FORMULATING AND MULTI-PROCESSING OF THERMALLY CONDUCTIVE PEEK COMPOSITES WITH SELECTIVE INTEGRATION OF CERAMIC FILLERS FOR ADVANCED AEROSPACE APPLICATIONS

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Abstract

The increased use of polymer-based materials has significantly impacted the thermal management of modern aircraft structures. PEEK, a promising aerospace-grade thermoplastic, has inherently low thermal conductivity, limiting its effectiveness in heat management applications. This current study addresses this challenge by designing PEEK matrix composites with tailored physical, thermal, and mechanical properties, optimized for multi-processing techniques including extrusion, film extrusion, and additive manufacturing. By systematically controlling filler properties and interfacial interactions, thermally conductive networks were established within the PEEK matrix using ceramic-based fillers like hexagonal boron nitride (hBN), titanium dioxide (TiO_2), and aluminosilicate (AlS). Melt compounding was optimized by twin screw extrusion with the optimized process parameters to enhance both in-plane and through-plane thermal conductivity (TC). The integration of hBN significantly improved PEEK's thermal conductivity, achieving in-plane and through-plane values of 12.45 W/(m.K) and 2.13 W/(m.K), respectively. To balance thermal performance with mechanical integrity, bi-filler hybrid systems were developed through co-extrusion. For instance, the hBN-TiO_2 system achieved an in-plane TC of 8.19 W/(m.K) and a through-plane TC of 1.70 W/(m.K), while hBN-AlS composites exhibited comparable thermal performance with enhanced mechanical robustness.

This study also explored the scalability of hBN/PEEK composites through various manufacturing processes. Additive manufacturing enabled the alignment of hBN fillers, improving dimensional stability and thermal conductivity. Film extrusion produced dimensionally stable films, which, when integrated with carbon fibers (CF), yielded a 369% improvement in through-plane thermal conductivity compared to traditional CF/PEEK composites. Figure 1 illustrates the step-by-step process, from compound formulation to processing techniques, outlining the developed methods for manufacturing thermally conductive PEEK matrix composites. This work establishes a comprehensive framework for designing highly thermally conductive PEEK composites, suitable for scalable manufacturing in aerospace applications.

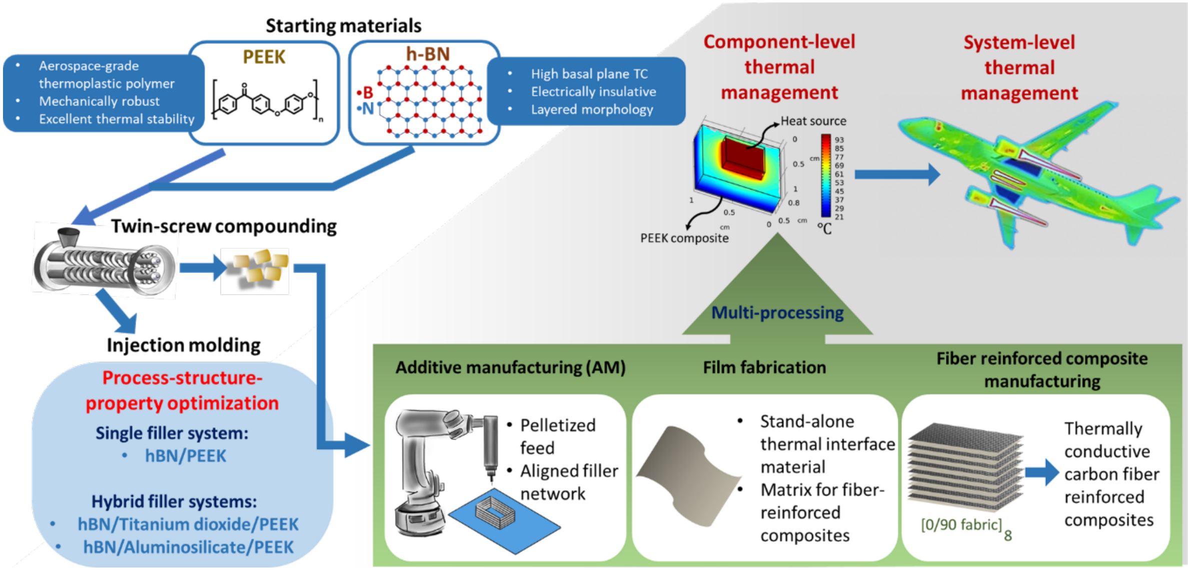

Figure 1. Routes for the development of thermally conductive PEEK matrix composites