PhD Thesis Proposal

Thesis title:

Shot-Peening and High-Temperature Oxidation of Titanium

Department / Research team:

ICB / PMDM / M4OXE

Thesis Supervision and, if applicable, co-supervision:

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Scientific Context

Mechanical surface treatments such as shot-peening (SP) induce severe plastic deformation in the near-surface region of metals, generating nanocrystalline structures, high defect densities, and residual stresses. Over the past fifteen years, our group has demonstrated that SP and laser shock peening significantly improve the high-temperature oxidation resistance of titanium, zirconium, and their alloys (~10 articles in scientific journals).

These improvements are generally attributed to modified diffusion pathways associated with grain boundaries and crystallographic defects. Recent results highlight a critical but still poorly understood role of nitrogen: shot-peened titanium shows enhanced nitrogen uptake during short high-temperature exposures, and nitrogen enrichment beneath the oxide scale is strongly correlated with reduced oxidation kinetics in near-alpha titanium alloys. This suggests a competition between oxygen and nitrogen incorporation controlled by the SP-induced subsurface microstructure.

However, the thermal stability of these nanostructures, the density of defects evolution at high temperature, and their behavior in oxidation and nitridation situations remain largely unexplored.

Objectives

The objective of this PhD is to establish a mechanistic understanding of how shot-peening modifies the high-temperature reactivity of titanium through coupled effects of microstructure, crystallographic defects, and light elements diffusion. The study will focus on pure Ti and two near-alpha alloys, Ti-6242S and Ti-XT.

The project aims to:

- Characterize the thermal evolution of SP-induced nanostructures during short exposures at 650–700 °C under controlled atmospheres (Ar, N_2, O_2, air).
- Quantify links between peening parameters, defect density, residual stresses, grain refinement, and near-surface mechanical properties.
- Assess reactive pre-treatments combining shot-peening and short nitridation exposures to intentionally tailor nitrogen enrichment and limit oxygen ingress.

- Evaluate oxidation resistance improvements in aeronautical alloys and identify the key microstructural features responsible.
- Separate and quantify oxygen and nitrogen contributions to mass gain using element-specific techniques.

Methodology

Shot-peened and untreated samples will be subjected to controlled oxidation and nitridation using furnaces and thermogravimetric analysis. Microstructural evolution will be characterized by X-ray diffraction (residual stresses, microstrain), SEM/EBSD (grain structure), nanoindentation (mechanical properties), and TEM and Atom Probe Tomography for nanoscale and atomic-scale analysis. Oxygen and nitrogen profiles will be quantified by Ion Beam Analysis and correlated with mass gain measurements.

Expected Outcomes

The project will deliver a quantitative framework linking shot-peening parameters, microstructural stability, and high-temperature oxidation behavior. It is expected to identify optimized surface treatment strategies for near-alpha titanium alloys and to demonstrate innovative hybrid mechanical–reactive treatments with strong technological relevance for aerospace applications.

Keywords: titanium, shot-peening, microstructure, high temperature oxidation and nitridation,

Candidate profile:

The candidate should hold a Master's degree in Materials Science, Mechanical Engineering, or a related field, with a strong interest in metallic materials and experimental research. Background in microstructure, diffusion, oxidation/corrosion, or surface treatments is desirable. Experience with materials characterization (XRD, SEM/EBSD, TEM, TGA) is a plus. The candidate should demonstrate scientific rigor, autonomy, teamwork ability, and good proficiency in English.