TAILOR MADE POLYMERIC FEEDSTOCKS FOR ADDITIVE MANUFACTURING USING POLYMER SCIENCE PRINCIPLES

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3-D printing of polymers has become an important manufacturing process in industry and among hobbyists. In fused deposition modeling, polymer filament is heated and deposited sequentially to build up the desired structure. This process, however, results in significantly weak interfaces between filaments and between layers, which in turn generates weak points in the sample. These weak interfaces manifest in anisotropic properties, where the sample is stronger parallel to the print direction than perpendicular to it.

To remedy this shortcoming, we have begun to examine methods to utilize polymer science principles to mitigate the impact of defects and weak interfaces on the structural properties of 3D printed samples. These include the development of reactive processing within the FDM deposition process, using both thermal and photo-initiated reactions. To improve the strength between layers and improve molecular entanglement of adjacent layers, we have also focused on the incorporation of surface segregating additives that will preferentially migrate to an interface and accelerate the diffusion of polymers across the inter-filament interface during the printing process. We will discuss our current research in this area that focuses on a process in which bimodal blends comprised of a parent, high molecular weight polymer blended with an identical but low molecular weight (LMW) polymer is utilized, as well as the addition of 3-arm and 4-arm star polymers as the surface segregating additive. In both cases, and improvement in tensile properties is observed as well as an increase in isotropy of the final fabricated product.

We will also discuss our work to rationally develop scalable processing protocols based on liquid-liquid phase separation (LLPS) to reproducibly create feedstock polymer powders that are suitable for AM by polymer powder bed fusion (PPBF). Design and control of this non-equilibrium process results in the formation of polymer particles that can be easily recovered. Understanding the fundamental thermodynamic driving forces and kinetic limitations that dictate final particle size and properties as a function of polymer solution concentration, polymer crystallinity, solvent type, polymer functionality, and quench temperature opens pathways to rationally control the size, shape, and morphology of the final particles. This foundational knowledge supports the production of novel PPBF feedstocks that enable the study of fundamental science problems associated with PPBF manufacturing.