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SEM/EDX Analysis of Bronze Disease

Brian Pauley*, Nicole Bishop

Introduction
Bronze disease is a type of self-progressing corrosion of bronze. This degradation is thought to be caused by humidity but proliferated through the formation of chlorine containing compounds that further react with the air. The origination of the bronze disease in this artifact is thought to have arisen from the tanning process used in the surrounding leather. It is highly probable that potassium chloride was used in the tanning process, providing the initial chlorides that cause bronze disease. The damage that this corrosion can cause can destroy priceless artifacts. An understanding of the bronze disease structure and chemical composition is crucial for the development of potential cures for bronze disease.

\[ Cu \rightarrow Cu^+ + e^- \]
\[ Cu^+ + Cl^- \rightarrow CuCl \]
\[ 4CuCl + 4H_2O + O_2 \rightarrow CuCl_3(OH)_3 + 2HCl \]
\[ Cu^+ + HCl \rightarrow CuCl + H^+ \]

The current proposed mechanism for the reactions that cause bronze disease corrosion.[1]

Methodology

- The electron beam is focused through the lenses and strikes the sample.
- The electrons are scattered in several ways.
- Elastic scattering is detected by the back scatter electron detector.
- Inelastic scattering causes inner shell electrons to be ejected and X-rays emitted by outer shell electrons dropping to fill vacancies.
- X-rays are detected by the X-ray detector.

Bronze Diseased SEM/EDX

Sources of the Elemental Constituents
- Copper (Cu) – Part of the Bronze Alloy
- Aluminum (Al), Silicon (Si), and Zinc (Zn) – Part of the Bronze Alloy
- Potassium – Possibly From of the Salts used in the tanning of the leather. Carbon may also show up in the same keV region. (KCl)
- Chlorine – Makes up the bulk of the diseased portions Cl\(^-\) possibly originated from the use of salts in the tanning process (KCl)
- Sulfur – Could also be a remnant from the leather tanning process

Conclusions
- Chlorine is observed in areas of the artifact with high corrosion. This matches the currently proposed mechanisms for bronze disease.
- Chloride deposition is found in higher concentrations in the same places copper is in higher concentration.
- The SEM/EDX provides a good topography and elemental map of the corrosion. This data can be used for developing a more effective cure for bronze disease.

Acknowledgements
- The University of Northern Iowa Museum and Nathan Arndt for providing the artifacts.
- The University of Northern Iowa Department of Chemistry & Biochemistry and Dr. Joshua Sebree for material, instrumentation, and guidance throughout the project.

References

World War I Artifact

- The artifact is a American uniform belt worn in Europe during combat in World War I. The belt is part of the University of Northern Iowa Museum's collection.
- The heaviest bronze disease corrosion is found where the brass is in direct contact with the leather.
- The sample piece was taken from the corroded rivet stud circled in red.

- Samples were collected from the belt’s riveting.
- A small 3mm long sliver was cut from the diseased end of the brass stud. This sliver was clean on the cut side and heavily patinated on the opposite side.
- Further sampling was taken from the areas where the disease had dissolved through the rivet.
- The samples were mounted onto the SEM sample platform with double sided carbon tape.

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