A study on the Impact and Adhesion of Block Copolymer Particles with a Silicon Substrate for Polymer Cold Spray Applications

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Deformation of a two-phase block copolymer (BCP) during high velocity impacts is studied experimentally and theoretically with an aim to use this material in cold spray (CS) additive manufacturing. Micron scale (10-20 μm) spherical particles of polystyrene-block-polydimethylsiloxane (PS-b-PDMS) are impacted on a silicon substrate by using a laser-induced projectile impact test (LIPIT) setup with impact velocities in the range of 50 to 600 m/s. Experiments indicate that polymer particles adhere to the substrate when their impact velocities fall within the range of 140 to 500 m/s. A constitutive model that accounts for the effects of both strain rate and temperature on the mechanical behavior of such materials is developed. A critical energy release rate function which depends on the surface temperature and rate of separation is formulated and used in a cohesive zone model (CZM) to model bonding of the BCPs on the substrate. The model parameters are calibrated by comparing the deformed and computed deformed particle shapes and coefficient of restitution values of the rebounding particles. Simulations show that the particles experience ultra-high strain rates (> 10^4 s^{-1}), large deformation, and temperature elevation due to plastic dissipation and interfacial friction. The outer rim of the contact interface is predicted to experience temperature levels above the glass transition temperature of the PS-domain of the BCP. Bonding is correlated with increase of contact area, plastic dissipation and temperature rise in the interface.