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Impact-Induced Plasticity in Ceramics: Millimeter-Scale Cold Spray Deposition of Ti_2AlC and $Al–Al_2O_3$ Systems

Ceramics exhibit high hardness and thermal stability but limited plasticity, making their deposition under high-strain-rate conditions (cold-spray) challenging due to insufficient deformation during particle impact. However, when ceramic powders are refined to the nanoscale and subjected to high-energy milling, increased defect density and dislocation content enhance deformability, enabling plastic accommodation. In this study, we demonstrate the first-of-its-kind millimeter-scale ceramic deposits using low-pressure cold-spray with helium gas. Two material systems were investigated: MAX-phase ceramic (Ti_2AlC) and 10 wt.%$Al–Al_2O_3$ powder , enabling a comparative assessment of deposition behavior governed by bonding characteristics and metallic content.

Static spray using the TTEC system with Ti_2AlC produced a conical deposit with a maximum height of 2.65mm, representing an unprecedented build-up for a predominantly ceramic system. This behavior is attributed to partial metallic character arising from weak Ti–Al bonds, enabling plastic deformation despite the absence of a metallic binder. In contrast, the $Al–Al_2O_3$ system achieved higher deposition, with maximum heights of 5.5mm for static spray and 3.79mm for raster spray.

SEM analysis showed high consolidation in both systems, with porosity below 1%. EDS revealed enrichment of the metallic phase in $Al–Al_2O_3$ deposits relative to the initial 10 wt.% feedstock. Ti_2AlC remained compositionally ceramic. Nanoscale particle shearing observed via SEM in both systems indicates localized plastic deformation within ceramic constituents. Microhardness of Ti_2AlC matched bulk values, whereas $Al–Al_2O_3$ remained aluminum-dominant.

This work demonstrates that ceramics at reduced length-scales and with favorable bonding architectures can exhibit impact-induced plasticity, enabling binder-free ceramic deposition via cold-spray.