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Laser Powder Directed Energy Deposition of Ti-21S: Microstructure, Mechanical Properties, and Corrosion Resistance

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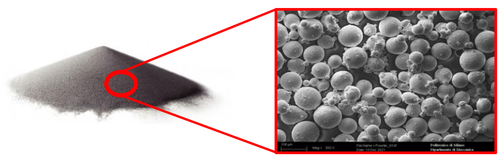
INTRODUCTION & AIM

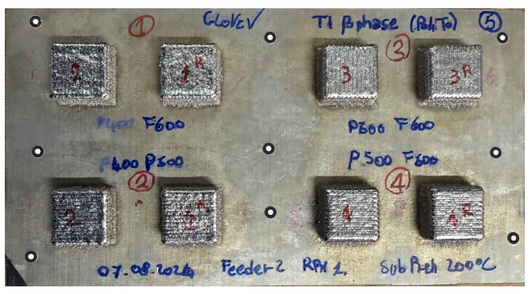
- Ti-21S is a β-titanium alloy with high strength, low density, and excellent corrosion resistance, suitable for aerospace and biomedical use.
- Conventional manufacturing is challenging due to poor weldability and high thermal distortion, leading to increased cost.
- LP-DED allows precise melting and layer-by-layer fabrication, enabling complex geometries with reduced material waste.
- Process parameters directly affect defects, microstructure, mechanical properties, and corrosion behavior.
- Aim: Optimize LP-DED parameters to produce dense, uniform Ti-21S parts and evaluate their microstructure, hardness, and corrosion resistance.

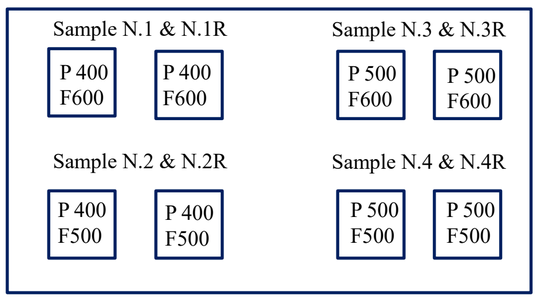
METHOD

- **Material:** Gas-atomized Ti-21S β-metastable powder (45–105 µm, argon atomized) was used as feedstock.



- **Process:** Samples were produced via Laser Powder Directed Energy Deposition (**LP-DED**) under argon shielding with 200°C substrate preheating.
- **Build Strategy:** Multi-layer 5 mm cubes were fabricated using a 0°/90° raster deposition pattern.





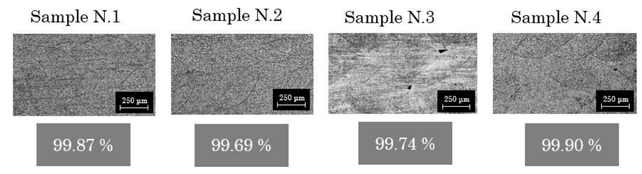
- **Parameter Matrix:** Four processing conditions were applied by varying laser power (400–500 W) and scan speed (500–600 mm/min), with two repetitions for each set.

	Power (W)	Speed (mm/min)	H.D (mm)	dz (µm)	Raster
S N.1 & N.1R	400	600	0.479	186	0°/ 90°
S N.2 & N.2R	400	500	0.501	151	0°/ 90°
S N.3 & N.3R	500	600	0.589	170	0°/ 90°
S N.4 & N.4R	500	500	0.605	201	0°/ 90°

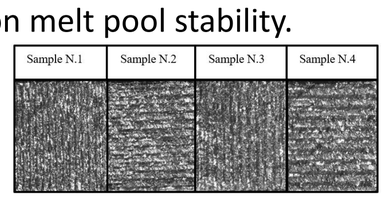
- **Characterization:** Archimedes density, surface roughness, SEM, XRD, microhardness, and electrochemical corrosion tests were conducted to evaluate microstructure and performance.

RESULTS & DISCUSSION

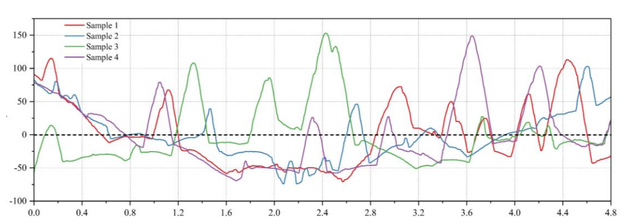
- Density: All samples achieved **>99.7%** relative density, indicating defect-minimized LP-DED processing; the optimized parameter set reached **~99.9%.**



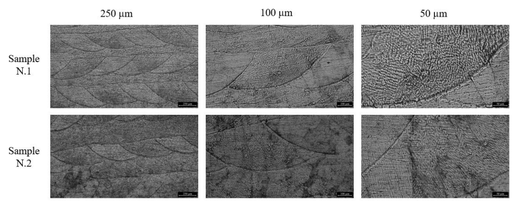
- **Surface Quality:** Surface roughness varied across builds, with sample N.2 showing the lowest Ra, demonstrating the effect of scan speed on melt pool stability.

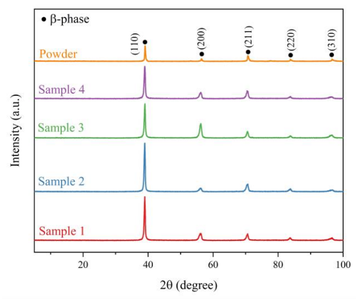


	Sample N.1	Sample N.2	Sample N.3	Sample N.4
Ra	13.725 µm	8.128 µm	16.219 µm	18.864 µm
Rz	59.654 µm	46.993 µm	70.128 µm	90.546 µm
Rt	119.548 µm	88.276 µm	122.258 µm	133.96 µm



- **Microstructure:** XRD and OM results confirmed a fully β-phase microstructure, typical for metastable Ti-21S produced under rapid solidification conditions.

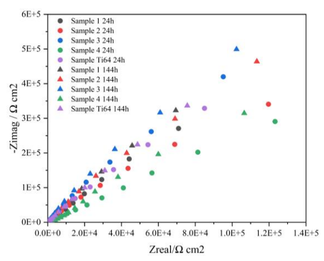




Mechanical Properties: Microhardness values ranged between ~330–390 HV, with sample N.4 achieving the highest hardness, correlating with refined β grains.

Sample Number	HV	SD
Sample N.1	357	24.4741
Sample N.2	378	12.5982
Sample N.3	332	19.3647
Sample N.4	388	15.4299

Corrosion Resistance: Electrochemical tests in 0.9 wt.% NaCl showed excellent passivation behavior and high charge-transfer resistance (Rct) across all samples, with performance comparable or superior to Ti-6Al-4V.



Sample Number	Time (h)	R_{ct} (kΩ)
Sample N.1	24	5.96×10^9
	144	6.52×10^9
Sample N.2	24	6.86×10^9
	144	1.06×10^{10}
Sample N.3	24	8.40×10^9
	144	1.11×10^{10}
Sample N.4	24	6.37×10^9
	144	6.77×10^9
Sample Ti64	24	6.16×10^9
	144	6.61×10^9

CONCLUSION

- DED optimized processing parameters resulted in enhanced density, hardness and uniform microstructural features across samples.
- Corrosion testing confirmed robust passivation behavior, indicating that LP-DED Ti-21S maintains excellent environmental durability.

FUTURE WORK / REFERENCES

- Investigate the effect of heat treatment on β-phase stability and grain refinement.
- Scale up LP-DED parameters to larger component geometries for industrial validation.