Summary of "Additive Manufacturing of Pure Niobium by Laser Powder Bed Fusion: Microstructure, Mechanical Behavior and Oxygen Assisted Embrittlement"

This study, published in *Materials Science & Engineering A* (2022), investigates the additive manufacturing of pure niobium (Nb) using laser powder bed fusion (LPBF), focusing on microstructure, mechanical properties, and the impact of oxygen-induced embrittlement. Conducted by researchers at Central South University, China, the study explores how LPBF parameters, particularly energy density, affect the densification, microstructure, and mechanical performance of Nb samples.

Densification and Processing:
The research demonstrates that LPBF can produce high-density Nb samples, achieving an average relative density of 99.7% with optimized parameters. Energy density, determined by laser power and scanning speed, significantly influences densification. At lower scanning speeds (e.g., 600–1000 mm/s), complete melting of Nb powder reduces porosity, enhancing density. However, excessive energy density (above 167 J/mm^2) increases porosity due to Marangoni convection and the "pool boiling effect," where high temperatures cause molten powder to vaporize, forming pores. Optimal densification was observed at an energy density of 146 J/mm^2, balancing complete powder melting and minimal porosity.

Microstructure Analysis:
X-ray diffraction (XRD) analysis revealed that LPBF-processed Nb exhibits a body-centered cubic (BCC) crystal structure with four distinct diffraction peaks. Oxygen, acting as an interstitial atom, forms solid solutions within the BCC lattice, slightly shifting diffraction peaks to lower angles at higher energy densities. This oxygen incorporation influences the microstructure, particularly at lower scanning speeds, where increased thermal input enhances oxygen dissolution.

Mechanical Properties:

The mechanical properties of LPBF-built Nb are highly dependent on energy density and oxygen content. At an optimal energy density of 146 J/mm^2, Nb samples exhibited excellent mechanical properties, with a yield strength of 625 MPa, ultimate tensile strength (UTS) of 670 MPa, and fracture elongation of 20%. These properties are attributed to a high density of low-angle grain boundaries and dislocations. As energy density increased, yield strength and UTS improved (e.g., from 565 MPa to 703 MPa and 639 MPa to 747 MPa, respectively), but plasticity decreased significantly due to oxygen-induced embrittlement. Oxygen-containing Nb (Nb-O) samples showed poor plasticity, with fracture elongation dropping below 2%, compared to pure Nb's 20% at 1000 mm/s scanning speed. This embrittlement is linked to interstitial oxygen interacting with dislocations, impeding their movement and reducing ductility.

Oxygen-Induced Embrittlement:

Oxygen plays a critical role in the mechanical behavior of LPBF-built Nb. Interstitial oxygen atoms interact with dislocation cores and vacancies, reducing fracture elongation (e.g., from 20% to 8% in Nb-O samples at 100 mm/s). This interaction, analyzed through principles calculation, indicates that oxygen restricts dislocation migration, leading to brittle behavior. The study highlights that controlling oxygen content is essential for maintaining the ductility of Nb in LPBF processes.

Conclusion:

The study successfully demonstrates the feasibility of producing dense, mechanically robust Nb components via LPBF. Optimal energy density (146 J/mm^2) yields high strength and good plasticity, while excessive energy density or oxygen incorporation leads to porosity and embrittlement. These findings provide valuable insights for optimizing LPBF parameters to fabricate high-performance Nb components, with implications for applications requiring high strength and ductility. The research was supported by the State Key Laboratory of Powder Metallurgy and funding from Hunan Province's Scientific and Technology Development Plan.