Polymer International special issue: Editorial

Title: PAEKing ahead into the 21st century

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Abstract:

As the field of macromolecular science celebrated its 100th anniversary in 2020, we organised a special issue of Polymer International devoted to the synthesis, processing and applications of polyaryletherketones (PAEKs). Developed over 40 years ago, PAEK polymers and their composites experienced a steady increase in use and applications due to their unique characteristics: high mechanical performance, high toughness, high operating temperatures, low wear, non-flammable and chemically resistant as well as their function as a class of bioinert, robust biomaterials. The contributions to the special issue engage the materials science community and include a mixture of spotlights, perspectives, reviews, and research papers, spanning the breadth of basic science and engineering to applied technical/medical science, with authors from academic and industrial backgrounds, which reflects some of the exciting recent developments in PAEK-based materials that is of interest to a broad readership. A further area of research not particularly highlighted within this review; but very much an active concern; is the development of PAEK-based thermoplastic composites for application in the aerospace and medical sectors.

SYNTHETIC CHEMISTRY

This special edition exhibits developments in the field of PAEK synthesis centred around three significant areas of interest: surface modification, the formation of three-dimensional networks and ion exchange membranes. In all cases the aromatic, ether, ketone backbones of this exceptional class of polymers acts as the property platform to approach new and difficult to reach application niches. The high Tg, thermal and chemical resistance of PAEKs combined with their excellent mechanical properties render this class of materials attractive to integration into ever more challenging fields of application. One area of note not exhibited within this special edition is the development of low dielectric constant PAEK based materials, which is an area of significant ongoing academic and industrial research.

Kuhire et al. report a thought-provoking reversible cross-linking of PAEK networks through the inclusion of pendent furyl species into the backbone during synthesis.1 The furyl units were subsequently exploited through an orthogonal and reversible cross-linking mechanism resulting in

tough three-dimensional networks. This interesting technique has the potential to be further exploited. Wei et al. investigate the effects of the inclusion of naphthalene into the repeating until of PEKK polymers, the inclusion of the naphthalene units results in an increase in the rigidity of the backbone exhibited through an increase in the glass transition by 10°C without significantly affecting the processing temperature of the polymer.2 The increased glass transition could significantly increase the application range of this sub-class of the PAEK family. Liu and co-workers report the development of a photochemical approach to modify the surface of PEEK membranes to impart antifouling properties to them which has potential for significant impact for the petrochemical, wastewater treatment, food processing, and biomedical industries.3

POLYMER PROCESSING & ADDITIVE MANUFACTURING

A larger number of papers focused on the processing aspects and the material – process relationship with a significant number dedicated to additive manufacturing, material extrusion more specifically (known as well as fused filament fabrication). As the material extrusion technology overlaps with composite manufacturing, some of the papers examined processing of PEEK composite materials. These studies are driven by the recent developments in PAEK materials, some specifically tailored for the new technologies evolving under the additive manufacturing umbrella. Additive manufacturing (or 3D printing) approaches are key technologies playing an important role in Industry 4.0, and the research articles in the special issue on this topic report the results of exciting recent developments in various areas. Xu and coworkers report their efforts to correlate the molecular weights of PEEKs extrusion parameters to the mechanical properties of materials produced via material extrusion.4 Davies and co-workers highlight the need for standards across the AM community, the work presenting differences in mechanical properties of vertical fused filament fabricated PEKK produced via 4 different printing strategies.5 Rinaldi et al. investigate the processability of carbon nanotubes (CNTs) PEEK composites in fused filament fabrication concluding that CNTs negatively impact the overall mechanical performance of the printed structures due to high melt flow and reduced diffusion between layers.6 Jiang and co-workers propose a new dispersion mechanism for multiwalled CNTs and PEEK, based on a solution processing method, to explain the improvement in mechanical data.7 Consul and co-workers direct their efforts towards carbon-loaded PAEKs composites and using a bonding fusion model examine the bonding mechanisms and degree of bonding achieved by new PAEK materials designed specifically for AM by comparison with well-established PEEK composite grades.8 Driven by the industry interest in PEEK composites, Matschinski et al. report the effect of nozzle design with variable outlet angle on the fibre length distribution and orientation in material extrusion process.9 Savage and co-workers deliver an exciting study describing the re-manufacture and repair of composites of carbon-fibre loaded PEEKs with retention/improvement of mechanical properties.10 Kurtz and co-workers evaluated the physical and viscoelastic properties of commercially available PEEK and PEKK with a view to understanding their printability in differing processing conditions, to yield materials with predictable performance in critical environments.11

TOWARDS TECHNICAL AND MEDICAL APPLICATIONS

The development of electrically conductive PEEKs is an exciting area at the interface of materials science and engineering, and Mokhtari and co-workers offer an interesting review of conducting PEEK-based composites highlighting the current state-of-the-art, supplemented by a research article describing the production of antistatic composite materials composed of graphite and PEEKs.12,13 Neergat and co-workers offer a thought provoking review on the topic of PAEKs for energy storage and conversion, which is supplemented by an interesting research article from Zhang and co-workers on sulfonated PEEK-based polyelectrolyte gels for supercapacitors.14,15 An elegant example of the

close collaboration between industry and academia is demonstrated by the perspective article from Schaffarczyk, Cölfen and co-workers discussing PEEK implant surface functionalization technologies and the need for a transparent quality evaluation system to facilitate the successful development and clinical translation of high-quality bone implants in the future, with a complementary spotlight article from de Araújo Nobre and co-workers at the Malo Clinic discussing the application PEEK-based materials for implant dentistry.16,17 Yilmaz and co-workers report an interesting method of engineering the surface roughness of fiber-reinforced CADCAM composite resins to deliver high bond strengths with a veneering resin.18

With a view to the future, it is noteworthy that the unique properties of PAEKs can play a role in helping society achieve the United Nations Sustainable Development Goals (SDGs), for example SDG 7 (affordable and green energy) and 13 (climate action) by application of PAEKs in the aerospace and the automotive sectors, where the weight reductions lead to significant increases in fuel efficiencies; SDG 9 (industry, innovation and infrastructure) by employing smart manufacturing and engineering solutions in the production of PAEK-based products (highlighted herein by the articles focused on PAEK processing and additive manufacturing), SDG 3 (good health and well-being) by application of PAEKs in healthcare applications (e.g. dentistry), and we believe that the growing appreciation of sustainability and circularity at a global level will see the development of novel processes and products involving PAEKs.

Finally, we would like to thank the Editor-in-Chief of Polymer International, Prof. Timothy Long and the editorial team at Wiley for their support regarding this special issue.

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