

Understanding the Unique Corrosion Phenomenon of Sanxingdui Embrittled Gold Masks Using Scanning Electrochemical Cell Microscopy (SECCM): Intergranular Corrosion of Au-Ag-Pb Ternary Alloy

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Abstract This research was prompted by the discovery of unusual corrosion in a series of archaeological gold masks crafted from 50 – 100 μm thick gold foil and unearthed from the Sanxingdui archaeological site in Sichuan, China. Despite the prevailing assumption that gold artifacts are corrosion-resistant and malleable, some of the gold masks unearthed in 2023 exhibited brittle and fragile characteristics. Morphological studies employing metallographic microscopy and scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS) revealed the presence of intergranular cracks and attributed the embrittlement to preferential corrosion of intergranular Pb-containing phases. Simulated samples of the Au-Ag-Pb alloy with compositions and microstructures similar to those of the ancient artifacts were created, exhibiting three main microscopic constituents: The Au-Ag continuous phase, the Au₂Pb phase, and the AuPb₂ phase intermingled with reticular Pb oxides.

Scanning electrochemical cell microscopy (SECCM) technology was employed to conduct a quantitative analysis of simulated Au-Ag-Pb alloy samples to compare the electrochemical properties of the different phases at the microscopic level. Tafel analyses were performed for each testing spots. The results revealed an electrochemical activity order of AuPb₂+Pb_xO_y >> Au₂Pb > Au-Ag, which elucidated the varying levels of retention observed for different components in gold masks. The AuPb₂+Pb_xO_y phase was the phase with the highest corrosion priority. Despite the relatively low electrochemical activity observed in the Au₂Pb phase, it demonstrated a notable advantage in activity compared to the Au-Ag phase. This finding aligns with the long-term corrosion observations observed in the gold mask samples.

The study provides a reference for subsequent protection strategies and shows the importance of corrosion inhibition in Pb-containing phases. It also demonstrates the potential of SECCM in analyzing and conserving metal artifacts.

Keywords Gold-Silver-Lead Alloy (Archaeological Metallic Artifacts); Scanning Electrochemical Cell Microscopy (SECCM); Intergranular Corrosion; Microzone Corrosion Behavior