Microstructural study of interfacial region of cold sprayed Cu coating on light alloy substrates

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Introduction

Cold gas-dynamic spray or commonly known as *cold spray* (CS) is a newer offshoot of thermal spray (TS) technologies. The distinguishing characteristics of the CS process are the use of a higher velocity (300-1200 m/s) stream of micron sized particles (1-50 µm), accelerated by a supersonic gas jet at a temperature significantly lower than the particle melting point. A recent variant of CS known as *Kinetic Metallization™* (KM) has also emerged which employs a substantially different powder delivery system, a sonic rather than supersonic gas velocity and a lower gas pressure.

The mechanism by which a solid-state particle deform and bond (both to the substrate and to other particles) in CS is not well understood. This microstructural study aims to elucidate the nature of adhesive bonding between the impinged particles and light alloy substrate materials in CS and KM processes.

Experimental procedure

Samples of Cu coating were prepared by CS on an Al alloy substrate and by KM sprayed on (a) extreme-purity (EP) Al, (b) Al alloy 5005 H34, (c) Al alloy 2124 T851 and (d) commercial-purity (CP) Mg substrates. Transverse section (TS) specimens of these coated samples were examined under light microscopy (LM), scanning electron microscopy (SEM) and scanning transmission electron microscopy (STEM).

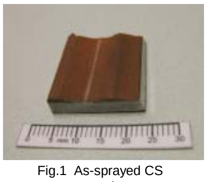

Fig.1 As-sprayed CS sample

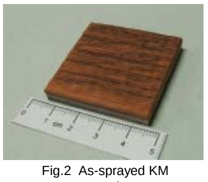

Fig.2 As-sprayed KM sample

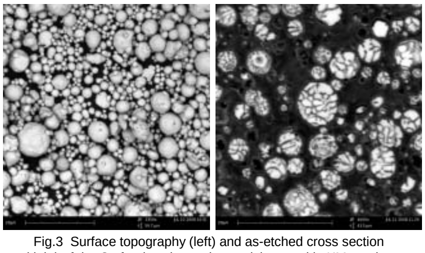

Fig.3 Surface topography (left) and as-etched cross section (right) of the Cu feedstock powder particles used in KM coating

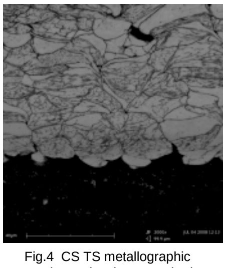

Fig.4 CS TS metallographic specimen showing as-etched microstructure of the deposited Cu layer at the coating-Al alloy substrate interface

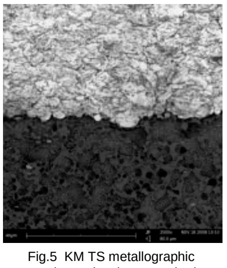

Fig.5 KM TS metallographic specimen showing as-etched microstructure of the deposited Cu layer at the interface with Al 5005 substrate

Fig.6 TEM micrograph of the coating-substrate interface of CS Cu on Al alloy specimen. Inset showing foil specimen

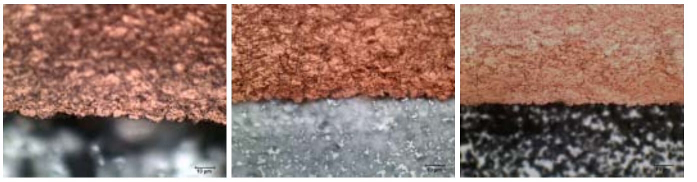

Fig.13 Optical micrographs showing as-etched microstructure of KM Cu coating on EP Al (left), Al 5005 (middle) and Al 2124 (right) substrates

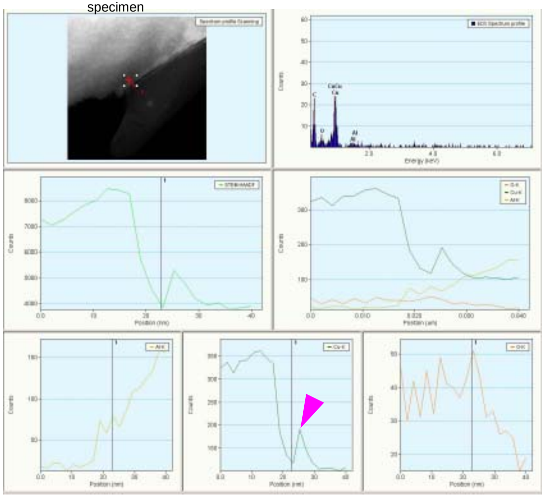

Fig.7 High-angle annular dark-field (HAADF) imaging of CS Cu-Al TEM specimen revealing a narrow reaction zone (~5 nm) of Cu-rich phase at a short distance (~10 nm) inside the Al alloy substrate from the interface

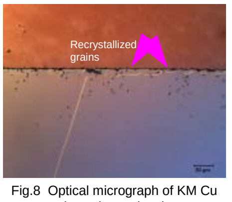

Fig.8 Optical micrograph of KM Cu coated specimen showing as-etched microstructure of EP Al substrate

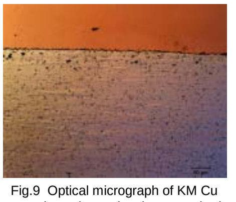

Fig.9 Optical micrograph of KM Cu coated specimen showing as-etched microstructure of Al 5005 substrate

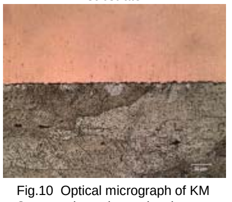

Fig.10 Optical micrograph of KM Cu coated specimen showing as-etched microstructure of Al 2124 substrate

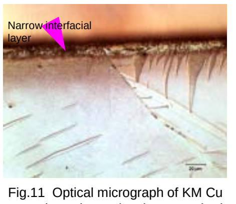

Fig.11 Optical micrograph of KM Cu coated specimen showing as-etched microstructure of CP Mg substrate

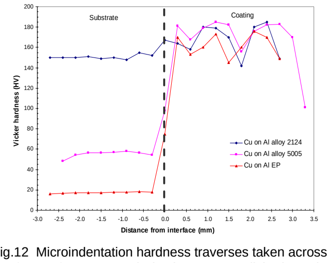

Fig.12 Microindentation hardness traverses taken across the interfaces of KM sprayed Al substrate as-polished specimens

Microstructural observations

- Under LM, the interface of the CS and KM coated light alloy substrates manifested regular, undulating profile with smooth-bottomed depressions and thin-lipped cusps
- LM examination of as-etched KM specimen revealed the presence of small, recrystallized grains contiguous to the interface on EP Al substrate whereas a narrow, continuous layer (5-10 µm thick) of disparate microstructure was observed between the coating and the CP Mg substrate
- Densities of CS and KM coatings were generally high with few observed porosities.
- As-etched interparticle boundaries within the Cu coatings produced a crowded squamous pattern. Within some particles, fine network of grains or subgrains, possibly dislocations was discernible.
- With HAADF imaging under STEM, CS coated specimen revealed a narrow reaction zone (~5 nm) of Cu-rich phase at a short distance (~10 nm) inside the Al alloy substrate from the interface
- Microindentation hardness traverses of KM sprayed Al substrates showed no significant hardness variation along either side of the interface

Further work

- TEM to study in detail the deformation and microstructural features at the interfacial region of KM and CS specimens.
- EDS with SEM and EDS/EELS with TEM imaging to qualitatively and quantitatively identify the phases and microconstituents in the interfacial microstructure.
- Electron backscatter diffraction (EBSD) to characterise sub-micron grain structure at the vicinity of the interface using bulk samples. EDSD will be useful for quantification of either side of the interface in terms of grain size, shape, misorientation and texture.

Acknowledgements

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