MATERIALS ENGINEERING AND SOCIETAL CHALLENGES

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Table of Contents

[1. Overview 3](#_Toc61120356)

[2. Energy and Transport 4](#_Toc61120357)

[2.1. Problems 4](#_Toc61120358)

[2.2. Solutions 5](#_Toc61120359)

[3. Environment and Climate 6](#_Toc61120360)

[3.1. Problems 6](#_Toc61120361)

[3.2. Solutions 7](#_Toc61120362)

[4. Information and Communication 7](#_Toc61120363)

[4.1. Problems 7](#_Toc61120364)

[4.2. Solutions 8](#_Toc61120365)

[5. Health 9](#_Toc61120366)

[5.1. Problems 9](#_Toc61120367)

[5.2. Solutions 9](#_Toc61120368)

[6. Conclusion 10](#_Toc61120369)

MATERIALS ENGINEERING AND SOCIETAL CHALLENGES

# Overview

Engineering materials are broadly classified as either metals, plastics, ceramics, or composites. The properties of each class of materials differ. Mechanical properties like modulus of elasticity, tensile strength, compressive strength, creep, and modulus of rigidity determine the use of each class of materials. These properties also affect the costs of the materials. Chemical properties like bonding, oxidation or affinity, and reactivity to different compounds also affect the uses. For instance, each material will react differently to hydrochloric acid. Electrical and thermodynamic properties are determined by chemical properties. Within each class, there are several sub-classes with different mechanical and chemical properties. Materials Engineering finds a way of using the extant knowledge of materials to develop newer and improved materials for various purposes in the field. To achieve this, the basic properties and uses of materials must be explored. Plastics have the weakest bonds among the classes of materials. This translates to a higher elasticity but a lower stress capacity. Moreover, they fail easily under high temperatures. Consequently, they are used for affordable components that do not require high strength but need extreme flexibility in low-heat conditions. Plastics, which are generally hydrocarbons of the order CH4, are further classified into thermosetting and thermoplastic plastics.

Ceramics like SiO4 are harder, withstand high heat, and more durable than plastics. Similarly, they are corrosion-resistant, unlike most metals. Nonetheless, they are the most brittle materials of all. As such, they are used for components that require no machining and are to operate in a corrosive high-temperature environment. Some composites are also used as semi-conductors due to their capacity to store charge. Types of ceramics include clays, refractories, magnetic, electrical, and abrasive ceramics. Metals are strong materials with high electrical and heat conductivity. Most of them are malleable and ductile, making them the most common materials in most engineering works and machinery. Metals are further classified into ferrous, non-ferrous, and alloy metals. The major challenge with metals is their high density. As engineers seek ways to increase the speed of machines and efficiency while lowering the costs and weight of the same, they are gradually replacing metals with composites. Composites are hybrids of two or more of the other three materials. They are better than the original materials in terms of chemical and physical properties. For instance, composites made of metals are as resilient but lighter than metals. They can be classified by reinforcement, stratification, or matrix. They include fibre-reinforced, particulate, laminar, and embedded composites.

# Energy and Transport

## Problems

Aeroplanes were built to withstand rapid temperature changes and speed. However, they are still heavy and yet to ascend high enough. Engines need to become lighter for faster transportation without compromising the efficiency of the machines. Moreover, the carrying capacity of planes needs to be improved to increase the mass that can be transported in one trip. Metals are a great hindrance to achieving the air dynamics that engineers theorize. Likewise, vehicles need lighter materials to improve speed. They also need newer and smaller but more powerful models of engines that will enable the shift from reliance on hydrocarbon fuels to renewable energy. The same applies to other major and upcoming forms of transport like Hyperloop, space exploration, and Maglev trains. Energy developments from steam engines and coal plants also demand better materials. Wind turbines, for instance, can generate more power if some materials were changed. Similarly, lithium-ion and lead-acid batteries need materials improvement to minimize ecological damage. More importantly, the shift from dependence on hydrocarbons to renewable energy also influences the use of materials in both energy and transport. Materials engineering improves the sustainability of technologies in the two sectors.

## Solutions

Maglev trains are one of the major accomplishments in the transport industry in the last decade. These trains were made possible by materials engineering since a competent understanding of materials is required to determine the maximum carrying capacity and clearance from tracks. Composites and plastics have replaced metals in aviation. Fibreglass is soaked with a plastic resin and the resin cures to make the material rock-hard. Carbon-fibre reinforced polymer (CFRP) accounts for about half of the Airbus A350 XWB (Pilot Mall 2020). The wings are made of CFRP since it offers a better strength-weight ratio than metals. The Boeing 787 is comprised of 80% composites by volume or 50% composites by weight (Pilot Mall 2020). This comparison between weight and volume show the relative advantage of composites over metals in lowering weight for the but at the volume. The lower weight saves on fuel and maintenance, meeting one of the greatest customer needs. Unfortunately, it takes longer to produce a machine using composites because they must cure, unlike metals. Moreover, composites are costlier than metals like aluminium. However, composites are easy to manipulate, thus, they improve construction and smoothness of aerodynamic surfaces (Pilot Mall 2020). They also lower the manpower required in construction since they eliminate the need for processes like welding. Mojave praises composites for allowing the company to make futuristic and spectacular planes in short time frames.

Scaled composites have been used for spaceships or suborbital space planes, allowing one model to reach an altitude of 328,000 feet. Just as coal shaped the 19th century, and petroleum changed the 20th, renewable energy is expected to change the 21st. Materials science research and discoveries will create new, sustainable, and economical energy technologies (University of Maryland 2014). Extant influences of materials engineering in energy include the use of semiconductors is photovoltaic cells and thermoelectric generators, combining metal catalysts with ceramic ion-conductors in hydrogen fuel cells and designing durable reactors for nuclear energy. These technologies are further miniaturized suing nanotechnology for higher efficiencies (University of Maryland 2014). Different materials can achieve different levels of power generation and conservation. Bakr et al. (2017) discuss perovskite, silicon, and thin-film solar cells. The article shows how the manipulation of materials can increase the efficiency of photovoltaic cells using hole-transporting materials (HTMs). Organic polymer solar cells (PSCs) have also been proved to have higher efficiencies. Essentially, material engineering has improved energy development, renewable energy devices, engines, and transport machinery.

# Environment and Climate

## Problems

Global warming, emissions of greenhouse gases (GHG), climate change, and pollution are some of the biggest challenges of this era. Other than pollution, the other three issues are connected. The excessive reliance on petroleum and coal in the past centuries affected the ozone layer. GHGs eventually formed a blanket in the atmosphere that distorts temperature regulation. Consequently, terrestrial radiation is trapped within the earth, causing a rise in temperatures. Pollution of soil, air, and water increase the health risks associated with poisoning from heavy metals and aerosols. For example, lead and arsenic fumes are carcinogenic. This means that they can cause cancer. Cyanide from gold mines destroys aquatic life if it gets into water bodies. Kovac (2000) reports of Hungary’s Tsiza River poisoning. The pollution occurred in Baia Mare, Romania, where 10,000m3 of cyanide-contaminated sludge flowed over a dam into Tsiza through rivers Lapos and Szamos (Kovac 2000). Heavy metals are mined for energy and electricity purposes. Lead is now recycled from old batteries but new ones still require it to be mined. Zinc and copper are used in electrical components, among other uses. Notably, power production and manufacturing are the main problems that lead to pollution.

## Solutions

Technology is the best solution that materials engineering has provided for environmental and climatic challenges. The introduction of hydrogen fuel cells as possible replacements for lead-acid batteries in electric vehicles is one such development. Lithium-ion batteries could also reduce dependence on heavy metals. Devices like mobile phones, which require some heavy metals like gold for specific components, have reduced their reliance on heavy metals too. Material scientists could find the best materials to replace the heavy metal components to reduce the effects of mining on the environment. Similarly, recycling of devices has reduced the presence of old devices in landfills. Material engineers found a way of recycling about 99% of parts of old devices. Lead-acid batteries, for example, are recycled with an efficiency of 99%. The 1% represents the lead that is lost as dust or fumes that later pollute the air and soil. Newer methods are being discovered to remedy the situation. Researchers are finding ways of removing GHGs from the atmosphere (Dagon 2016). Material engineers could help in the development of these technologies by finding the most reliable materials. Development of components for harnessing tidal and sound waves for energy, in addition to wind and solar, requires proficiency in material science. Engineers keep developing different technologies for producing power to reduce environmental damage and climate change. In essence, developing renewable energy technologies that do not emit or rely on carbon could rapidly reduce global GHG emissions.

# Information and Communication

## Problems

Advances in information and communication technology (ICT) have been fast. However, there are a lot of barriers to achieving seamless communication. 5G technology was expected to be operational by the beginning of this year. The prospect could improve the reliability and speeds of internet and information dissemination. Personal devices like laptops and mobile phones need improvement. The cost of devices could be lowered but affordable materials for components are unavailable. Development of new materials for ICT is fundamental to innovation, higher-power applications, enhanced device performance, and improved energy efficiency (Eggeman 2016). Telecommunications requires materials engineering but most challenges cannot be solved without cooperation with other professionals.

## Solutions

Better devices have been made since the first phone and computer were commercialized. Materials engineering has enabled engineers and computer system architects to make devices more efficient and convenient. The Z1 of the 1930s took up an entire room. Punch cards, transistors, and vacuum tubes were associated with the 1st to 3rd generations of computers. Since Intel introduced the 8008 processor in 1972, computers have evolved to become smaller and smaller. The 6th generation could evolve to include virtual and augmented reality but the components will be informed by research from materials science. The first mass-produced commercial phones were launched in 1973 by Motorola. Since then, both software and hardware designs have improved. Current phones are smaller, faster, internet-enabled, and capable of much more. This evolution was possible because material engineers were able to manipulate semiconductors and design motherboards ergonomically. Other noteworthy innovations include magneto-electrics for memory and field sensing, superconducting spintronic, IoT and visible light communication, and quantum light sources (Eggeman 2016). Therefore, materials engineers open the path to innovation in ICT.

# Health

## Problems

Biotechnology and medical engineering require some expertise in material engineering. As the medical sector embraces technologies like telehealth and robotics, there is a need for improvements of materials. Robotics for surgery need to be consolidated and made smaller to improve functionality and reduce medical risks. Other machineries like radiology, liposuction, and chemotherapy equipment need to be made in cheaper but more reliable ways so that more hospitals across the world can afford them. Moreover, orthopaedic patients require stronger but more flexible, affordable, and safer replacements. Plastic surgeries can be improved through material science too. Healthcare costs are high globally because of the high cost of materials and machinery. Some procedures are also unsafe but materials engineering can provide solutions. The main challenges in healthcare that can be solved through materials engineering include cost, safety, and quality.

## Solutions

Cost reduction through material science is the main role of material engineering in healthcare. Costs are connected to most of the materials used in care. For instance, the high cost of heart transplants can reduce by using synthetic materials and pacemakers. Engineers had to assess the risks of using specific materials for such purposes. Artificial hearts are designed to last for only five years. Materials engineers can find ways to improve the lifetime of these components. Other prosthetics are also dependent on knowledge from materials engineering. Titanium, platinum, and vanadium are commonly used for pumps and other prosthetics because they are biocompatible. Additionally, better wheelchairs and other support equipment have been built through materials engineering. The equipment must be corrosion-resistant, biocompatible, and durable. Life-support machines, paediatrics machines, and things like blood storage bags are all developed after considering the material science aspect. It can be surmised that materials engineering enhances the safety of patients and staff while improving the quality and reducing the costs of care.

# Conclusion

Overall, materials engineering is an essential field of knowledge. Research of materials complements innovation by providing the knowledge of materials that engineers need to develop new solutions. In ICT, engineers can improve personal devices and telecommunications by improving the technology that supports the hardware. Likewise, in healthcare, materials engineering promotes innovation to reduce the costs of care and improve its quality and safety. Similarly, in environmental and climate assessment and correction, proficiency of materials improves innovation and allows for the realization of news solutions like carbon removal from the air. Lastly, in energy and transport, materials reduce costs and improve safety and sustainability by reducing reliance on hydrocarbons, making machinery lighter, and improving power efficiency.

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