Effects of Laser Power during Laser Assisted Cold Spraying of Al-12wt%Si on Stainless Steel

Monnamme Tlotleng[1,2], Eyitayo Olakanmi[2], Sisa Pityana[1,3], Mukul Shukla[2], Esther Akinlabi[2]

1. National Laser Center, Council for Scientific and Industrial Research, P.O. Box 395, Pretoria, 0001, South Africa

2. Department of Mechanical Engineering Science, University of Johannesburg, P.O.Box 524, Auckland Park, 2006, South Africa

3. Department of Chemical and Metallurgical Engineering, Tshwane University of Technology, Private Bag X 680, Pretoria, 0001, South Africa

OBJECTIVES

This study seeks to demonstrate Laser Assisted Cold Spraying (LACS) by depositing Al-12wt%Si on stainless steel substrate. LACS is a newly designed, assembled and commissioned technology in the CSIR, laser materials processing laboratories. The basis on which Al-12wt%Si powder is used are validated by the idea that this powder was available, cheap and its spherical nature is suitable to be used with technology. Also, this study wanted to demonstrate that any powder can be deposited on substrate using cheap gases like nitrogen, under no controlled environment , without pre-heating the gas. In addition, sufficient power used to soften the substrate will lead to efficient coatings.

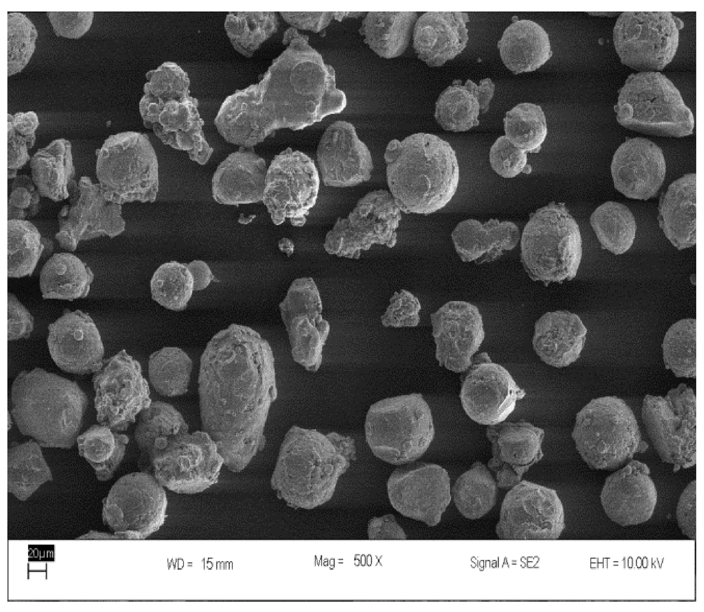
BACKGROUND

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 against 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 and titanium and its alloys are normally coated with bio-ceramics to help induce their bio-compatibility and osse-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 components distortion, cracks, porosity, oxidation, high residual stress and require inert environments during deposition[2, 3,4].

To overcome this shortcoming, researchers used cold gas (CS) techniques for power depositions or coating. CS is a non-melting technology which deposit particles by entraining them in a supersonic gas jet thereby accelerating before impinging the deposition zone. However, concerns such as use of expensive gases, controlled inert environments (Ar), pre-heating of the gas which make this technology cost ineffective have restricted the number of applications for this technology. To it 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 predecessor, to deposit Al-12wt%Si on stainless steel substrates. This technology is cheap in that processing gas (N2) is not pre-heat and operation are open to atmosphere (no Ar used).

MATERIALS AND METHODS



The SEM picture of Al-12wt%Si powder used in this study. The particle size (PSD) was +45-90 microns. The use of this powder was premised on knowledge that this PSD range is typical for CS coatings powders and they are cheap than narrow-band powders. Stainless Steel substrates used in this study had dimensions of 100 mm X 50 mm X 5 mm. Before spraying process the substrate was roughened by grit sand blasting so to improve adhesion of coating to their surfaces.

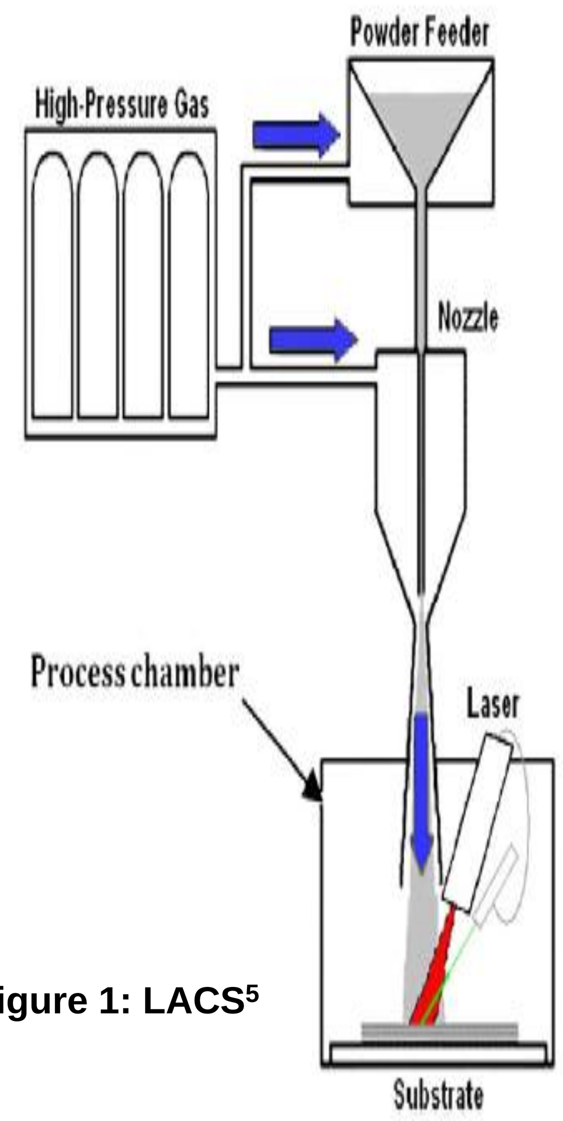
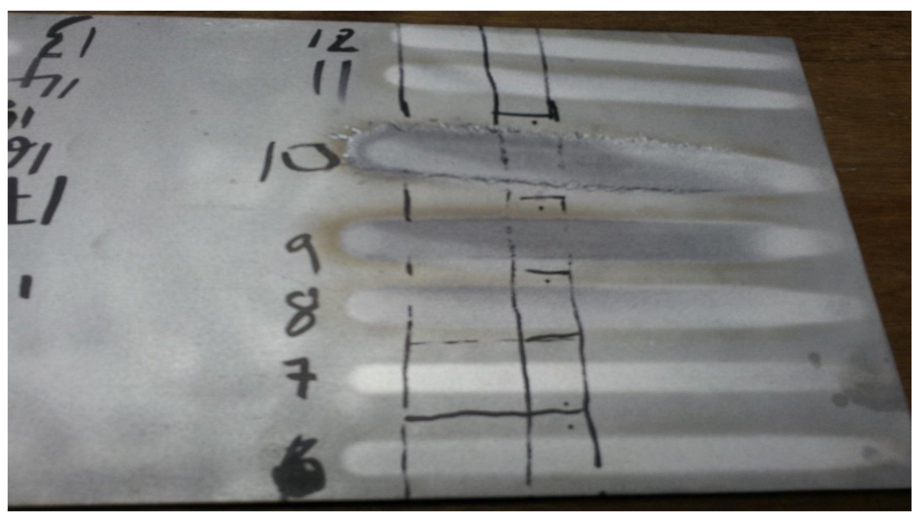


Figure 1: LACS[5]

Figure 1 demonstrate our LACS set-up. Typically, nitrogen gas tanks which are highly compressed are required. Powder contained in container with a electric blanket which demoist powder particles are used. The powder feeder has controlled rpm which controls the feed rates which will be entrained within compressed N2 at 30 bar. Note that the main gas inlet is split into two lines: one going to the powder container (entertainer) and to the nozzle (accelerator). The laser source softness the substrate and breaks the oxygen layer (Al_2O_3) so that effective bonding is achieved. The Process chamber is present only to control spills and allow for powder recycling.

RESULTS AND DISCUSSION



This picture show 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.

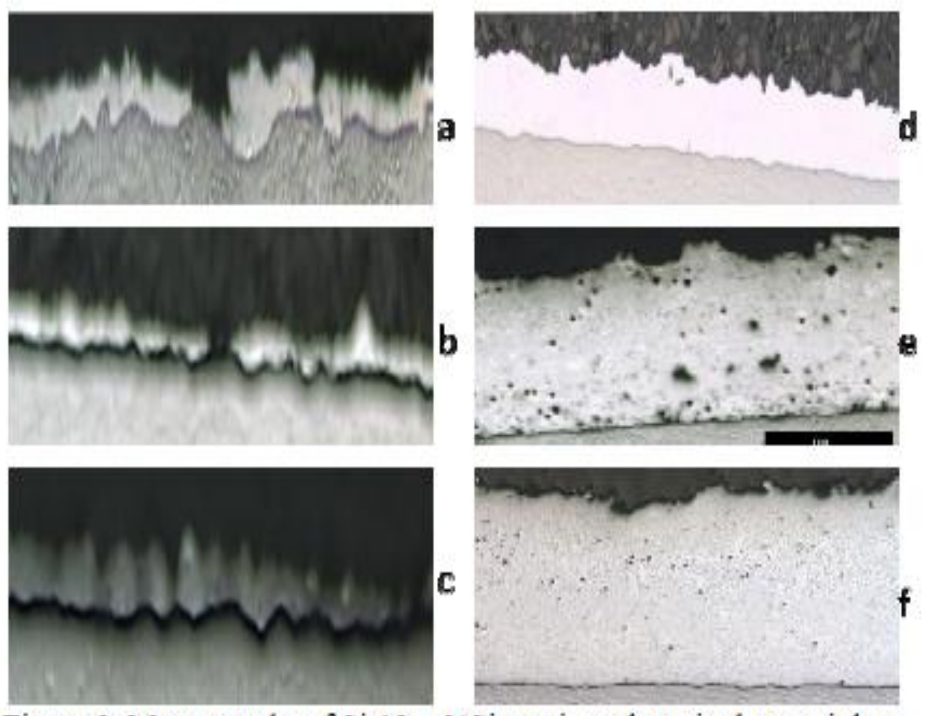


Figure 2: Macrographs of Si-12wt%Si coatings deposited on stainless steel using LACS at laser powers: (a) 1.0 kW, (b) 1.5 kW, (c) 2.0 kW, (d) 2.5 kW, (e) 3.0 kW, and (f) 3.5 kW

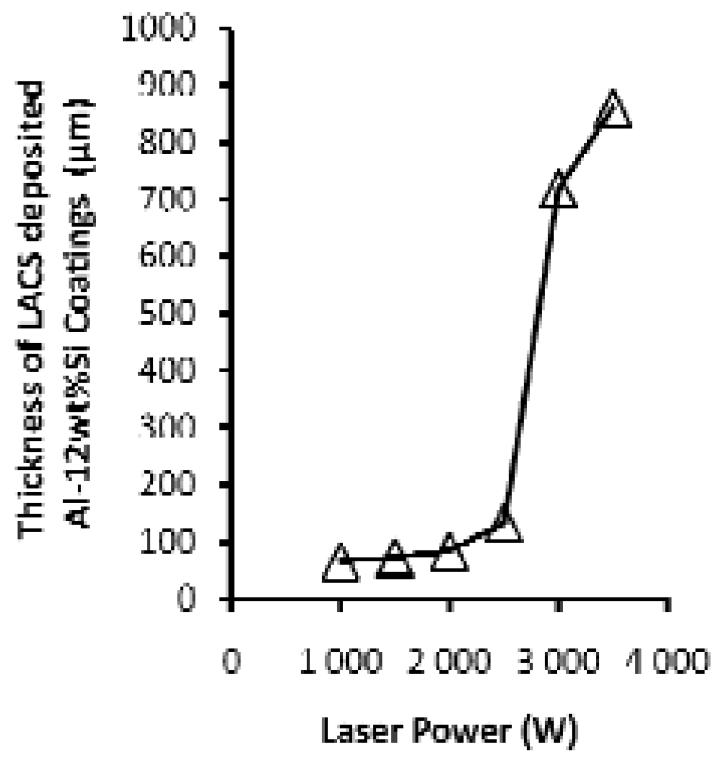


Figure 3: Effects of laser power on coating thickness

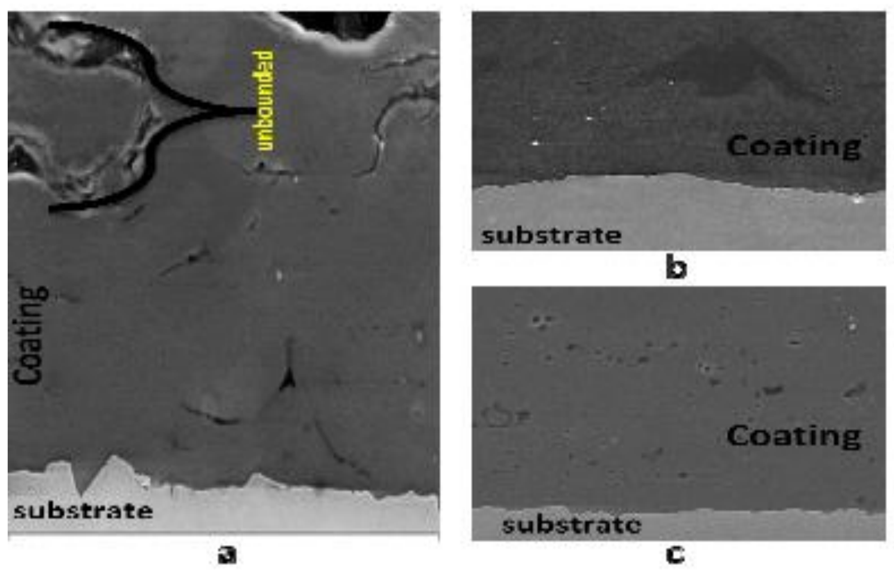


Figure 4: Microstructures of LACS deposited Al-12wt%Si coatings at varying laser powers: (a) 2.0 kW, 2.5 kW, and (c) 3.0 kW

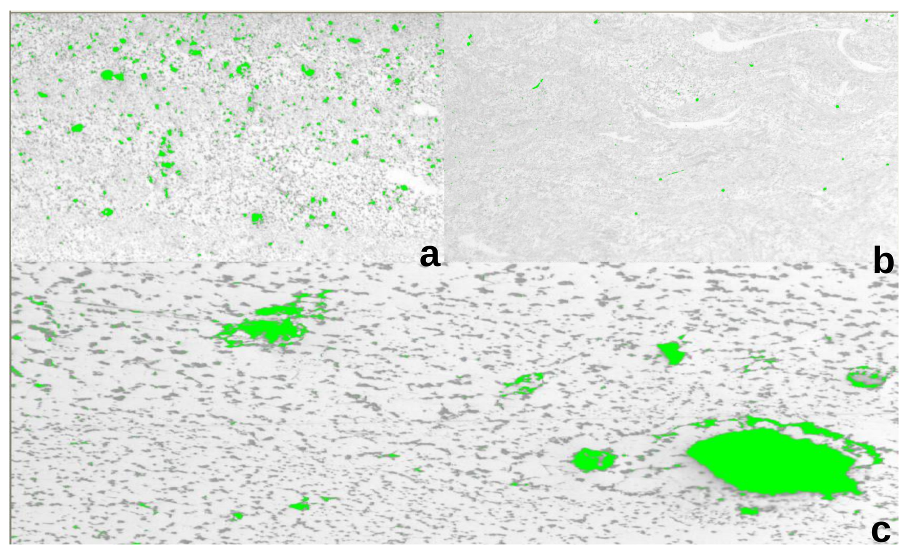


Figure 5: Porosity analysis in the LACS deposited Al-12wt%Si coatings produced with various laser powers: (a) 2.0 kW, (b) 2,5 kW and (c) 3,0 kW.

Results indicated that layer thickness of the coatings increased with increase in the applied laser power (Fig 2). In addition, thin; discontinuous tracks of coating with weak bonding are observed at 1-2 kW laser power (Fig 2a-c) while thick; continuous coatings with strong and coherent bonding were achieved with laser powers 2.5 -3.5 kW (Fig 2d-f). Figure 3 indicate 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 by Fig 4a might corroborate[6]. Olakanmi *et al* (2009) made an observation that mullite film that normally cover 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 that 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%.

CONCLUSION AND FUTURE WORK

- **We have successfully deposited Al-12wt%Si on stainless steel substrate;**
- **Laser power has significant impact on the adhesion properties of power 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 coating technologies, retain properties of HAP since no there is not heating and it stems out that HAP during plasma spraying melt and during cooling it crystallises on the base materials thereby influencing their coating durability and inducing cracks and porosity which are undesirable.

REFERENCES

1. **Li, W. *et al* (2007) *Applied Surface Science*. 253, 7124-7130.**
2. **Manivasagam, G. *et al* (2010) *Recent Patents on Corrosion Science*. 2, 40-54.**
3. **Cockburn, A. *et al* (2008) *Proceedings of LAMP2009*. 1-6.**
4. **Tekmen, C. *et al* (2009) *Surface & Coatings Technology*. 203, 2046-2051.**
5. **Lupoi, R. *et al* (2011) *Materials Letter*. 65, 3205-3207.**
6. **Olakamni, E. *et al* (2009) *Materials Proceedings and Properties*. 1, 371-380.**