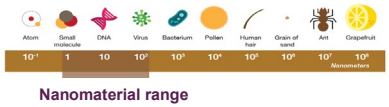
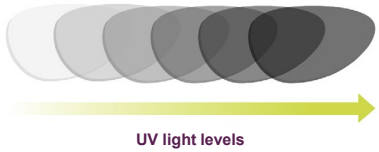
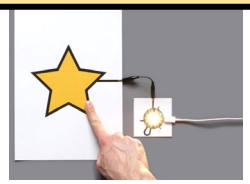
1.4 Smart and Modern Materials

Modern Materials	Do not occur naturally. They are existing materials that have been altered to improve their properties.
Smart Materials	Are materials with physical properties that can be varied by an external input such as temperature, light moisture, force or electrical current.

Material	Description	Applications	Advantages	Disadvantages
Shape-memory Alloys (SMAs): 	Can be plastically deformed (shape changed, stretched or crumpled) and will return to their original shape when heated or a current is applied.	• Glasses frames. • Medical stents. • Tweezers and hooks. • Orthodontic wires.	• Lengthen life of a product. • Reduced overall size, less complexity.	• Expensive. • Continuous use can cause metal fatigue.
Nanomaterials:  Nanomaterial range	Made of tiny components less than a millionth of a millimetre in at least one direction. They may be particles, nanowires, nanotubes or thin films and surface coatings.	• Fire-retardant materials. • Sunscreen. • Tennis rackets. • Motorcycle helmets. • Car bumpers.	• Larger relative surface area can improve their strength, elasticity, magnetic, electrical, thermal conductivity and absorbent properties.	• Unusual physical and chemical properties – may need specialist risk assessment relating to health and the environment.
Photochromic glass:  UV light levels	Darkens/Changes colour when exposed to light and reverses in the dark. Tiny silver halide particles are added to glass, ultraviolet light then causes a chemical reaction.	• Sunglasses. • Plane cockpit windows.	• Adapts easily to changing conditions. • Can undergo thousands of cycles without a change in performance.	• May be slow to react. • User cannot control the reaction.
Reactive glass: 	Uses electrochromatic technology to change from transparent to opaque by applying voltage while allowing light to pass through from both sides.	• Welding masks and goggles. • Windows.	• Retains heat, so reduces energy bills. • Instant privacy without permanent blocking of light.	• Expensive. • Requires electricity source.

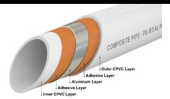
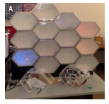
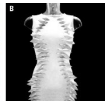
Modern Materials	Smart Materials
Do not occur naturally. They are existing materials that have been altered to improve their properties.	Are materials with physical properties that can be varied by an external input such as temperature, light moisture, force or electrical current.

Material	Description	Applications	Advantages	Disadvantages
Piezoelectric materials: 	Generate a small electric charge when compressed (sensors). Can work in reverse, by generating movement when an electric charge is applied (actuators).	• Generating energy. • **Sensors:** burglar alarms, keyless car entry, seat belt sensors, keypads. • **Actuators:** for precise position control such as digital cameras.	• Sustainable. • Low maintenance. • Compact size useful in micro-electronics. • Actuators have a high response speed and can create a large force.	• Wear out. • Has temperature, load and voltage limitations.
Temperature-responsive polymers: • **Polycaprolactone (PCL) -** is a low temperature, hand-mouldable polymer • **Thermochromic pigments** - temperatures trigger a change of colour in special dyes. • **Poly (N-isopropylacrylamide) (PNIPAM)** changes from a liquid to a solid when heated.	Can change physical properties with a change in temperature. Some change colour with a change in temperature. Some can be moulded and remoulded at very low temperatures. Some are a liquid at a low temperature but can solidify with a relatively small rise in temperature.	• Can deliver drugs, cells or proteins to patients in a controlled way when mixed with liquid polymers. These are injected into a patient n gel forms and released when the temperature is increased. • Can be used as sensors and gel activators. • Polymorph can be shaped using only hand pressure, can be reused.	• Useful in biomedical applications.	• Still being researched so wider applications may take time to be established/developed.
Conductive inks: 	Contain pigments that allow small currents to flow through even when dry. Made with silver, carbon, graphite or other precious metal coated base material.	• Drawing working circuits on polyester and paper. • Improvising or improving circuits on PCB's • Printing RFID tags for tickets.	• Easy to use. • Lighter and more economical than traditional circuit boards. • Low waste. • Ink can be folded.	• Silver is expensive. • Difficult to get circuits right.

1.4 Composite materials

Composite Materials

A material that has enhanced properties and/or characteristics (physical or chemical) through combining two or more significantly different materials
A composite consists of reinforcing materials and a bonding agent called the matrix.
Most composites have excellent strength to weight ratios.

Material	Description	Examples
Concrete 	Made of course aggregate (gravel), aggregate (sand), cement and water. It hardens to gain **compressive strength** but has a low **tensile strength**. Tensile strength can be improved by adding steel rods, producing reinforced concrete. It is relatively cheap and can last for 100 years.	• Mainly used for construction but it can be used for smaller products such as park benches and bins.
Plywood: 	Is a manufactured board made of wood veneers bonded with glue to create a flat surface. It always has an odd number of layers to balance the stresses around a central core. The grains of each level run at 90 degrees to the sheets above and below to increase the stability.	• Graded for interior and exterior use depending on water resistance. • Sheds, cladding, flooring and furniture.
Fibre/Carbon glass:  	Plastic can be reinforced with fine glass or carbon fibres to make a higher strength to weight ratio. These fibres form a flexible fabric that are built up in layers with polyester resin. It can be sanded for a smooth finish and colour can be added either at the start or end of the process.	• **Glass reinforced plastic (GRP)** – best suited for large structural forms such as boat hulls, baths and car bodies. • **Carbon fibre reinforced plastic (GFRP)** – is stronger so used for propeller blades, body armour and golf clubs.
Reinforced polymers: 	Phenolic resins are combined with cotton fabrics to make inflammable laminated plastic sheets, rods and tubes. They are about half the weight of aluminium and are strong, tough, with insulating properties at high temperatures.	• Engineering components like gears and bearings. • Substitutes for exterior timbers as weatherproof and do not need treatment.
Robotic materials:   	Materials that couple sensing, activation (movement), computation and communication and can react to their surroundings autonomously.	• Vehicles or uniforms that change colour to match surroundings. • Prosthetics with a sense of touch. • Plane wings that change shape depending on conditions.

1.4 Composite materials

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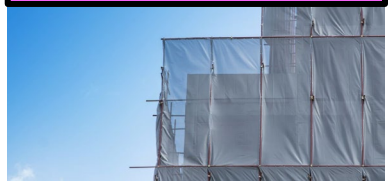
A composite consists of reinforcing materials and a bonding agent called the matrix.
Most composites have excellent strength to weight ratios.

Material	Advantages	Disadvantages
Concrete	• Excellent compressive strength. • Good heat and sound insulator. • Can be moulded into complex shapes with a variety of surface finishes, so has many applications. • Can be manufactured on site, so reduces transport issues. • Durable, fire-resistant. • Will last for a long time.	• Can be damaged by corrosion of reinforcement bars, fire or radiant heat and freezing trapped water.
Plywood:	• High strength to weight ratio and strong in all directions • High impact resistance, so not easily damaged. • Versatile – can be used inside and outside. • Economical use of wood as less wastage and available in large sheets.	• Although plywood is strong and stable, layers can separate if they become wet.
Fibre/Carbon glass:	• Low maintenance, durable and good resistance to ultraviolet (UV) light and most chemicals. • Able to be formed into most 3d shapes, with added surface texture. • Lightweight with an excellent strength to weight ratio.	• Breathing in the fibres can cause respiratory problems.
Reinforced polymers:	• Strong with good wear resistance and excellent machining qualities (will not blunt tools as much as metal). • Good insulator of heat and electricity with low water absorption. • Available in a range of forms. • Good dimensional stability (does not change shape in heat or moisture rich environments).	• Expensive.
Robotic materials:	• Can react to surroundings without connection to a computer. • Can react quickly and appropriately by themselves. • Can change colour, shape and the load they can carry.	• Expensive and complex.

1.4 Technical Textiles

Technical Textiles

Are developed for their function rather than their appearance. Some textiles can be used for many applications across a range of categories and industries. This is due to their physical and working properties. They can be strong, lightweight, waterproof, tough, breathable, biodegradable and versatile and are increasingly economical.

Material	Description	Applications	Advantages	Disadvantages
Agrotextiles: 	Improve or increase agricultural production. They may be made from nylon, polyester or natural materials such as jute and wool.	• Shading • Thermal insulation • Wind-breaks • Weed suppression • Netting	• Durable • Reduces the need for weed killers and pesticides • Can be cheap	• Could change ecosystems by altering natural circulation of water, carbon and other nutrients.
Construction textiles: 	Developed to improve construction appearance and longevity.	**Structures:** • Waterproof membrane, concrete reinforcement. **During construction:** • Hoarding nets, awnings, tarpaulin, canopies.	• Strong and light • Resistant to degradation by chemicals, sunlight and acids. • Stable in different heat conditions.	• May be expensive or hard to source. • May degrade over time.
Geotextiles: 	Used in civil engineering where soil, rock or other geotechnical material needs to be stabilised, filtered, drained or reinforced. They retain their structure in the ground.	• Non-woven or woven mats for reinforcing banks or draining flat land.	• Do not rot. • Deal well with water. • Cost effective.	• Easily blocked by sediments and organic matter. • Ineffective if damaged.
Domestic textiles: 	Used domestically, even if developed for other purposes.	• Cleaning wipes. • Furnishings. • Wadding. • Linings. • Carpets. • Flooring.	• Hardwearing. • Stain resistant. • Absorbent.	• Can be expensive. • Fire risk for some textiles. • Can be difficult to clean.

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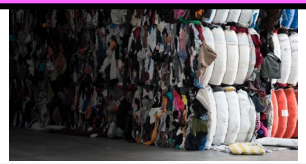
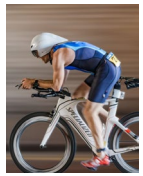
Material	Description	Applications	Advantages	Disadvantages
Environmentally friendly textiles: 	Use organically grown fibres such as hemp, wool, cotton or bamboo or recycled materials.	• Geotextiles. • Agrotextiles. • Fashion.	• Processed with fewer chemicals and naturally more resistant to mould and pests.	• Can be expensive.
Protective textiles:  	Provide protection against heat, harmful chemicals, gases, pesticides and even bullets.	• **Clothing –** heat and radiation protection for firefighters, molten metal protection for welders. • Tents for severe weather. • Parachutes and mountain safety ropes. • Disposable chemical protection overalls.	• Can be resistant to many external inputs but still breathable and light.	• Expensive. • Not environmentally friendly.
Sports textiles:  	• Combine function with comfort for high performance. • Can be lightweight • Streamlined and breathable. • Remove moisture. • Sense heart rate. • Control bacteria. • Block UVA/UVB rays. • Resist impact.	• Running shoes. • Cycling shorts. • Rugby tops. • Swimsuits.	• Can improve athletic performance.	• Expensive. • Not environmentally friendly.