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Meet Our New Colleagues

This column presents selected thermal spray research from graduating Ph.D. students as a way of introducing these researchers to the larger thermal spray community and helping them to apply their skills to existing needs. Recently graduated and soon-to-graduate (within 6 months) students are encouraged to submit a short description (1-2 pages) of the research they performed during their studies to Kendall Hollis, JTST Associate Editor at: Los Alamos National Laboratory, P.O. Box 1663, MS G-770, Los Alamos, NM 87544; e-mail: kjhollis@lanl.gov. With agreement of the student's thesis advisor, selected submissions will be published in the upcoming issues of JTST.

Splat-Substrate Interactions in High-Velocity Thermal Spray Coatings

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The aim of Dr. Trompetter's recently completed Ph.D. thesis was to investigate splat-substrate interactions in high-velocity thermal spray coatings. In particular, the aim was to determine the interfacial bonding mechanisms present in solid particle coatings. The study also investigated the effect of variables such as substrate hardness, heat, and surface oxide on the splat-substrate bonding process.

Previously, our knowledge of solid splat bonding processes within thermal spray coatings had been very subjective where mechanical and chemical bonding has been expected to contribute. In this thesis, a successful collaboration with the University of New South Wales electron microscopy unit was formed. This collaboration allowed the splat-substrate interface to be investigated with focused ion beam (FIB) microscopy, cross-sectional SEM, and cross-sectional TEM. In cross-section images of individual splats, it was observed that the splat-substrate interface was well bonded where interfacial mixing and turbulent behavior had occurred providing strong mechanical bonding between the splat and the substrate. These features were generally found at the sides of the splat-substrate interface which exhibited strong bonding (Fig. 1). Conversely, smoother undisturbed interfaces were found at the bottom of the splat that exhibited weaker bonding and sometimes separated interfaces (Ref 1).

For solid NiCr splats thermally sprayed on aluminum substrates, a new form of interlocking feature was found for the first time at the splat-substrate interface. Jets of aluminum substrate material were found to extend up to 100 nm from the substrate into the thermally sprayed NiCr particle perpendicular to the interface (Fig. 2). For the solid and semimolten splats investigated, the size of the turbulent features was found to be proportional to the splat diameter. This is in agreement with the amount of interfacial instability estimated by Reynolds number calculations (Ref 2, 3). This finding together with no evidence of chemical bonding across the particle-substrate interface demonstrated that mechanical bonding is the dominant bonding mechanism for solid splat coatings. It was found that chemical bonding only played a role when splats and/or the substrate become molten.

The effect of substrate hardness was investigated by thermally spraying onto a range of substrate materials. Cross sections of the splats showed that solid splats penetrated deeply into soft substrates, whereas harder substrates resisted particle penetration and exhibited higher percentages of molten splats. Cross sections of NiCr solid splats are shown in Fig. 3. Good agreement with observations was achieved by modeling the conversion of particle kinetic energy into heat depending on the amount of plastic deformation due to substrate hardness (Ref 4).

The effect of substrate oxide was investigated by thermally spraying onto substrate materials with "thick" surface oxide layers. It was demonstrated that during the coating process, the surface

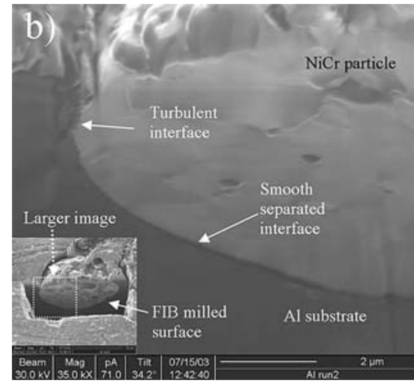

Fig. 1 NiCr alloy particle thermally sprayed via the high-velocity air-fuel (HVAF) technique onto an aluminum substrate and sectioned by focused ion beam (FIB) milling (Ref 1)

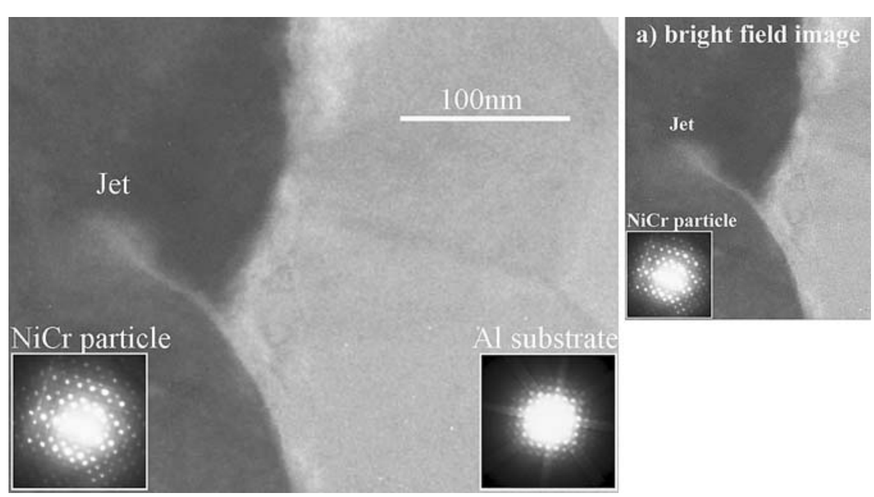

Fig. 2 TEM bright-field image of the splat-substrate interface between a 12 µm NiCr splat embedded in an aluminum substrate (Ref 1)

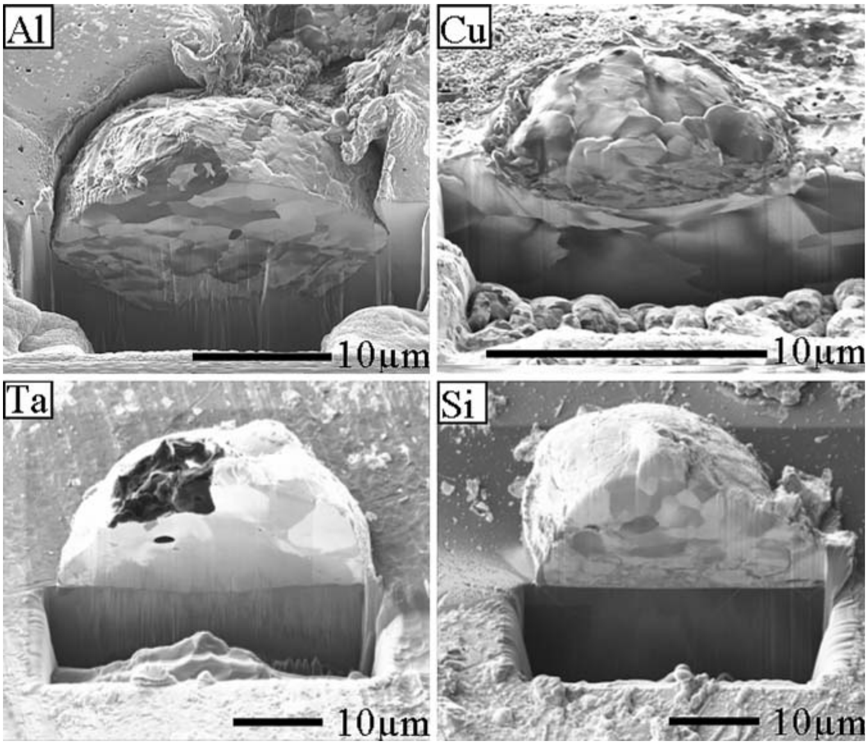

Fig. 3 NiCr particles HVAF sprayed on various substrates (Ref 4)

oxide remained present at the interface between the particle and the substrate. Redistribution of the oxide over a large surface area occurred due to plastic deformation of the substrate. Successful bonding occurred when small-scale oxide redistribution for solid splats or penetration of the oxide material by molten splats is achieved. This result strengthens the theory that surface oxides impede splat bonding and that successful bonding occurs only when the surface oxide is disturbed.

In conclusion, Dr. Trompetter studied the bonding interface of individual HVAF thermally sprayed NiCr splats. His thesis has provided new insights into the bonding mechanisms and the effect of surface oxides within high velocity thermal spray coatings.

Acknowledgments

Dr. Trompetter recently completed his Ph.D. thesis in Engineering from Auckland University in New Zealand in a part-time capacity while being a staff member of GNS Science (formerly the New Zealand Institute for Geological and Nuclear Sciences) at the National Isotope Centre in Lower Hutt, New Zealand. The Ph.D. topic started as a collaborative project initiated by his Ph.D. supervisors, Associate Professor Margaret Hyland of the School of Engineering and Dr. Andreas Markwitz of GNS Science. A successful collaboration with Professor Paul Munroe and his team at the University of New South Wales electron microscopy unit in Australia allowed the interface of individual bonded splats to be investigated in ways not seen before.

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