

Metal-ceramic functionally gradient material produced by laser processing

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A technique of injection with a powder feed of a mixture of metal + ceramic which combines the processes of laser alloying, cladding and injection, has been applied to study the feasibility of using a continuous wave CO₂ laser to produce a functionally gradient material. A 2 kW CO₂ laser has been used to produce, on a nickel alloy substrate, single alloy/clad tracks and three totally overlapping clad tracks using powder mixtures of Al-10 wt% SiC, Al-30 wt% SiC and Al-50 wt% SiC, respectively. The variation of composition and structure with position in the processed material has been investigated with reference to the effect of processing traverse speed and the powder feed rate.

1. Introduction

The performance of a component may be improved by isolating the main structural material from the environment by means of a coating. Because the coating material and the substrate typically have different physical and mechanical properties, failure of the system is commonly associated with the interface. To reduce the likelihood of failure at the coating-substrate interface, additional layers between the substrate and the surface coating are sometimes employed to improve performance, for example, the intermediate bond layer incorporated in plasma-sprayed thermal barrier systems. Even such complex coating systems still contain discrete layers with regions of discontinuity of composition, structure and properties. A new concept is currently receiving much interest, particularly in Japan; instead of coating a substrate, bulk components are envisaged with controlled progressive changes in structure and properties thereby alleviating the interfacial problems. Materials with such changes within the component section are termed functionally gradient materials (FGMs). Examples of functional gradient materials which have been studied include Ni-ZrO₂, NiCr-ZrO₂, Cu-TiB₂, Ti-TiN, Ni-NiO, SiC-C and Ti-TiC [1-3].

The methods so far used to produce FGMs have included chemical and physical vapour deposition, powder metallurgy, plasma spray and self-propagating high-temperature synthesis. All these methods have some draw-backs, for example, slow rate of chemical and physical vapour deposition, the limitations on size and shape of powder metallurgy and the small number of systems amenable to self-propagating synthesis. FGMs have considerable potential and rapid, flexible production routes are required.

High-power lasers, such as the CO₂ type, are already used in coatings technology making use of the advantageous features, namely a clean source of

energy, high local heat input, non-contact heating, and rapid and flexible processing which is amenable to computer control. Monson *et al.* [4] have used a laser to produce a clad layer of variable composition as a function of distance along the surface of a substrate. However, it appears that systematic studies have not been reported on the production of controlled compositional gradients normal to a substrate surface over distances greater than those in typical coatings. The present paper reports for the first time exploratory experiments aiming to produce composition gradients of this type, i.e. to obtain FGMs.

The laser surface treatments most relevant to FGMs are cladding, and cladding incorporating injection of particles (e.g. of ceramic). Cladding involves the continuous feed of a powder of the coating material into a laser-generated molten pool of the material as the substrate is scanned relative to the beam. Normally the powder is fully melted and some alloying with the substrate occurs. Cladding has been employed to produce a wide range of substrate-coating combination, including yttria-stabilized zirconia (YSZ) and YSZ + alumina [5, 6].

With particle injection the particle size and the processing parameters must be selected so that the interaction time is insufficient to produce significant melting/solution of the particles. Thus a particle-reinforced metal matrix composite is produced on the surface of a metal substrate with a fine-scale matrix microstructure resulting from the rapid cooling [7-10]. In the same way as for cladding, the substrate is scanned with respect to the laser beam.

Cladding and injection can be combined in a single process; referred to here as cladding with particle injection. The powder feed consists of two or more species, with different melting points, typically the dominant one being a metal and the other a ceramic. The powder mixture is fed into the laser beam but only

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