Stent Design using Nano-Structured Materials

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Abstract

Coronary artery disease (CAD) and myocardial infarction are life threatening conditions that can be treated with endovascular prostheses. However, the frame structure of the latter -- the stent — is prone to mechanical failures after long term usage. In order to improve current design, in this work, we present the use of Nano-Powder technology utilizing Cold Gas-Dynamic Spray (CGDS) and a methodology to manufacture stent with this new technology. Results obtained from preliminary samples document the possibility of producing new materials with properties that are more desirable for stent applications.

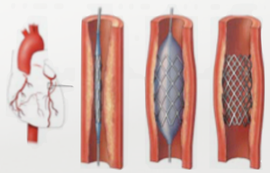


Figure 1. Stenting Procedure

Introduction

- Permanent metallic implants have fatigue long-term drawbacks which limit their longivity
- Clinical observations on coronary restenosis reveal that the scaffolding function of stent is required to last for 6 months
- Therefore there is need to develop degradable stents that can fulfill the function and disappear
- The material for degradable stents must have the following characteristics:
  - ✓ Biocompatible, and degradation products of the material must also be biocompatible
  - ✓ Material must stay in place for several months before its complete bio-resorption
  - ✓ Radial force of the stent must be sufficient for scaffolding function during the requested period
- Our objective is to use CGS to create a material with more appropriate mechanical properties and to assess the possibility of controlling degradation rate using galvanic corrosion effect

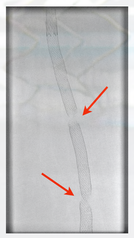


Figure 2. Fractured Stent due to dynamics loading

Methodology

- Powders of 316L stainless steel and a dissimilar metal, with particle size ranging from 15 to 45 µm, are mixed together using a tumbler for 1h
- Powder mixture is cold sprayed onto a substrate to obtain a coating of the material

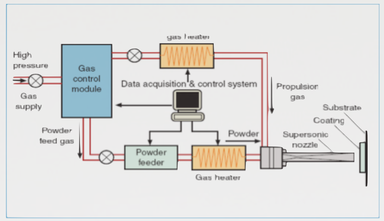
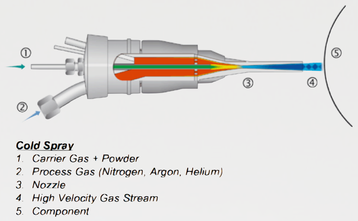


Figure 3. Block diagram of cold spray system



Cold Spray
1. *Carrier Gas + Powder*
2. *Process Gas (Nitrogen, Argon, Helium)*
3. *Nozzle*
4. *High Velocity Gas Stream*
5. *Component*

Figure 4. Diagram of the KINETIKS 4000 spray gun

- Samples of the material undergo different heat treatments for ductility improvement
- Corrosion depletion tests and potentiodynamic polarization scan were performed

Results

- Experiments, whose objective was to achieve an increase in ductility, using composites of 316L stainless steel and L605 cobalt chromium as cold-sprayed powders has yielded the following results:

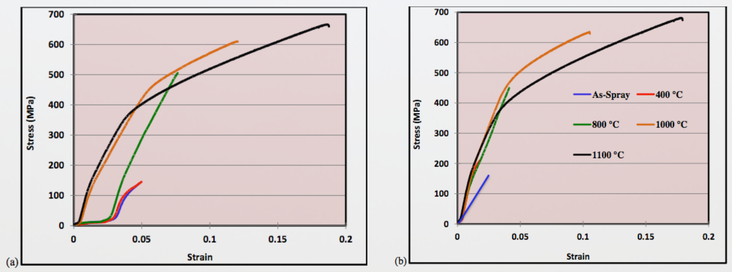


Figure 5. Effect of heat treatment on tensile properties of (a) 316L-25% Co; (b) 316L-33.3% Co deposited coatings

Results (continued)

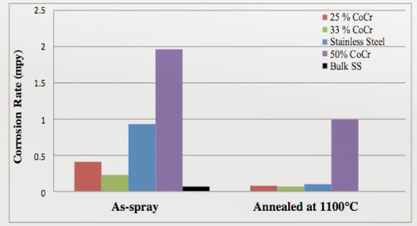


Figure 6. Corrosion rate comparison between as-sprayed and after annealing at 1100°C

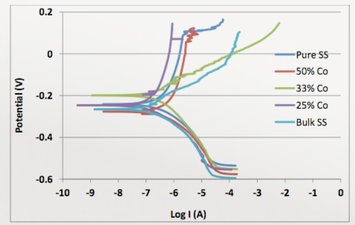


Figure 7. Polarization curve shows effect of annealing at 1100°C on corrosion resistance

- Recent results reveal successful deposition of 316L and Fe composite powders onto a 6061 aluminum substrate
- Galvanic corrosion rate of cold sprayed 316L and Fe alloy is currently being assessed for bio-degradation

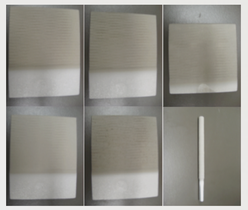


Figure 8. Cold spray deposited coating of composite 316L and pure iron powders onto aluminum substrate

Conclusion

- Results show improved ductility and toughness of the cold sprayed coating after heat treatment
- Evaluation of the corrosion rate of 316L and Fe mixture cold sprayed alloy is needed to control the bio-degradation for the needed duration
- The results support the feasibility of using Cold-Spray technology to produce stents with superior properties for medical treatment

References

[1] A. Bandar, "The use of cold sprayed alloys for metallic stents", M.S. thesis, Dept. Min. and Mat. Eng., McGill University, Montreal, Canada, 2012.

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