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Experimental Fabrication of Porous Additive Manufactured Material

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Introduction

- Nuclear industries benefit from thermal barrier coatings (TBC) that increase material performance in high temperature environments.
- Porosity can be used as a mechanism to increase bulk or surface material performance and applied as TBC for improved stress accommodation and negative thermal conductivity.
- Functionally graded materials (FGM) are materials manufactured with complex spatial and structural compositions which result in tailored material properties
- This study presents additive manufacturing (AM) experiments of porosity gradient FGM with wire arc additive manufacturing (WAAM) and digital light photoluminescence (DLP).

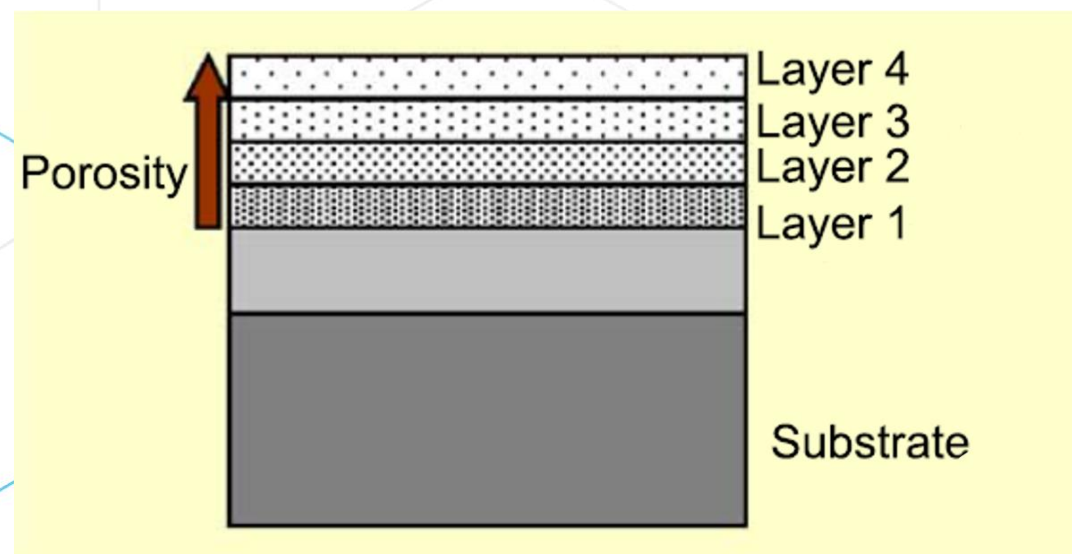

Figure 1. AM porous gradient diagram[2]

Porous Thermal Barrier Coatings

- In energy conversion systems, TBC can improve efficiency by enhancing inlet temperatures and temperature differences[1]
- Lack of fusion or entrapped gas that occurs during manufacturing and are called porosity and generally considered process defects.
- Porosity gradient materials are used as TBC mechanisms that decrease thermal conductivity, increasing thermal insulation and reducing residual stress[2]. Figure 1

Additive Manufacturing

- Well suited to fabricate porous gradient FGM due to the capability to spatially control composition.
- **Material** : 316L Stainless Steel
- **WAAM**: based on gas tungsten arc welding, a CNC machine is used to control tool path and develop large weld beads that are layered for 3D parts.
- **LENS**: Laser Engineered Net Shaping, directed energy deposition method where powder is injected into melt pool.
- **DLP:** UV light-based AM method that binds material in a green slurry. Final parts are cured, releasing the binding agent and sintered, causing densification.

WAAM / LENS Experiments

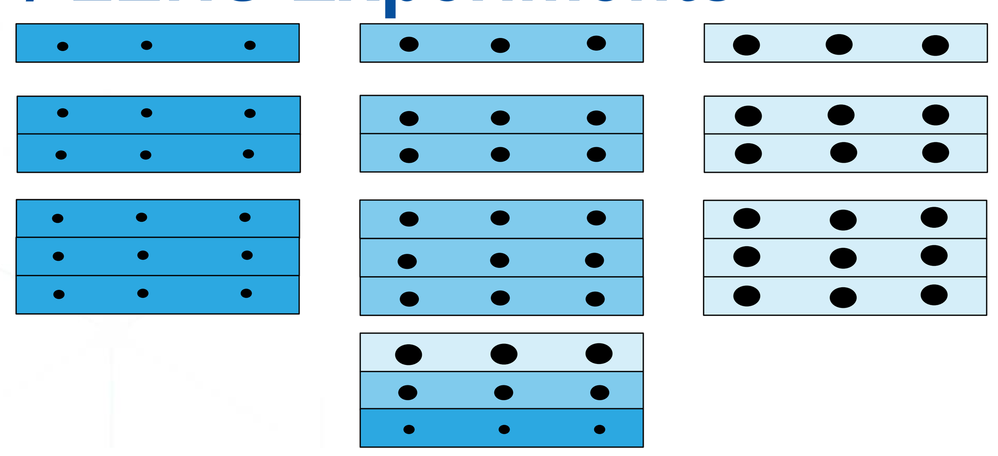

Figure 2. WAAM fabrication sample matrix.

- High deposition travel speeds, heat input, and gas flow rates are used to investigate if porosity can be induced with increased solidification rates and gas entrapment.[3]
- Single-track, multi-layered, and gradient builds.

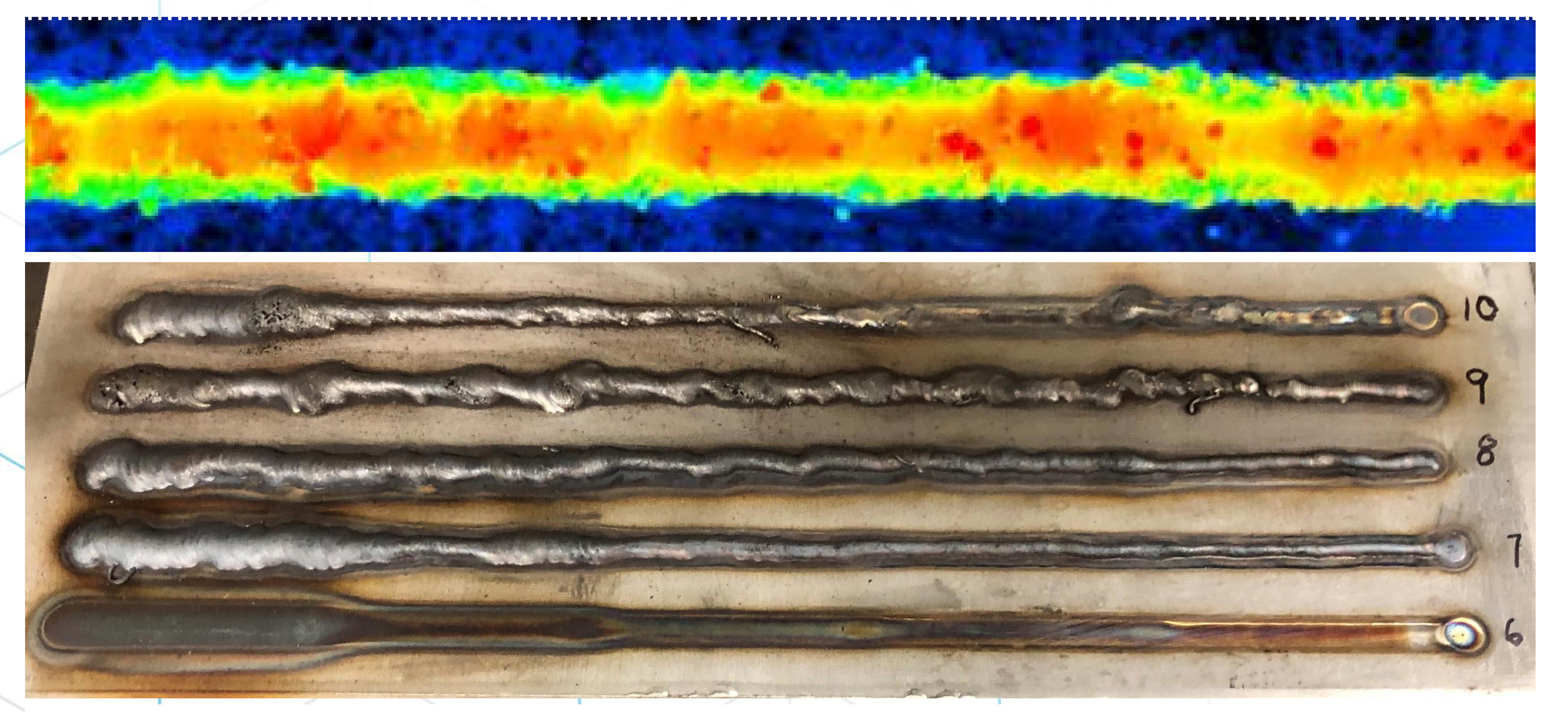

Figure 3. Laser-optical height profile of LENS track, WAAM welds.

DLP Experiments

- Fabrication of FGM with predesigned shape and size pores.
- Samples will be heat treated at different temperatures for sintering densification effects.
- Assist with model validation of pore geometry and thermal conductivity.

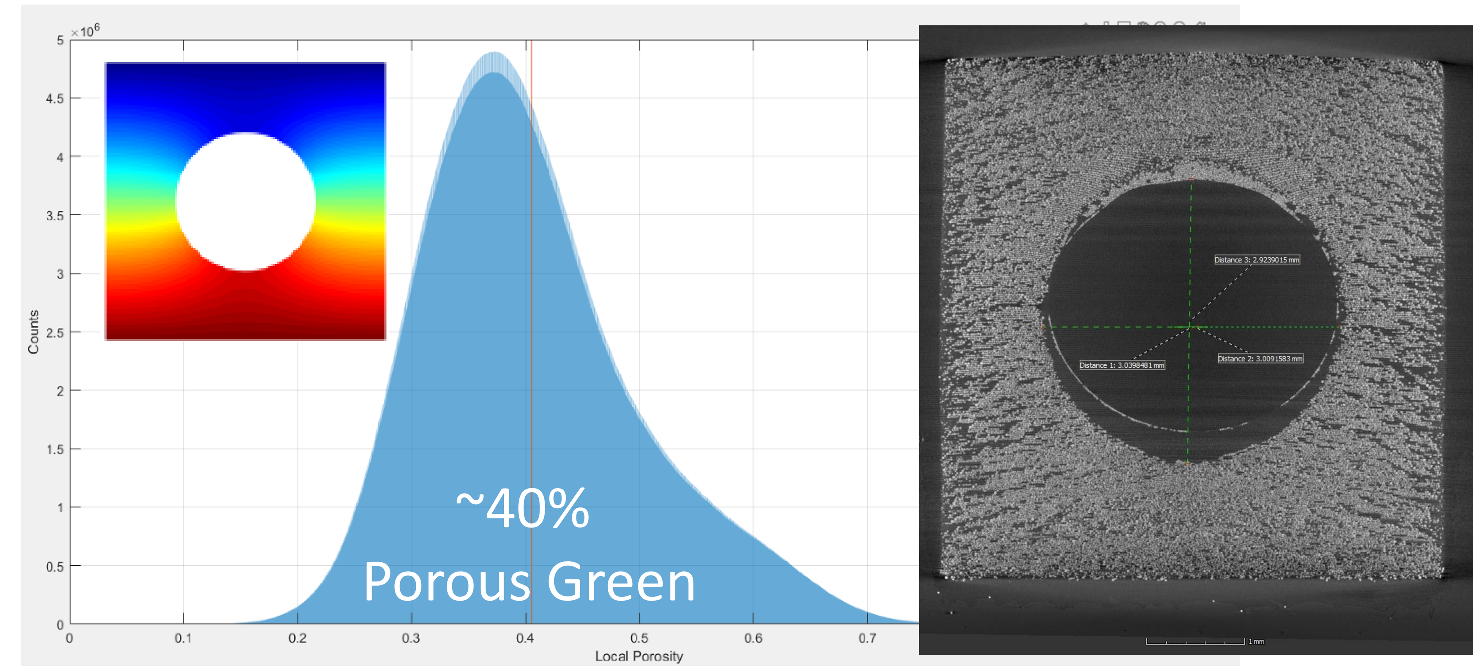

Figure 4. 2D thermal model, porosity distribution histogram, CT scan.

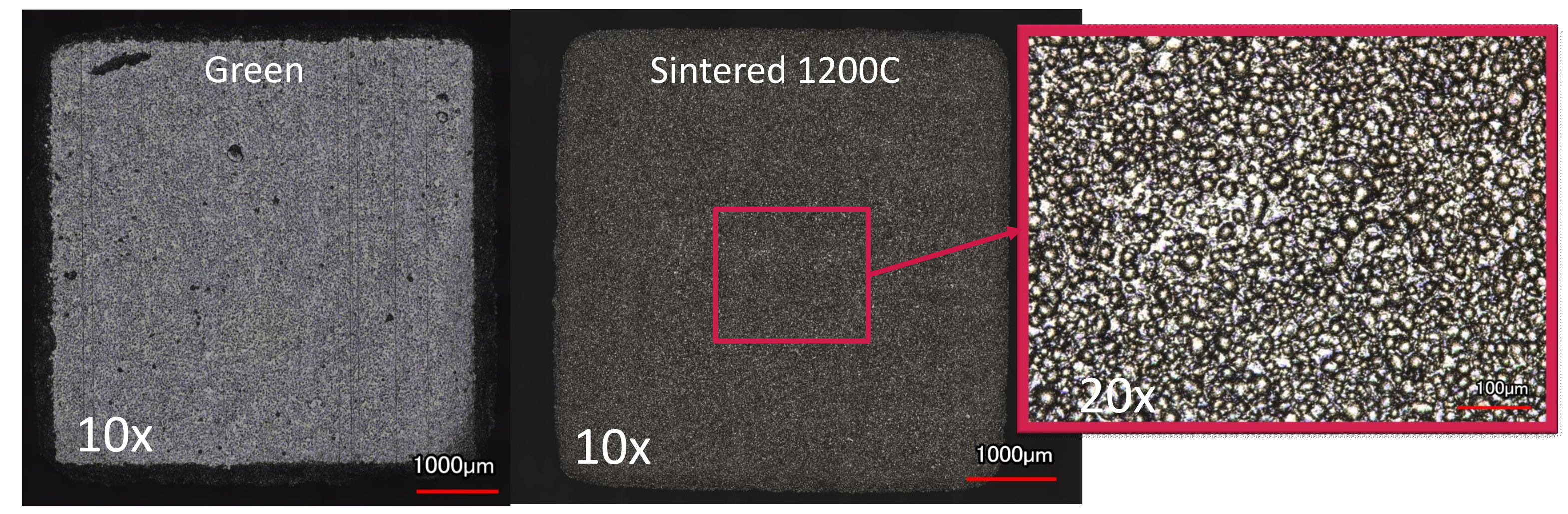

Figure 5. DLP green, post-sintered, microstructure.

- Densification = 3.897%
- Reduction in volume = 20.6%

Future Work

- Microstructure characterization with advanced microscopy
- Spatially designed LENS porous gradients

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(2) Portinha, A.; Teixeira, V.; Carneiro, J.; Martins, J.; Costa, M. F.; Vassen, R.; Stoever, D. Characterization of Thermal Barrier Coatings with a Gradient in Porosity. *Surf. Coat. Technol.* **2005**, *195* (2–3), 245–251. https://doi.org/10.1016/j.surfcoat.2004.07.094.

(3) Ryan, E. M.; Sabin, T. J.; Watts, J. F.; Whiting, M. J. The Influence of Build Parameters and Wire Batch on Porosity of Wire and Arc Additive Manufactured Aluminium Alloy 2319. *J. Mater. Process. Technol.* **2018**, *262*, 577–584. https://doi.org/10.1016/j.jmatprotec.2018.07.030.

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