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SOUTHERN POLYTECHNIC
COLLEGE OF ENGINEERING AND
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MICROSTRUCTURE, MECHANICAL, & CORROSION CHARACTERIZATION OF ADDITIVE MANUFACTURED TZM-TI64 BIMETALLIC STRUCTURES

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BACKGROUND

Bimetallic structures (BS) combine two metallic alloys within a single component to leverage complementary thermo-physical, mechanical, and corrosion-resistant properties. By integrating dissimilar alloys, BS overcome the limitations of single-material components and enhance performance in demanding environments [1]. Refractory alloy-based BS composed of Molybdenum alloy TZM (Mo–Ti–Zr–C) and Titanium alloy Ti-6Al-4V (Ti64) are of interest for aerospace, propulsion, and nuclear applications because TZM provides high-temperature strength while Ti-6Al-4V offers lower density and strong mechanical and corrosion performance [2]. Joining these alloys is difficult due to differences in melting temperature, thermal expansion, and the formation of brittle intermetallics, challenges also observed in Mo/Ti laser welding studies [3]. Wire Arc Additive Manufacturing (WAAM) offers a promising solution, enabling large-scale deposition, efficient material use, and controlled layering that supports metallurgically bonded or graded interfaces [2], [4]. Despite these advantages, limited research exists on the microstructure, mechanical integrity, and corrosion behavior of WAAM-fabricated TZM–Ti64 BS. Studies on TZM produced by WAAM report distinct solidification features and defects affecting mechanical response [4], while broader bimetallic AM literature highlights the need for deeper understanding of interfacial phase formation and long-term performance [1].

MATERIALS AND METHODS

Figure 1. Experimental Setup

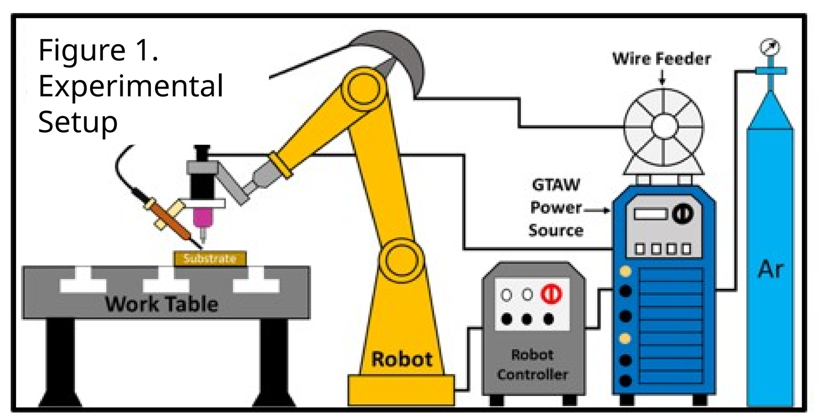


Figure 2. Thin Wall Sample

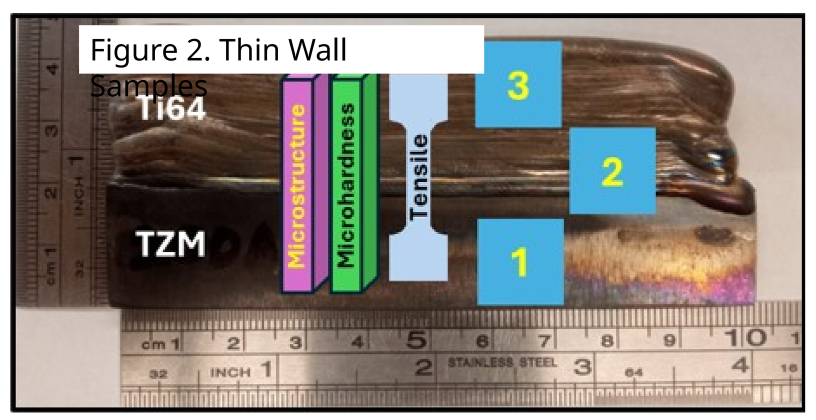
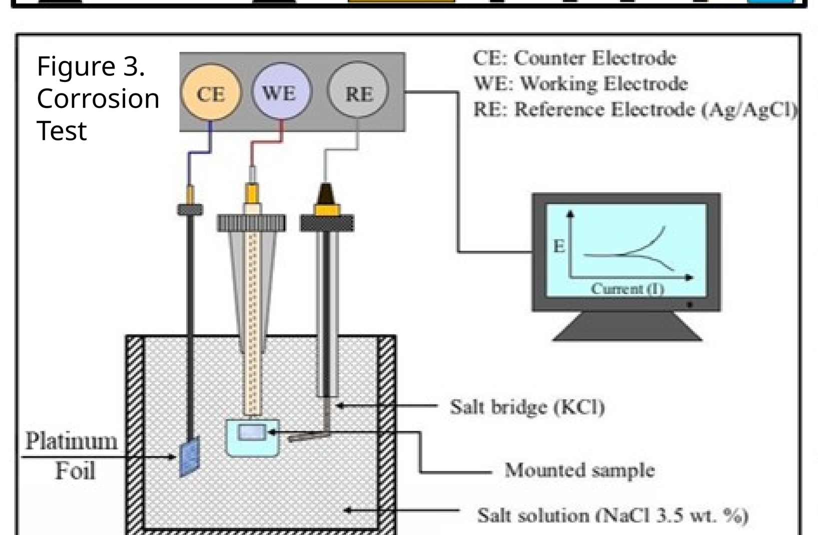


Figure 3. Corrosion Test



Process Parameter	Value
Current(A)	180
Wire Feed Rate(cm/min)	150
Travel Speed(cm/min)	20
Electrode-to-workpiece distance(mm)	5
Electrode tip angle	45°
Torch angle	90°
Shielding gas	99.999% Ar
Shielding gas flow rate(l/min)	15

Bimetallic TZM–Ti64 thin-wall structures, shown in figure 2, were fabricated using a wire arc additive manufacturing (WAAM) system shown in figure 1. Commercial TZM (Mo–0.5Ti–0.08Zr–0.02C) and Ti-6Al-4V (Ti64) filler wires were sequentially deposited onto a commercial TZM substrate (Mo–0.5Ti–0.08Zr–0.02C) to produce a metallurgically bonded BS using Gas Tungsten Arc Welding (GTAW) based WAAM setup shown in figure 1. The process parameters current (180A), wire feed rate (150cm/min) and travel speed (20cm/min) were adopted based on single bead experiments performed as shown in the table above.

From TZM–Ti64 BS thin wall, cross-sectional specimens were sectioned perpendicular to the build direction (figure 2). Samples were mounted, mechanically ground and polished following metallographic sample preparation procedure. Microstructural characterization was performed using a Nikon MA100 optical microscope (figure 3) and a TESCAN VEGA3 Scanning Electron Microscope (figure 4). Microhardness and tensile tests were carried out to assess the mechanical response, and corrosion behavior was evaluated using the electrochemical test setup illustrated in figure 3. Corrosion samples of size (1cm x 1cm x .2cm) were cut from thin wall at locations as shown in figure 2. Samples were taken from TZM side, Ti64 side and TZM-Ti64 interface. Corrosion test was carried out using 'Biologic SP200' Potentiostat corrosion setup

ABSTRACT

This work presents the fabrication and characterization of bimetallic TZM–Ti-6Al-4V thin-wall structures produced using wire-arc additive manufacturing (WAAM). Microstructural, mechanical, and electrochemical analyses were conducted to evaluate interface quality and overall material performance. Optical and SEM imaging confirmed a continuous, defect-free metallurgical interface with a narrow transition region formed by thermal diffusion during deposition. Hardness measurements showed distinct gradients across TZM, the HAZ, and Ti64, consistent with the differing alloy systems and process thermal history. Tensile testing demonstrated a ductile response characteristic of the thin-wall geometry, and corrosion testing indicated improved stability on the Ti64 side compared to TZM. These results demonstrate the feasibility of fabricating refractory alloy based bimetallic structures using WAAM and provide foundational insight for multi-material components in high-temperature and structural applications.

EXPERIMENTAL SETUP

Figure 3. Optical Microscope Images

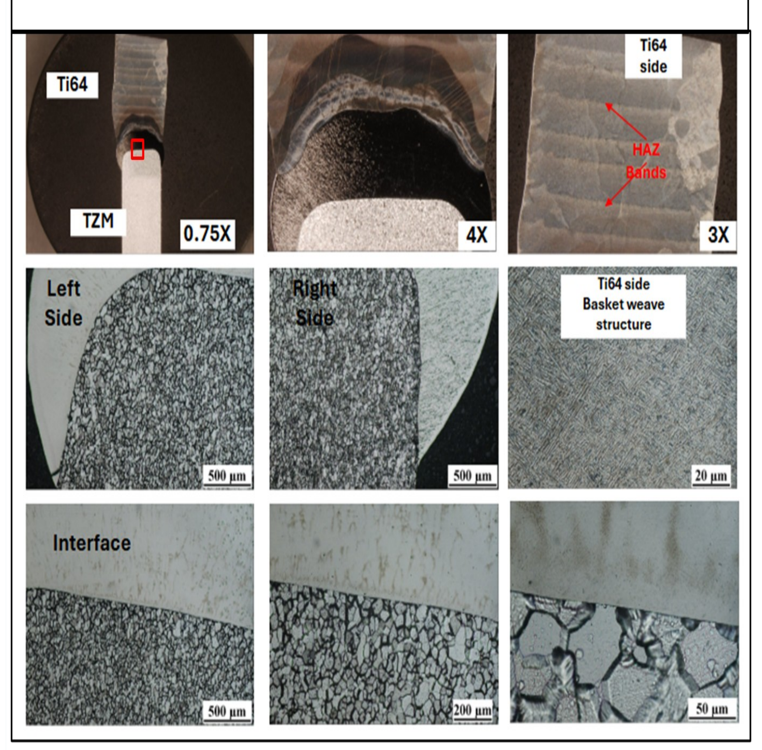
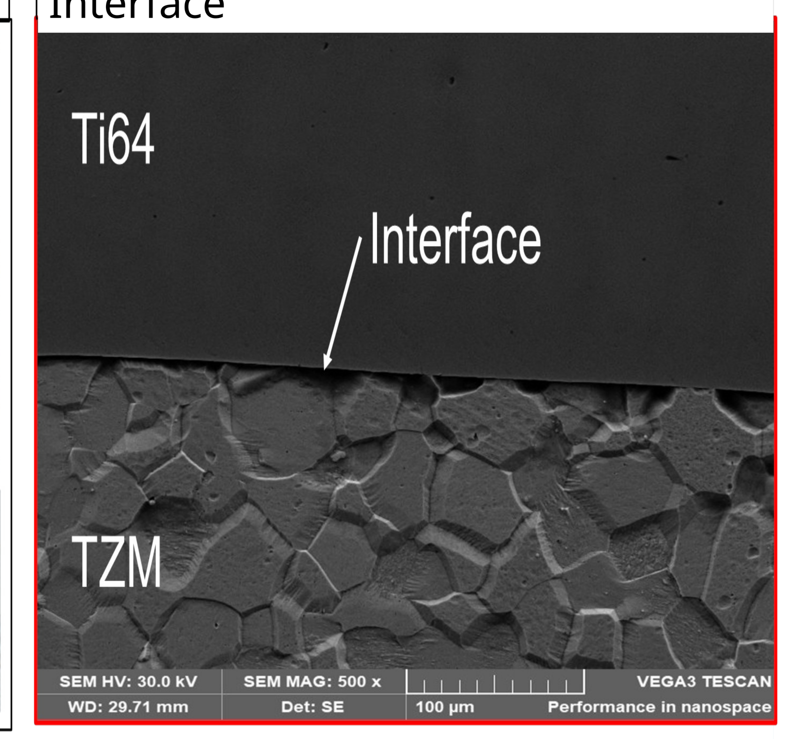


Figure 4. SEM Image of TZM – Ti64 Interface



Microstructural analysis shows a continuous and defect-free interface between the TZM substrate and the WAAM-deposited Ti-6Al-4V. Optical imaging reveals a well-bonded transition with no evidence of porosity, cracking, or delamination across the fusion boundary. The Ti-6Al-4V region exhibits fine basket-weave α/α′ features and HAZ banding, while the TZM side retains coarse equiaxed grains, yet the interface remains smooth and uninterrupted. SEM observation further confirms a clean metallurgical interface, showing a uniform diffusion layer above the TZM grains without voids or intermetallic-related cracking shown in figure 4, which are typical microstructures of powder-metallurgy-based TZM components. Together, these results indicate strong bonding and stable microstructural integrity across the bimetallic interface.

RESULTS & DISCUSSION

Figure 5. Corrosion Test Results

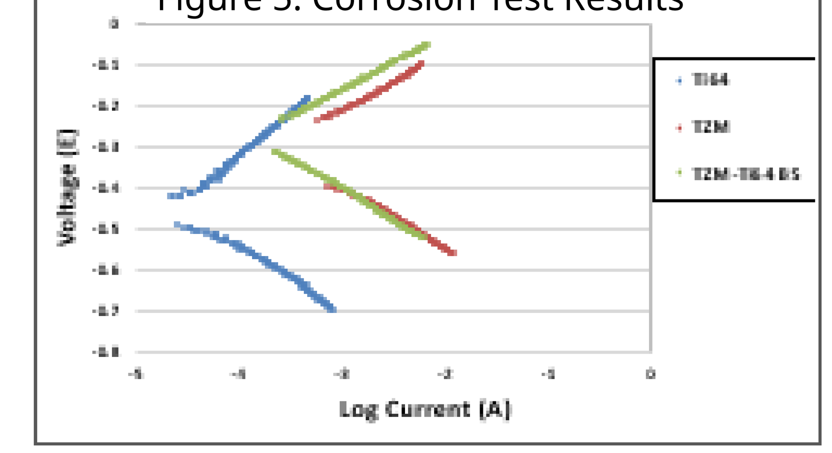


Figure 6. Corrosion Rate Comparison

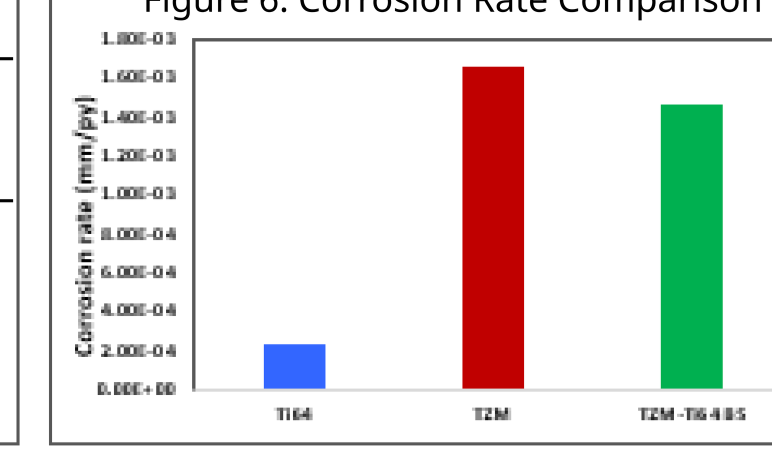


Figure 7. Tensile Stress-Strain Curve

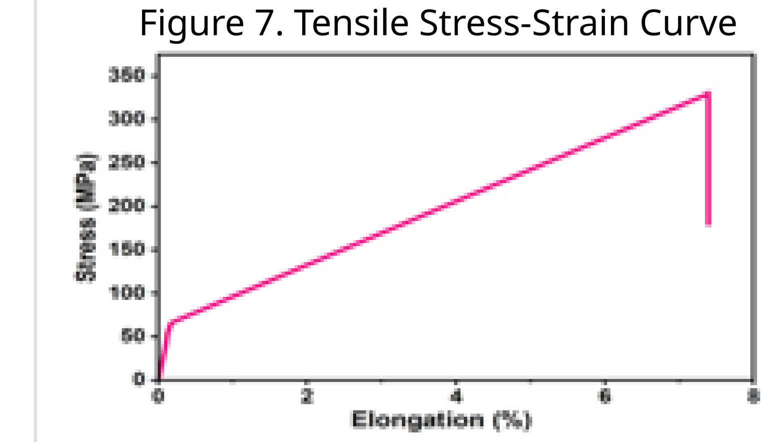
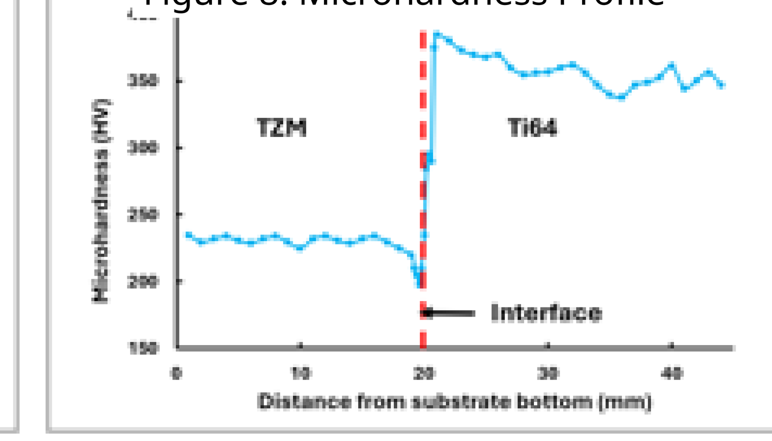


Figure 8. Microhardness Profile



Ti-6Al-4V showed the best corrosion resistance with a rate of 2.3×10^{-4} mm/yr, while TZM exhibited the highest rate at 1.66×10^{-3} mm/yr, and the TZM–Ti64 BS fell between them at 1.46×10^{-3} mm/yr (figure 6). The corrosion polarization behavior is presented in figure 5. The hardness profile demonstrated a steady 225–235 HV in the TZM region, a softened HAZ dropping to 198 HV, a sharp interface rise to 235 HV, and a rapid increase into the Ti64 region reaching 385 HV before stabilizing around 340–360 HV (figure 8). Tensile testing showed a peak strength of approximately 331 MPa with fracture occurring near 7.5% elongation, as shown in figure 7, confirming a ductile overall response. Tensile strength of TZM-Ti64 BS is in between the tensile strengths of TZM and Ti64.

CONCLUSIONS

WAAM successfully fabricated continuous, defect-free TZM–Ti64 thin-wall structures with strong metallurgical bonding across the interface. The corrosion, hardness, and tensile evaluations all showed clear transitions consistent with the distinct alloy regions and the thermal gradients of the WAAM process. Together, these results demonstrate that dissimilar-metal deposition of TZM and Ti64 is feasible and can achieve stable mechanical and electrochemical performance suitable for multi-material component applications. These findings are supported by corrosion results (**Figures 5–6**), mechanical data (**Figures 7–8**), and interfacial characterization (**Figures 3–4**).

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