Guest Editorial

Advanced Polymeric Materials: Innovations and Applications in Cutting-Edge Technologies

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Polymers are versatile materials with numerous uses in daily life, industry, and technology. Polymer-based products, such as plastics, rubber, fibers, and adhesives, are all around us. In addition to general applications of polymers, their recent use in high-tech applications is remarkable. Here we are discussing a few of them, specifically in the fields of biomedical, energy harvesting, wearable sensors, smart windows, aeronautics, and ballistic applications.

Polymers in Biomedical Applications

Drug delivery and biomedical imaging

Drug delivery can be targeted based on the stimuli present at the specific target site. For example, tumor sites show acidic pH and high temperatures due to the high metabolic activity of cells. To enhance therapeutic efficacy and reduce side effects, chemotherapeutic drugs can be incorporated into dual-responsive polymer hydrogels containing different functional groups. Conjugated polymer nanoparticles, or polymer dots (CPDT), have been incorporated into these to develop a range of biomedical diagnostic and therapeutic methods. For example, these CPDTs are incorporated into biological probes to bind their biomarkers, followed by the fluorescence microscopy imaging entry routes of nanoparticles and their final locations in cellular compartments to evaluate the therapeutic effects (Hoang et al. 2021; Zhang et al. 2022).

Vaccine development

To improve immunogenicity for vaccine distribution, a number of natural and synthetic biodegradable nanopolymeric materials have been employed. Furthermore, vaccination antigens encapsulated in polymer-based nanoparticles delivered via the mucosal channel can shield antigens from degradation while also ensuring that the encapsulated antigen is liberated at the target site, triggering robust immune responses. For example, lipid nanoparticles (LNP) of a size smaller than 100 nm encapsulate and protect the mRNA that preserves the genetic information encoding the SARS-CoV-2 virus's spike protein from degradation, allowing cellular absorption and mRNA release. One of the four components of lipid nanoparticle mRNA COVID-19 vaccines is PEGylated lipids. Within the spectrum of COVID-19 vaccine varieties, the new Pfizer/BioNTech and Moderna vaccines consist of PEGylated lipid nanoparticles that encapsulate and protect the mRNA (Liu et al. 2022; Wilson and Geetha 2022).

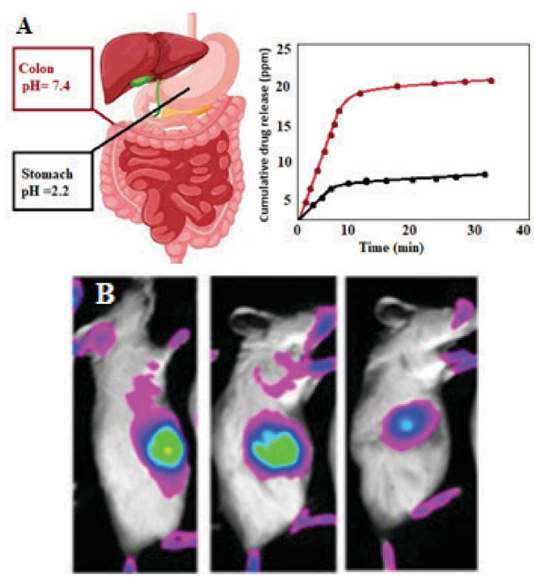

Figure 1. A) Dual responsive drug delivery and B) fluorescence imaging.

Figure 2. Vaccines containing PEGylated lipid nanoparticles.

Polymers in Solar Energy Harvesting/Power Generation

Energy harvesting devices are those that absorb and transform environmental energy—such as heat, light, motion, or vibrations—into electrical energy that may be used. In energy harvesting devices, polymer materials have become a significant class of materials, especially for portable and malleable designs. Conjugated polymers are used in polymer solar cells, commonly referred to as plastic solar cells, serving as light-absorbing components, electron donors, acceptors, and/or materials that facilitate the transport of holes. Conjugated polymers first produce excitons, through the absorption of incident light, forming bound electron–hole pairs. These excitons, or pairs of excited holes and electrons, undergo charge extraction and material transport after separating into unbound carriers at the donor/acceptor interface, driven by the intrinsic electric field. Then, electrons and holes, acting as free charge carriers, will occupy the anode and cathode, respectively. Ultimately, these charge carriers will flow through an external circuit, completing the transformation from light to electricity (Al-Azzawi et al. 2022; Hwang and Yasuda 2023).

Polymers in Wearable Sensors

The polymer nanocomposites that are produced by combining conductive polymers with inorganic/carbon nanoparticles serve as the main basis for these electrochemical devices. The development of polymer nanocomposite-based wearable sensors for health and medical diagnostics, prosthesis, sports, robotics and virtual environments has been greatly aided by recent advancements in wearable technology and nanotechnology. Adhesive or elastic straps can be used to attach wearable electronics to clothing or apply them directly to the skin to monitor bodily signals and motions. Developments in materials science and nanotechnology have recently led to the creation of very flexible, stretchable, and sensitive wearable sensors. In this domain, several instances have been documented: piezoresistive sensors designed for strain sensors, reinforced with carbon nanofillers acting as the conducting material, and utilizing a triblock copolymer (styrene–butadiene–styrene) thermoplastic elastomer as a polymeric matrix (Dios et al. 2019).

Polymers in Smart Window Coatings

Since windows are a necessary component of cars, buildings, and greenhouses, they are among the least energy-efficient elements because of the high permeability to sunlight, particularly the near-infrared (0.7–2.5 µm), which makes up 51% of all solar energy. In warm weather, smart window coatings allow for the blockage of inward infrared radiation from the sun, while in cold winter, they help the room retain heat. These coatings' active ingredients filter both visible and near-infrared (NIR) light, which enables window settings to be customized to optimize energy efficiency. Processes that use energy are therefore greatly reduced. Polymer compounds based on reflectance or NIR absorption can be used to create smart window coatings. Saturated silicone polydimethyl siloxne, for instance, is an excellent option for the transparent emitter. This is attributed to its minimal absorption of solar radiation and decreased reflection within the atmospheric range. These characteristics results from the alternate attachment of methyl moieties and vinyl-terminated cross-linkers along the silicon and oxygen atom chains (Zhou et al. 2020).

Polymers in Aeronautics and Ballistic Applications

The aerospace industry has made extensive use of lightweight fiber-reinforced polymer (FRP) composite components. This is attributed to their high strength-to-weight ratio and great temperature tolerance. Currently, the most sophisticated civilian aircraft in the world, the Boeing 787 and the Airbus A350, employ 50% and 52% of composite materials, respectively. The three most common fiber types found in aerospace applications are carbon fiber, fiberglass, and aramid. Aramid fibers, which are strong and heat-resistant synthetic fibers, are also known as aromatic polyamides.

Kevlar fibers exhibit high degree of orientation along the fiber axis and belongs to the aromatic polyamide family. In ballistic applications, the human body behind the armor will bear a greater portion of the shock if the fibers are unable to absorb all of this energy without expanding too much. It would be of little use to the wearer to have a vest that could absorb the whole energy of a speeding bullet, but that needed to stretch out like a rubber band to do so. For ballistic fibers, tensile strength and tensile modulus are crucial characteristics. In the latest generation of lightweight, concealed body armors with significantly enhanced ballistic protection, Kevlar is a common material (Shih et al. 2022).

Figure 3. Polymer fibers in A) ballistic and B) aeronautical applications.

Materials for thermal protection systems are crucial to the aerospace sector as they are employed in the production of heat shields. The part in that of protecting the spacecraft's aerodynamic surfaces, cargo, missiles, warheads, and probes from excessive heat as they approach through a planet's atmosphere. Ablative plastics absorbs heat and generally protects other parts from heat when exposed to high temperatures they decomposed to gas and forms a porous char and thereby dissipating heat and leaving a thermal barrier on the substrate. Phenolics, phenyl silanes, nitrile phenolics, nitrile rubber, silicones, epoxy polyamides and novolac epoxies are considered as ablative materials in above applications (Kumar et al. 2022).

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Cover Page

The cover page shows IUPAC Top Ten Emerging Technologies in Chemistry in 2023. This year's selection emphasizes the collaboration between chemistry and other scientific fields to bridge the gap between academia and industry, towards sustainability and a better society. Because chemistry is far more than the "central science"— it's the "connecting science".

IUPAC Top Ten Emerging Technologies in Chemistry were Wearable Sensors, Photocatalytic Hydrogen, Chloride-Mediated Removal of Ocean CO_2, GPT Language Models in Chemistry, Synthetic Electrochemistry, Artificial Muscles, Phage Therapy, Biological Recycling of PET, Depolymerisation, and "Low-Sugar" Vaccinations.

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The editor invites from the membership the following items for publication in the next issue of the Chemistry in Sri Lanka which is due to be released in May 2024.

- *Personal news of the members*
- *Brief articles of topical interests*
- *Forthcoming conferences, seminars and workshops*
- *Latest text books and monographs of interest to chemists*

All publications will be subjected to approval of the 'Editorial and Publicity Committee' and the Council of the Institute of Chemistry Ceylon. Further, prospective career opportunities for chemists, could be advertised in Chemistry in Sri Lanka at a nominal payment. The editor in chagrge welcomes suggestions from the members for improvement of the publication.