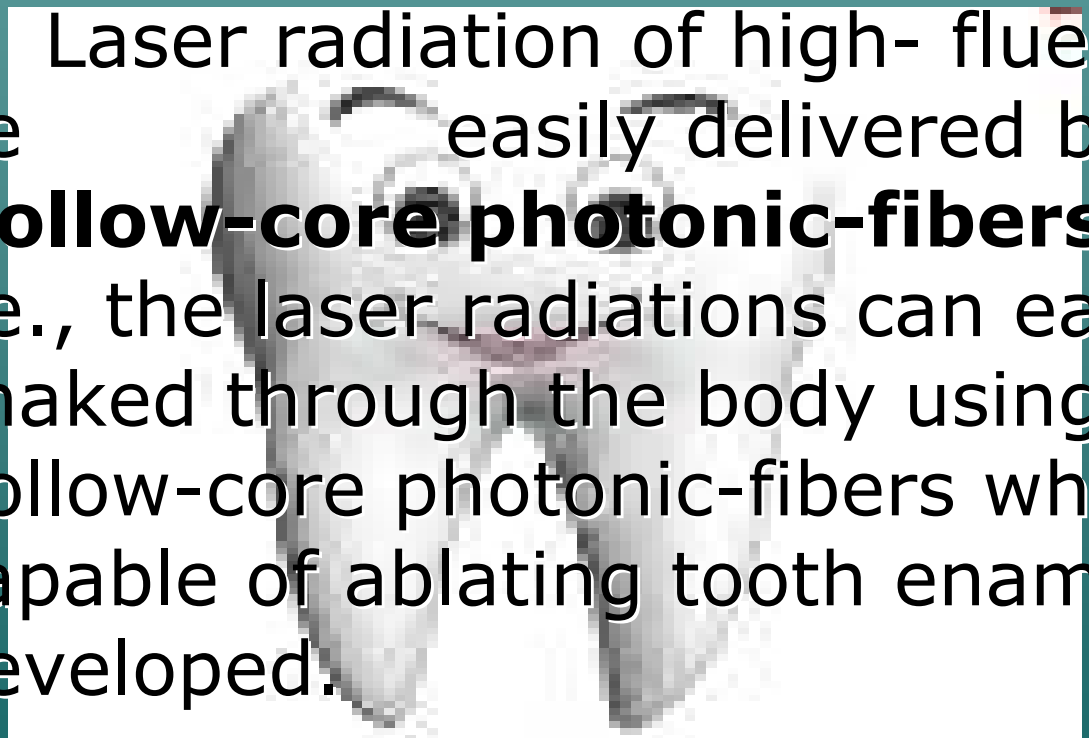
WHAT ARE SMART COMPOSITES?

- Smart composites contain **AMORPHOUS CALCIUM PHOSPHATE (ACP)** that is very much useful in dentistry.
- One of the basic building blocks of tooth enamel is **hydroxyapatite**; it is also an inorganic component of dentine. In the case of carious attack hydroxyapatite is removed from the tooth resulting in cavities or white spots.

ACP also exhibits the property of being **rapidly converted into hydroxyapatite (HAP)** when its level goes low and acts as **a source for calcium and phosphate useful in preventing caries.**

Thus **if the pH in mouth drops below 5.8 these ions will be generated within seconds which ultimately forms a gel**. This gel becomes amorphous crystals resulting in calcium and phosphate ions **in about 2 minutes**.

WHAT ARE SMART FIBRES ?



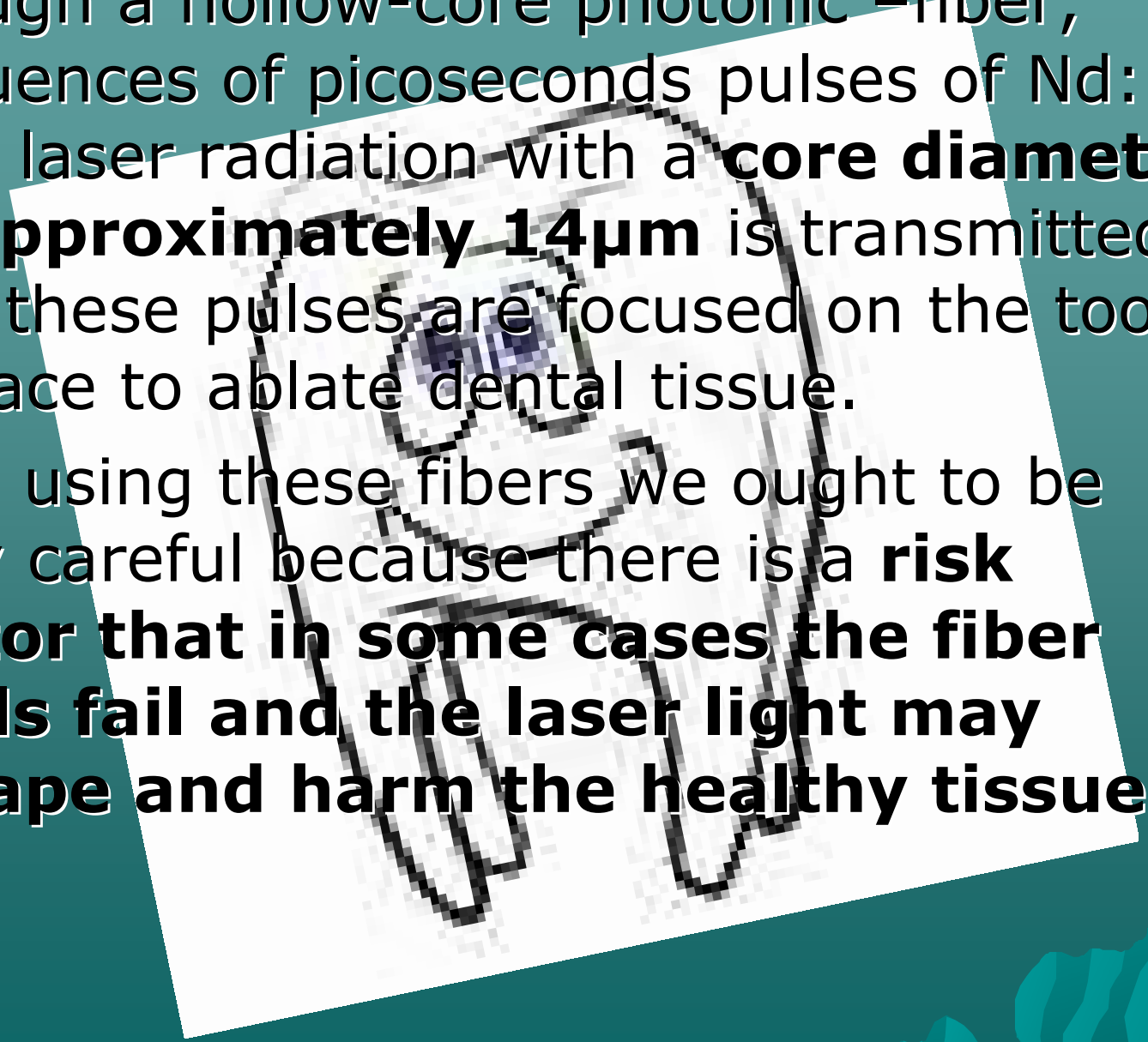
Laser radiation of high- fluency can be easily delivered by **Hollow-core photonic-fibers (PCFs)** i.e., the laser radiations can easily be snaked through the body using this hollow-core photonic-fibers which are capable of ablating tooth enamel been developed.

These photonic fibers are known as **SMART FIBERS.**

IMAGE OF LASER DENTISTRY

Through a hollow-core photonic –fiber, sequences of picoseconds pulses of Nd: YAG laser radiation with a **core diameter of approximately 14µm** is transmitted and these pulses are focused on the tooth surface to ablate dental tissue.

While using these fibers we ought to be very careful because there is a **risk factor that in some cases the fiber walls fail and the laser light may escape and harm the healthy tissue.**



CONCLUSION:

The recent advances in the design of smart materials have created novel opportunities for their **applications in bio-medical fields**. One of the applications is the dental restoratives.

The numerous applications they have been put to, no wonder tells us that these **"smart materials"** hold a real good promise for the future.