EXAMINATION OF GILDED BRONZE USING NONDESTRUCTIVE EDDY CURRENT TECHNIQUES

Johanna R. Bernstein and Blythe McCarthy*

Department of Materials Science and Engineering, The Johns Hopkins University, Baltimore, MD 21218

***Department of Conservation and Scientific Research, Freer Gallery of Art, Smithsonian Institution, Washington, DC 20560**

Objective

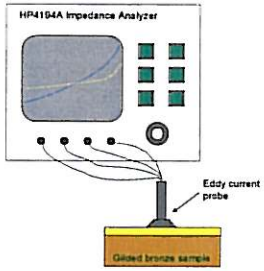
This research examines the use of nondestructive eddy current testing techniques to characterize gilding layers on bronze. The main goal is to distinguish the layers by composition and application method.

Introduction

An artist's choice of gilding technique results in a gold surface layer of specific chemical composition and thickness. The properties of the layer vary depending on the gilding method used. Previous technological studies of gilded objects have been undertaken to identify gilding methods and materials using chemical and microscopic techniques. However, these techniques may be inadequate or inappropriate. Often, only limited sampling of museum objects and archaeological artifacts is acceptable, if sampling is permitted at all. The use of nondestructive eddy current techniques can overcome these sampling limitations.

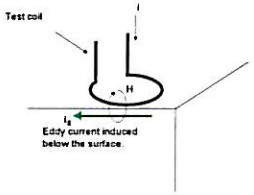
Gilded bronze statue of an ancient Buddhist deity[4].

EXPERIMENTAL PROCEDURES

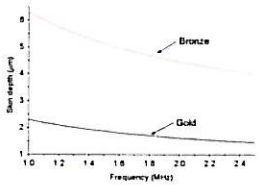


An impedance analyzer was used to measure the change in coil probe impedance from 5 kHz to 2.5 MHz. Samples consisting of gold layers on a bronze were tested. The samples varied by gold layer composition, thickness and application method. The experimental set-up is shown at left.

Eddy currents are produced in the samples by electromagnetic induction. The magnetic field accompanying the current in the wire produces a secondary, or eddy, current in an adjacent conductive material, as shown at right.



The eddy current skin depth, δ, can be calculated as a function of AC frequency, f, the permeability of the material, μ, and the conductivity of the material, σ:

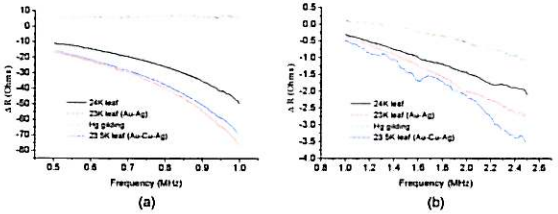


$$\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$$

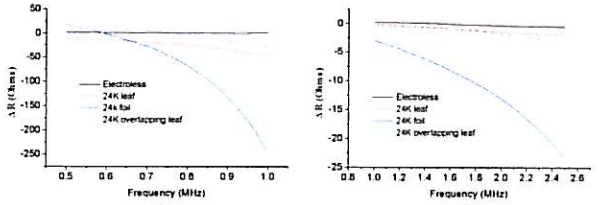
Gilding layer thickness:

Fire gilding	1 – ≥50 μm
Foil	1 – ≥50 μm
Leaf	0.1 – 1 μm
Depletion	0.2 – 2 μm

RESULTS



Measurements were made on gold layers of different composition using four different probes, each with a different frequency range. These results show the difference in real impedance for each layer for (a) 500 kHz – 1 MHz and (b) 1 – 2.5 MHz ranges. The differences are particularly clear at the upper end of each range.



Impedance measurements were also made with on bronze samples with gold layers of varying thicknesses. These results show the difference for (a) 500 kHz – 1 MHz and for (b) 1 – 2.5 MHz. The real impedance changes most dramatically as the thickness of the gold layer increases.

CONTINUING RESEARCH

- Measurements will be made on Chinese Buddhist bronzes dating from the 5th to 19th centuries in the Freer Gallery of Art collection. These results will be compared with previous metallographic analyses [3].

- Development of eddy current test probe appropriate for use on art objects for use with commercially available, relatively inexpensive impedance analyzers. For example, this may include the design of curved probe heads and flexible coils.

- Adaptation of software in commercially available instruments for art objects applications.

REFERENCES

[1] M. Bartolini, B. Colombo, M. Marabelli, A. Marano and C. Parisi, "Non-destructive Tests for the Control of Ancient Metallic Artifacts." *Metals 95*, 43 – 49 (1997).

[2] M. Mach, G. Pöhlmann and B. Stöckle, "Die Messung von Patinaschichtdicken auf Kupfer und Bronze mit Hilfe des Wirbelstromverfahrens." *Wiener Berichte uber Natruwissenschaft in der Kunst*, 6-8, 211 (1991).

[3] P. Jett and J.G. Douglas, *Mat. Res. Soc. Symp. Proc.*, 267, 205 (1997).

[4] P. Jett and W. T. Chase, "The Gilding of Metals in China", in *Gilded Metals*, Color Plate 34, (2000).

ACKNOWLEDGEMENTS

The authors would like to thank Professor Robert E. Green Jr. of the Center for Nondestructive Evaluation, The Johns Hopkins University, for the use of the impedance analyzer and laboratory space. Financial support was provided by the National Center for Preservation, Technology and Training, National Park Service.