Materials

Advanced Materials Research for a Green Future

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Environmental concerns, such as pollution, greenhouse gas emissions, sustainability, global warming, and climate change as one of the biggest challenges of our times, have triggered a variety of societal responses. Solutions to problems related to energy transformation, storage, supply and efficiency, heat exchange, hydrogen storage, carbon capture and storage, etc. largely depend on materials and their properties.

More efficient use of energy and materials, combined with technology optimization and innovation, could play a key role in achieving multiple environmental and economic benefits. Although many opportunities exist, material efficiency is still not realized in practice to its full potential. In the future, steel, aluminium, cement, and other hard-to-abate heavy industries will see much wider use of green hydrogen and electrification, with on-site carbon-capture technology playing an important role. Furthermore, manufacturing should continue to make gains in efficiency, reducing emissions intensity, sensors deployment and analytics, digital transformation, etc. Additive manufacturing, lean production, circular design, and more robust material recycling practices can reduce waste and emissions, at the same time provide low-weight minimum-energy demanding designs. Increased recycling leads to reductions in waste volume and generally leads to reduced GHG emissions. Nevertheless, some advanced materials have limited recycling potential, although they may still be used in downgraded end-of-life applications.

Materials are central to most environmental protection strategies. To increase cost-effectiveness, efficiency, safety, performance, and to address environmental concerns there is an urgent need to develop advanced materials and manufacturing technologies that allow novel light-weight, energy-efficient designs. For each renewable technology to progress, materials development and improvement is needed to help us build a greener future. All renewable technologies face material challenges. Materials must be lighter, stronger, and more durable to resist corrosion from inclement atmospheres and high temperatures.

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A Complete Understanding and Information on Mechanical Properties

In order to properly use materials in design, a complete understanding and information about their mechanical properties must be obtained. It is also vital to know how these properties are affected by the conditions of a specific material application. Factors such as the size of the part, surface condition, loading direction, and loading rate may result in changes to these properties that must be considered in design. Furthermore, as the design especially of automotive components is constantly being pushed toward the limits of the materials used, unsuitable and outdated measuring methods as well as deviations from the defined material properties and excessive measuring uncertainty can lead to unexpected premature failure of the component itself, as well as to environmental problems. Therefore, sophisticated and reliable determination of material properties with low uncertainty is crucial in modern design aimed for a green future. Small deviations in a testing specimen's diameter or improper surface preparation may result in large increase in measurement uncertainty and failure probability.

Surface Engineering Can Have a Huge Impact on Sustainability

For the green future, it is extremely important to develop new, advanced materials. However, making surface changes to extant materials can often result in the greatest benefits in performance as well as the envi-

ronment. Surface engineering is about modifying the surface of what lies beneath, to make it perform better, last longer, or even achieve a different function entirely. So, surfaces can prevent or control the product's main life cycle, indeed completely determining their operational characteristics (such as wear, corrosion, and fatigue). But they can also have a huge impact on sustainability, by ensuring the optimized use of scarce materials, reducing energy losses due to friction, increasing wettability, providing tissue-compatibility, etc.

Slovenian Cooperative Research Results

In addition to advanced research and high-tech research facilities, close cooperation between universities, research institutions, and the private sector is needed to develop functional materials and solutions that can effectively support society's journey into the green future. A great example of such collaboration was Slovenian program MARTINA (Materials and Technologies for New Applications; www.martina-eu.net/en/), involving 16 partners (3 universities/faculties, 6 research institutes and centres, 7 companies), where through the joint research and development the following materials with superior properties were developed and introduced:

- Three ultra-high-strength steels for the automotive and transportation industry, providing 10-20% higher strength at up to 5-times better fatigue resistance, reduced need for heat treatment, and diminished heat affected zone influence. Two steels are aimed at forged load-bearing components and one for safety construction elements in lightweight designs.
- Two tool steels with reduced non-metallic inclusions, better fatigue and heat checking resistance, improved machinability, and 60% higher thermal conductivity, thus focusing on reduced energy consumption and material use.
- New high-strength Al alloy (registered as 6086 type) produced with a high share of scrap. This addresses requirements on lightweight design, reduced material CO_2-footprint, reduced energy use, and raw material input.
- A completely new magnetic material and production process based on anisotropic magnetic particles in a thermoplastic matrix, allowing production and magnetization in a single stage and magnets with up to 40% better magnetic field effectiveness.
- Application of metallic nanoparticles in different polymeric materials, providing completely new structural properties such as antibacterial effects and wear resistance, electrical conductivity, magnetic properties, etc. ■

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