Commissioning of laser assisted cold spraying technology

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OBJECTIVES

This study demonstrates the potential of a newly designed, assembled and commissioned laser assisted cold spraying (LACS) technology at the National Laser Centre, Pretoria, South Africa, to deposit Al-12wt%Si coatings on stainless steel substrate for low temperature corrosion application. The effects of laser power on the microstructure and thickness of LACS deposited Al-12wt%Si coatings on stainless steel substrate are also presented.

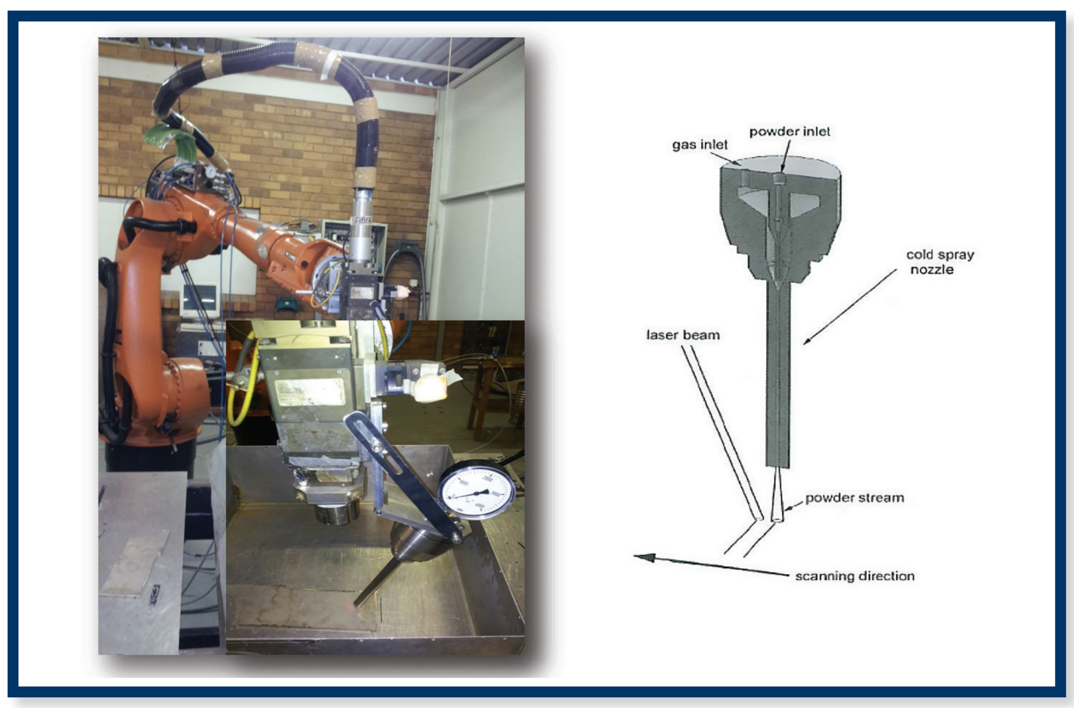
BACKGROUND

The durability of engineering components is determined by their surface integrity when they encounter corrosion and wear in their operating environments. Corrosion and wear are good environments under which coating materials must be evaluated, as they help improve the integrity of coatings[1]. Tissue engineering is one application under which metal coatings can undergo corrosion and wear. The results are not desirable given the amount of toxicity associated with them. In tissue engineering, stainless steel, cobalt and alloys, as well as titanium and its alloys are normally coated with bio-ceramics to help induce their bio-compatibility and osseo-integration while ridding them of corrosion and wear. Coatings are normally achieved by thermal deposition techniques not only limited to laser cladding, vacuum plasma and high velocity oxy-flame. However, it has become obvious that these techniques are faced with problems such as component distortion, cracks, porosity, oxidation and high residual stress, and require inert environments during deposition[2,3,4].

To overcome this shortcoming, researchers used cold gas (CS) techniques for powder depositions or coating. CS is a non-melting technology which deposits particles by entraining them in a supersonic gas jet, thereby accelerating them before impinging the deposition zone. However, concerns such as use of expensive gases, controlled inert environments (Ar), preheating of the gas, which makes this technology cost ineffective, have restricted the number of applications for this technology. Therefore, LACS technologies are been exploited to achieve efficient, less expensive surface processing and coatings which have good surface properties[5].

This study will employ a newly assembled LACS technology, which is believed to be effective and cheap as compared to its predecessor, to deposit Al-12wt%Si on stainless steel substrates. This technology is cheap in that processing gas (N_2) is not preheated and the technology operates in open atmosphere (no Ar is used).

MATERIALS AND METHODS



Al-12wt%Si powder with particle size distribution (PSD) of +45-90 microns was used. The use of this powder was premised on knowledge that this PSD range is typical for CS coating powders and, this powder is cheap when compared to narrow-band powders. This Al-12wt%Si powder was deposited on stainless steel substrates with dimensions of 100 mm X 50 mm X 5 mm. Before the spraying process, the substrate was roughened by grit sand blasting so to improve adhesion of coating to its surface.

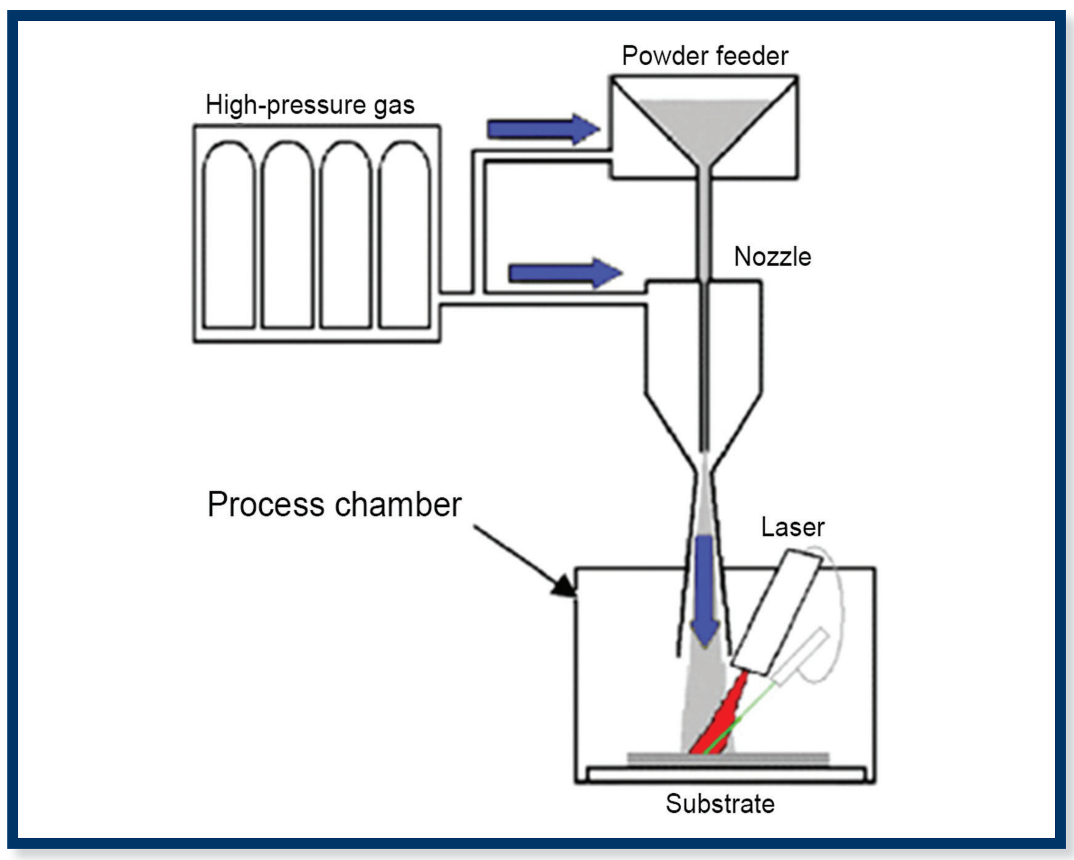
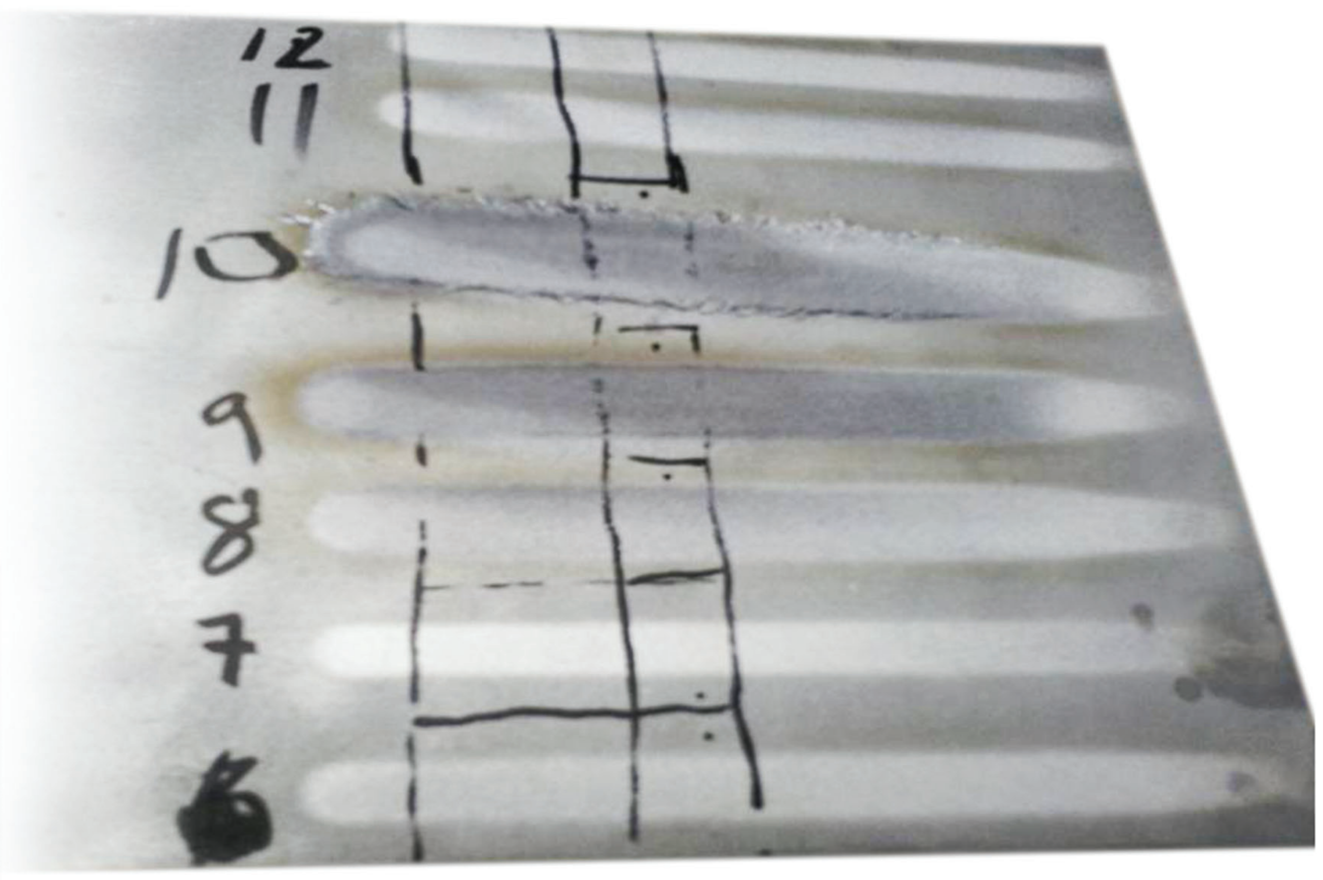


Figure 1: LACS5

Figure 1 demonstrates our LACS setup at the CSIR. Typically, highly compressed nitrogen gas tanks (30 bar) are used to entrain Al-12wt%Si so that supersonic speed is achieved. Different powder feed rates are achieved by setting different powder feed speeds in revolutions per minute (rpm). Note that the main gas inlet is split into two lines: one going to the powder container (entrained) and to the nozzle (accelerator) as shown by the nozzle drawing herein. The laser source softens the substrate and breaks the oxygen layer (Al_2O_3) so that effective bonding is achieved.

RESULTS AND DISCUSSION

The picture on the right shows Al-12wt%Si powder coatings on stainless steel substrate. What is important to note is that line scan 7 is cold spraying. It can be seen that it is different from scan lines 8–10, which show thick powder coatings achieved with LACS.



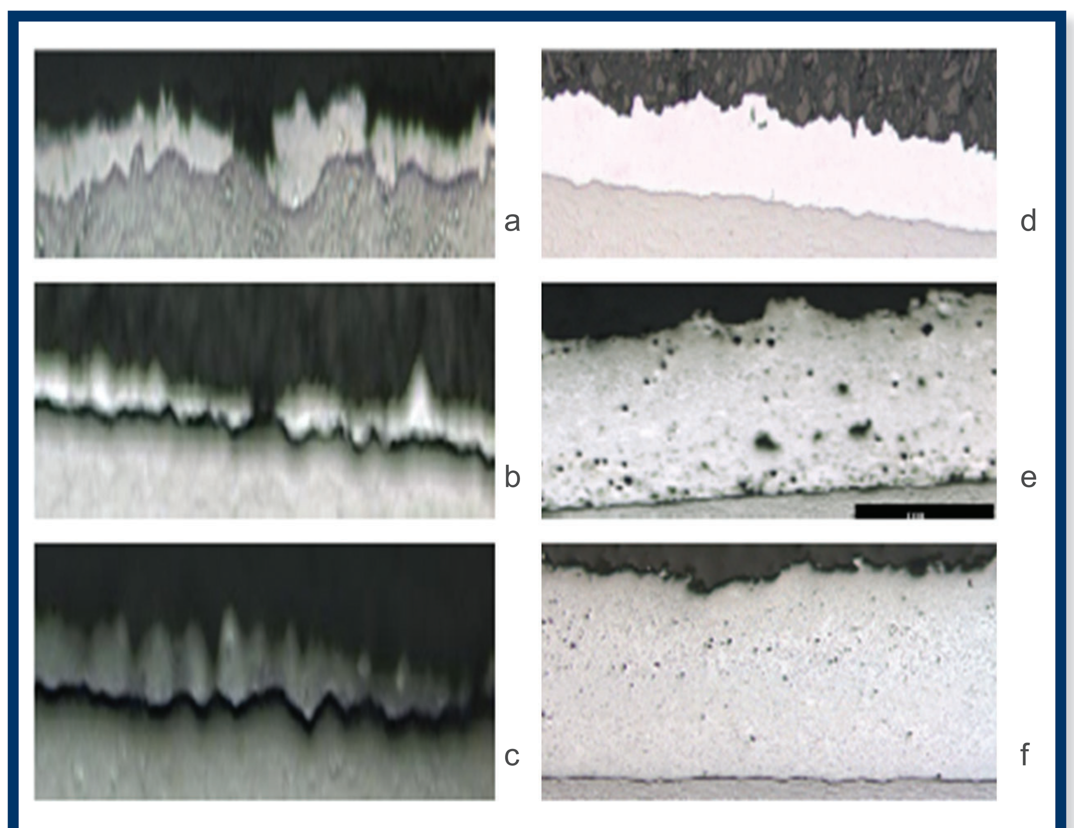


Figure 2: Macrographs of Si-12wt%Si Coatings deposited on stainless steel using LACS at laser powers: (a) 1.0 kW, (b) 1.5 kW, (c) 2.0 kW, (d) 2.5 kW, (e) 3.0 kW and (f) 3.5 kW

Results indicated that layer thickness of the coatings increased with increase in the applied laser power (**Figure 2**). In addition, thin, discontinuous coating tracks with weak bonding are observed at 1–2 kW laser power (**Figure 2a–c**) while thick; continuous coatings with strong and coherent bonding were achieved with laser powers 2.5–3.5 kW (**Figure 2d–f**). **Figure 3** indicates that the variation in laser power has significant influence on the thickness of the coatings. **Figure 4a–c** indicates microstructures, which are free of cracks and porosity, at the interface with the substrate and the coating itself. The few cracks and an unbounded particle shown in **Figure 4a** might corroborate[6]. Olakanmi et al. (2009) made an observation that mullite film, which normally covers the Al-Si powder, can be broken with enough heat from laser power, thereby leading to good bonding, no porosity and crack free coating. **Figure 5a–c** shows high porosity results at laser power 3.0 kW, no porosity at 2.5 kW and little porosity at 2.0 kW. Porosity values are (a) 2.64%, (b) 0.16% and (c) 4.12%.

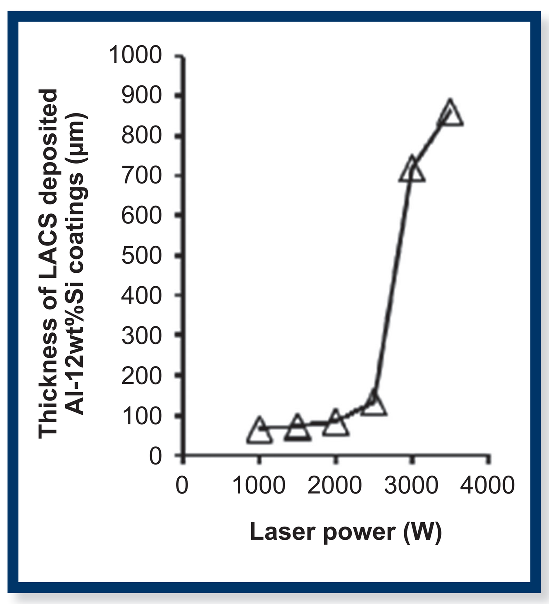


Figure 3: Effects of laser power on coating thickness

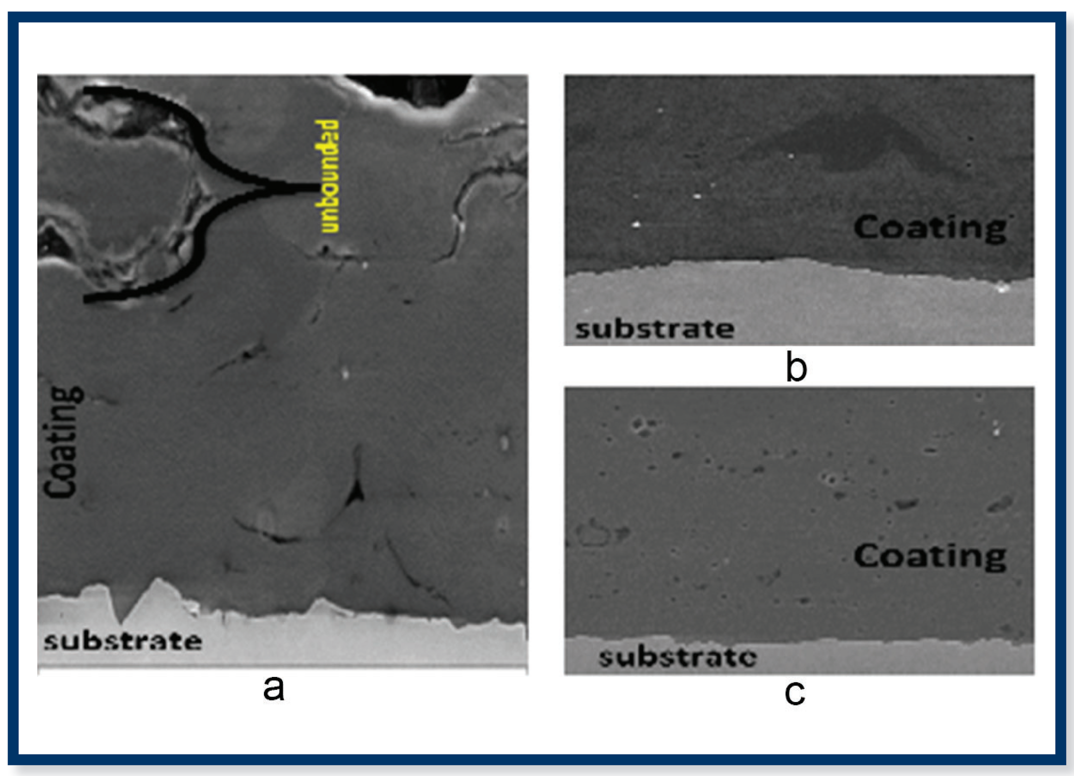


Figure 4: Microstructures of LACS deposited Al-12wt%Si coatings at varying laser powers: (a) 2.0 kW, 2.5 kW, and (c) 3.0 kW

LACS technology at the CSIR has been commissioned to fabricate, in future, commercially viable bio-compatible hip implants for humans made from Ti-HAP coating components.

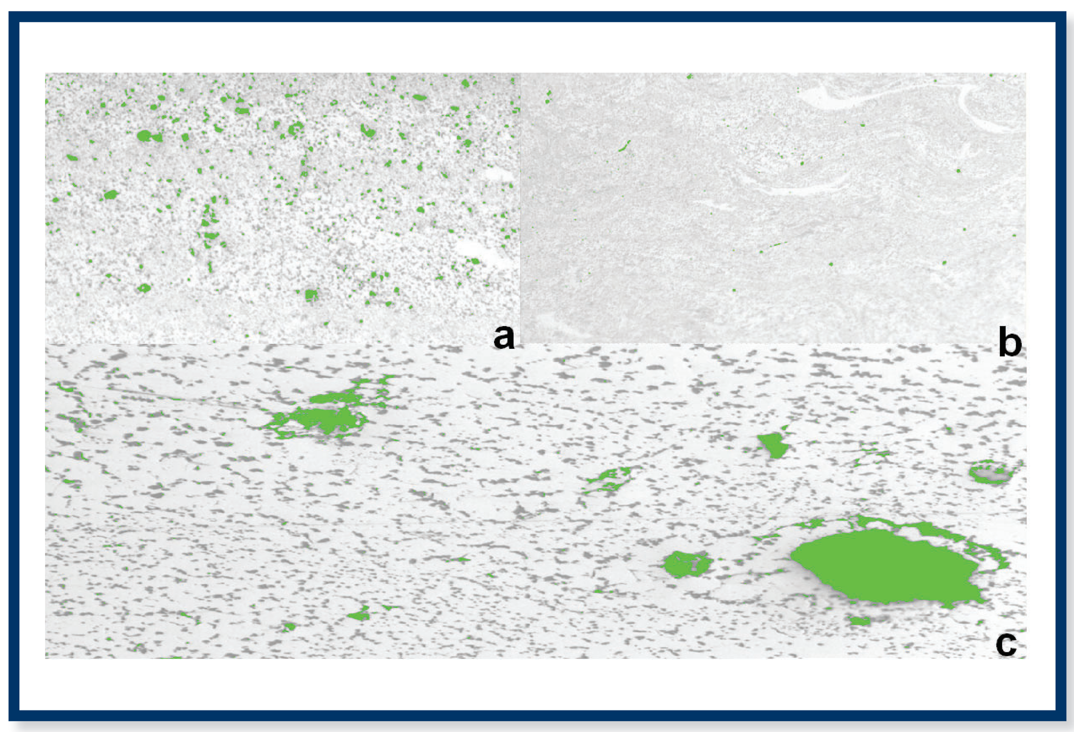


Figure 5: Porosity analysis in the LACS deposited Al-12wt%Si coatings produced with various laser powers: (a) 2.0 kW, (b) 2.5 kW and (c) 3.0 kW

CONCLUSION AND FUTURE WORK

We have successfully deposited Al-12wt%Si on stainless steel substrate. Laser power has a significant impact on the adhesion properties of powder particles on metals, as well as the coating thickness, porosity and cracks. Therefore it may be inferred, realising overlaying results, that our LACS technology is successfully commissioned.

Our future work is detailed around the fabrication of bio-compatible material which are aimed at hip implants. This will be achieved using commercial pure titanium (powder) and hydroxyapatite (HAP-coating) on Ti-6Al-4V (substrates). We believe our LACS technology will, unlike current plasma coating technologies, retain properties of HAP. It stems from the fact that HAP melts during plasma spraying, and crystallises on the base materials during cooling, thereby influencing coating durability and inducing cracks and porosity which are undesirable.

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