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Laser fabrication nanocrystalline coatings using simultaneous powders/wire feed

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HIGHLIGHTS

- Simultaneously feeding TC17 wire and Stellite 20–Si_3N_4–TiC–Sb mixed powders formed composites.
- Sb addition in laser molten pool was favorable to the formations of UNs.
- UNs were intertwined with amorphous, leading the yarn-shape materials to be produced.
- Ti entered into molten pool from the wire and TA1, which may react with Si or N.

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ABSTRACT

Laser melting deposition (LMD) fabrication is used to investigate feasibilty of simultaneously feeding TC17 wire and the Stellite 20–Si_3N_4–TiC–Sb mixed powders in order to increase the utilization ratio of materials and also quality of LMD composite coatings on the TA1 substrate. SEM images indicated that such LMD coating with metallurgical joint to substrate was formed free of the obvious defects. Lots of the ultrafine nanocrystals (UNs) were produced, which distributed uniformly in some coating matrix location, retarding growth of the ceramics in a certain extent; UNs were intertwined with amorphous, leading the yarn-shape materials to be produced. Compared with substrate, an improvement of wear resistance was achieved for such LMD coating.

1. Introduction

Direct LMD fabrication is a novel manufacturing technique developed about a decade ago which can directly fabricate 3D near net shape and fully dense components from metal powders in one step [1,2]. During such fabrication, the powder is fed at a controlled rate into the focal point of a laser where individual particles are melted as the movement of the laser follows the path defined by a CAD file of a component [3]. Recently, nano-composite coatings have become very popular because of their high toughness and stiffness along with the superior hardness and wear properties; amorphous alloys have attracted increasing attention because of their excellent properties, such as high hardness, corrosion and wear resistance, etc. [4,5]. Laser fabrication is a promising method to prepare the amorphous-nanocrystals reinforced coatings on metals substrate, improving the surface performance of metals substrate.

In the last few years, lots of the effects have focused mainly on the powder feed laser deposition, while less work has been carried out on the microstructure performance of the simultaneous mixed powders and wire feeding laser deposited composites. The problem of single powders feed laser deposition is that low capture rate of the powders (10–30%), leads to wastage of the scattered powders (i.e. 90–70% of the feedstock) [6]. Through experimental work, it was confirmed that simultaneous LMD of the Stellite 20–Si_3N_4–TiC–Sb mixed powders and TC17 wire on titanium alloy can form the wear resistance amorphous-nanocrystalline composite coatings. In this study, LMD fabrication is used to investigate the feasibilty of simultaneously feeding wire and mixed powders in order to increase the utilization ratio of materials and the quality of the laser fabricated composite coatings. Laser wire deposition technology will have a great application potential in industry fabrication fields.

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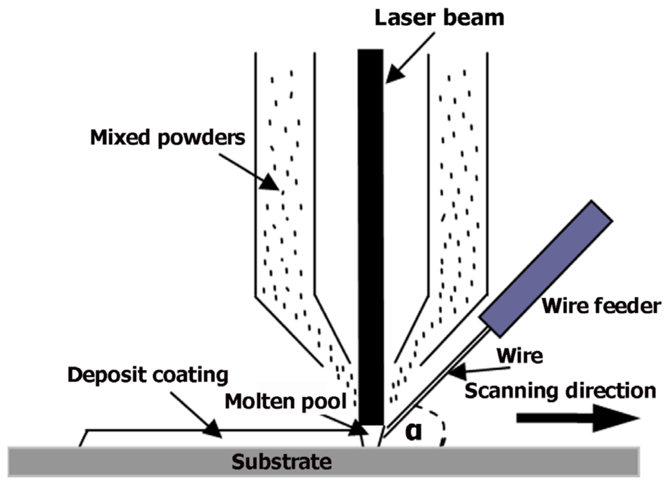

Fig. 1. Schematic of direct LMD with simultaneous mixed powders and wire feed.

2. Experimental

A LMD technique was conducted on a YAG (HL 3006D) laser materials processing system equipped with four-axis computer numerical controlled (CNC) laser materials processing machine under the vacuum environment, coaxial powder feeding device (DPSF-3) were employed to melt surfaces of samples; a CNC-controlled wire feed system, including a precision wire feed nozzle developed in-house, was used which can deliver wires with a diameter equal to or large than 0.4 mm.

Materials used to be substrate: TA1 titanium alloy samples (10 mm × 10 mm × 32 mm) for wear test, or samples (10 mm × 10 mm × 10 mm) for microstructure analysis, chemical compositions (wt%) of TA1: 0.3Fe, 0.15Si, 0.1C, 0.05N, 0.015H and bal. Ti. Samples surfaces were ground with emery paper to remove the oxide scale, and rinsed with alcohol before a LMD process. The TC17 wire was used in this experiment, chemical compositions (wt%) of TC17: 4.60Al, 1.72Sn, 1.91Zr, 4.01Mo, 3.81Cr, 0.137O and bal. Ti; the powders mixture of Stellite 20 (≥ 99.5% purity, 50–150 μm), Si_3N_4 (≥ 99.5% purity, 50–150 μm), TiC (≥ 99.5% purity, 50–150 μm), and Sb (≥ 99.5% purity, 5–50 μm) were used for a LMD technique. Compositions (wt%) of 80Stellite 20–7Si_3N_4 – 10TiC–3Sb were used to deposit on a TA1 alloy by a LMD process, chemical compositions (wt%) of Stellite 20: 2.45C, 32.50Cr, 1.00Si, 17.00W, 3.00Fe, 1.000Mo, 3.00Ni, bal. Co. Laser power = 1.8 kW, scanning velocity = 5–11.0 mm/s, powder feed rate = 15 g/min, wire feed rate = 5 mm/s, wire diameter = 1 mm and laser beam diameter = 4 mm, and an overlap of 30% between successive tracks was selected. Whole experiment process was in progress in an Ar environment box. During the LMD process, the substrate was irradiated by laser beam while the powders mixture and wire were also sent to the laser molten pool simultaneously, forming the composite coating (see Fig. 1).

Microstructural morphologies of such LMD composite coating were analyzed by means of a LEO 1525 scanning electron microscope (SEM) and a Titan 80–300 high resolution transmission

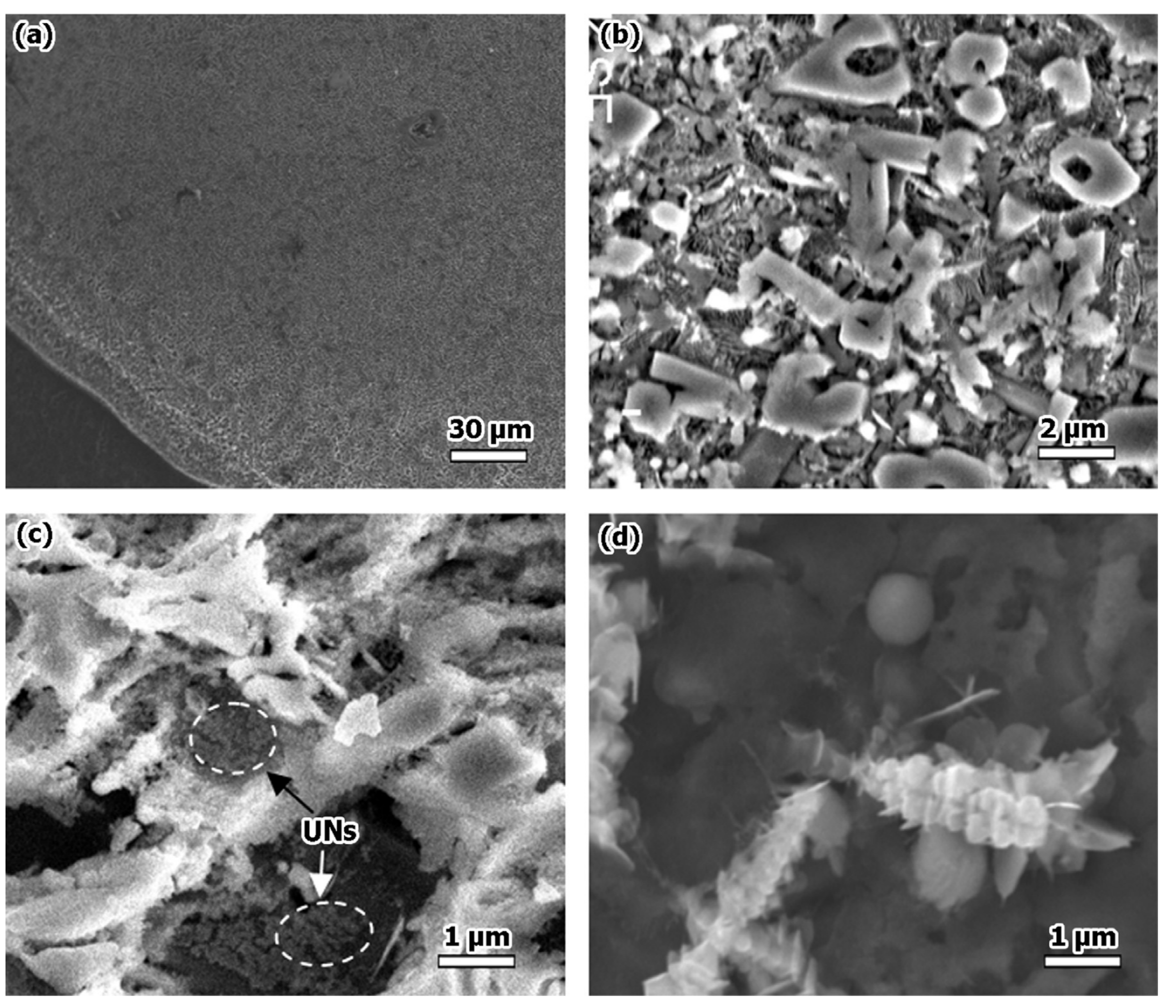

Fig. 2. SEM images of LMD coating: (a) bond zone; (b) middle-coating; (c) UNs; (d) dendrites.