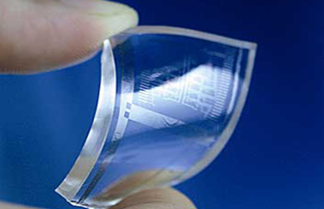
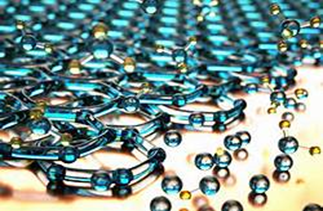
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SMART MATERIALS

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Introduction

Smart materials are defined as materials which are specially designed to have one or more properties that can be significantly changed in a controlled manner under the influence of external stimuli. These external stimuli or influences include the temperature, force, moisture, electric fields, magnetic fields and pH.

These most important aspect of the changes which smart material may potentially undergo is that these specific changes are reversible. This of course makes these materials all the more interesting to produce or to work with.

So why the term “*smart*”? This is due to the fact that the usage of smart materials requires no human control nor does it require the input of human energy. This means that when creating smart materials, possible internal properties of the material, which directly affect said material, are sought for to be able to determine how this specific smart material can be applicable to future implementation of any (industrial) product. This, of course, is a very big aspect of why research on and the usage of smart materials has to be encouraged.

In the case of a smart metal for example, what the inventors have done is create a very thin lamination of two different metals. Because such a material has two different coefficients of expansion, due to the presence of two metals, when heated for example, one side will expand faster than the other which in turn result in a curling action of the material. So in this case the metal changes its form and shape due to a stimulus as basic as the temperature. Something that is also very interesting is that due to the fact that the temperature may possibly vary, the rate of deformation of such a metal may also vary. Whether a product should possess such a quality (the fact that the rate of change can vary) ultimately depends on what said product will be used for. So where can such a metal be used? I think of myself sitting in my future office. A big office in a beautiful building with large windows which let in the sunlight. When there is too much sunlight shining through the office windows, instead of me having to get up out of my office chair to close the blinds or curtains, there are small particles of this aforementioned metal integrated in the glass of the windows that react to the excess of sunlight by expanding and thus blocking the sunlight from shining through in my office. Again, due to the fact that this expansion may vary, the blocking of the sunlight can be either partially or fully. This is an example of how such a smart material, in this case a smart metal, can be used.

Having said this, however, smart materials can be used in much more complicated scenarios or situations. For example: Military applications, Wastewater applications and Medical applications, among others.

In Military applications smart materials are basically used to create smart sensors. The military incorporates these smart materials when making Micro Air Vehicles, Nano Air Vehicles, Intelligence gathering sensors and Smart Dust, among others.

Then in Wastewater applications, smart materials are being implemented for example in the form of efficient adsorbents. The adsorbents are being used to reduce the variety and amount of dyes in waste water. Research has shown that adsorption, using efficient adsorbents, is an effective method for elimination of reactive dyes from wastewater. This method is considered to be environmentally friendly, biodegradable and to include very low costs.

In Medical applications smart materials are mainly used to create different features and functions in medical devices. For example the most popular metallic shape memory material: Nitinol. The main reason why Nitinol is being used in medical devices is because of its self-expanding stents. To prevent a blood vessel from collapsing for example.

Smart materials in our society.

Nowadays, smart materials are part of our daily life and we are so used to some of them that we do not think about their nature. Some of the most well-known materials are the piezoelectric materials, discovered in the 1880's by Pierre Curie. Since then, their use has increased and research in new applications is continuously done. Another highly used type of smart materials are the Thermo-responsive materials. A more new type of smart materials are the Shape Memory materials and Nanomaterials. In this section, we are going to explain how do some these materials work and we are going to give some examples of their use in daily life.

Piezoelectric materials

When a mechanical stress is applied to a material, an electric charge is induced on the surface of the material. The voltage produced by this induced charge is proportional to the applied stress. This phenomenon is known as piezoelectricity. Piezoelectric materials are found in nature and the most common natural piezoelectric material is the quartz crystal. However, there also exist man-made piezoelectric materials. These piezoelectric materials are more efficient than natural piezoelectric materials and they are mostly ceramics. Even if a material is piezoelectric, piezoelectricity is not always present. This effect only occurs if the material is at a certain temperature, known as the Curie temperature. The Curie temperature varies for each material.

The converse effect is also possible, obtain a mechanical stress from an electrical charge, and the materials that present this effect are known as actuators.

One widely known use of the piezoelectric materials is the so called Piezo-ignition, an effect used in lighters, camping stoves or gas grills, for example. When a button on the device is pressed, a spring-loaded hammer hits a piezoelectric crystal, quartz for example, or ceramic. As a consequence, a high-voltage is produced and a subsequent electrical discharge that ignites the gas present in the device.

Piezoelectric materials are also used as crystal microphones. These microphones consist of a thin strip of piezoelectric crystal attached to a diaphragm. If there is a change in the pressure close to the diaphragm, it is deflected and a stress is applied to the crystal, which produces an electrical charge. The electric charge obtained with these microphones is comparatively large but their frequency response is not as good as another type of microphones. However, piezoelectric materials are still used as contact microphones to amplify the sound of acoustic instruments, to sense drum hits or to record sound in challenging environments like underwater under high pressure.

As mentioned above, research in piezoelectricity has never stopped. New environmentally friendly applications are researched nowadays. One example is the use of piezoelectric materials for wind energy harvesting. At Cornell University, a “piezo-tree” was created. This three contains leafs made of a flexible piezoelectric material. When the leaves are bent by the air an electric signal is produced and stored in a capacitor [6]. At the same university, another wind generator was designed. The generator consists of a series of pads attached to piezoelectric cells that generate current when the pads flutter in the wind.

Thermo-responsive materials

As the name states, thermo-responsive materials are smart materials that present a modification of their properties when they perceive a change in temperature. There is a large number of properties that change with temperature in this kind of smart materials, one of this properties is the color. Materials that present a change in their color due to a change in temperature are called thermocromic materials. Some thermocromic materials are paintings, papers or inks that have practical and recreational applications.

A new thermo-responsive device has been designed in China in 2013. It is a temperature responsive supercapacitor that shuts down when it gets too hot. Supercapacitors are layers of pseudocapacitors and they have high power densities, which allows faster charge and discharge cycles. These type of cycles can present an uncontrolled temperature increase, usually known as thermal runaway. This effect is dangerous because it can generate explosions and break down of the devices where the capacitors are used. This problem has been overcome by researchers at the Beijing University of Chemical Technology, where they designed electrodes for supercapacitors covered with a layer of a thermo-responsive polymer. This polymer shrinks when it reaches a threshold temperature inhibiting the charge transfer and further heating of the device [7].

Thermo-responsive materials are also used in green technology preventing the overheating of buildings. As previously mentioned, smart metals that can help us to block the sunlight into the building. The use of thermo-responsive metals for smart buildings is an actual research in smart architecture that has already been implemented for small structures and is expected to be further developed in coming years [8]. An example of an actual application of thermo-responsive materials in architecture is a smart building in the University of South Denmark. The building has a facade that consists of triangular movable elements that regulate the inflow of light inside the building. These elements contain a thermo-responsive metal that activates a mechanism to close the panels and block the sunlight if the temperature is above a threshold and open them allowing the inflow of light when the temperature is below the threshold [9].

Shape memory materials

Shape memory materials are smart materials that recover their original shape at the presence of an external stimulus. The stimulus can be a change in temperature, the presence of an electric or magnetic field, etc. Shape memory materials can be used in many fields, from aerospace engineering to medical devices.

An example of medical application is the use of self-expanding metallic stents. These stents have a compressed shape when cooled and they expand when they are under body temperature conditions. They are compressed and placed into a sheath outside the body, once they are placed in the desired obstructed vessel they are extruded from their external sheath and due to the change in temperature, they recover their expanded shape and they open the vessel to blood flux.

YOUR PART

Conclusion

There are a number of smart materials that are already part of modern society whether it be for home usage, medical applications or for industrial purposes.

However, smart materials are not implemented in every industry yet. Because the world is continuously changing and aiming for perfection combined with convenience and durability, smart materials may become one of the most important foundations for (technological) innovation and sustainable growth in different areas of our daily lives. For that reason, research on smart materials should continue by and for all different areas of innovation so that we can ultimately benefit from the full potential of smart materials.

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