Ultrahigh-Strain-Rate Dynamic Effects of Molecular-Weight Distribution of Polystyrene upon Plasticity and Fracture Properties in Cold Spray Deposition

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ABSTRACT

Cold spray (CS) achieves deposition of sprayed solid micro-particles due to interfacial heating induced by extreme plastic deformations that occur at micro-particles and stationary substrate interface during high-speed collision events. Laser-induced projectile impact test (LIPIT) uses ultrafast stroboscopic imaging (pulse-duration<1 ps) to capture the motion of individual micro-particles impacting a target at ultrahigh strain rates (UHR>10^6 s^{-1}). We use LIPIT to conduct single particle impact experiments, essential in understanding the extreme collisions in CS processing.

Monodisperse polystyrene microparticles (PS-µPs) (diameter~40 µm) with varying molecular weights (MW), 10 kDa, 20 kDa, 40 kDa, and 100 kDa, were impacted on PS and silicon substrates. Plastic shear flow within a colliding PS-µP becomes the dominant deformation channel over brittle fragmentation when adiabatic heating and thermal softening are promoted by increasing target substrate rigidity. Higher MW (>20 kDa) is essential in suppressing early onset of brittle fracture while promoting adiabatic heating. However, an excessively high MW∼100 kDa reduces the PS-µPs adhesion to substrate due to insufficient surface wetting driven by particle elasticity. Furthermore, LIPIT experiments were conducted with four MW-blended PS-µPs produced with weight ratios, 20:80, 40:60, 60:40, and 80:20 of 10 kDa PS and 100 kDa PS to understand the rheological effects and competition between plastic shear and fracture. The 60:40 blend shows lowest critical velocity of 400 m/s, while best bonding between PS-µP and silicon substrate is observed from 80:20 blend. Due to competing requirements for adiabatic shear flow and interfacial wetting, proper MW distribution becomes critical for CS of glassy polymers.

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