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MULTIPHYSICS SIMULATION OF MOLTEN METAL DROPLET DYNAMICS FOR HYBRID PRINTING APPLICATIONS

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Abstract. Hybrid metal printing technologies, such as StarJet®, offer a non-contact approach for the direct deposition of molten metals, enabling a wide range of applications, including high-resolution PCB interconnection, flexible electronics on polymer substrates, and localized soldering of electronic components on thermally sensitive materials. These advanced manufacturing techniques rely on the precise ejection and impact of micrometer-scale molten droplets at elevated temperatures, where fluid dynamics, heat transfer, and phase change phenomena are tightly coupled. In this study, we numerically investigate the behavior of droplets of a tin-silver-copper alloy impacting solid surfaces. The model is based on the Navier-Stokes equations coupled with heat transfer and phase change, incorporating temperature-dependent thermophysical properties to accurately capture both spreading and solidification stages. The droplets have diameters of approximately 400 μm and impact the substrate at high velocities, leading to characteristic timescales on the order of milliseconds. High-speed camera measurements were conducted to validate the droplet dynamics, while the lack of thermal imaging posed challenges in assessing the temperature field during impact. Despite this, the simulations yield valuable insights into the transient interaction between hydrodynamic and thermal effects, supporting the development and optimization of hybrid metal printing strategies.

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