SAND2014-15819D

Ceramic hardened Au, the new gold standard?

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Introduction: E-beam deposited Au-ZnO

E-beam deposition was used to deposit 2 µm thick Au-ZnO films, where the ceramic phase consisted of a well-dispersed, grain boundary (GB) nanometer domains that effectively limited GB mobility and inhibited grain growth under significant mechanical (strain) and thermal loads.

These materials are NOT nanocomposites but rather oxide-dispersion (Hall-Petch) strengthened metals, retaining the bulk transport properties of the matrix material: gold (Fig.1). These materials display excellent tribological-electrical properties, with diminishing optimal performance for ZnO concentrations below about 5 vol. % (1.5 wt. %).

Grain size and resistivity correlation

Electron microscopy and x-ray techniques (Fig.2) were used to determine grain size to composition correlation. A fast, inexpensive and non-destructive method of resistivity measurement that can be ...

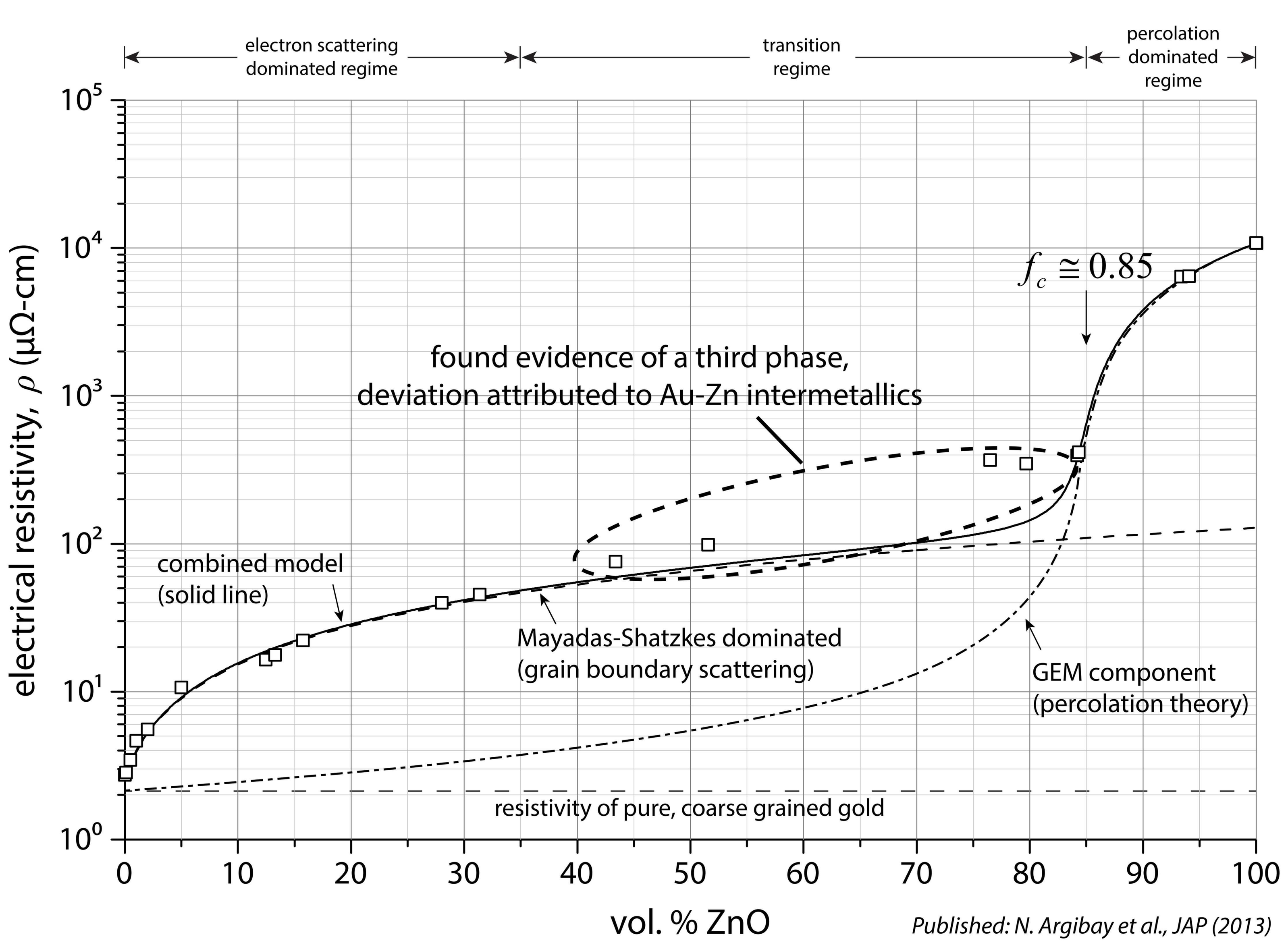

Figure 1. Below 30 vol. % ZnO concentration, Au-ZnO behaves not as a composite, but as a ceramic hardened metal with respect to electrical transport properties.

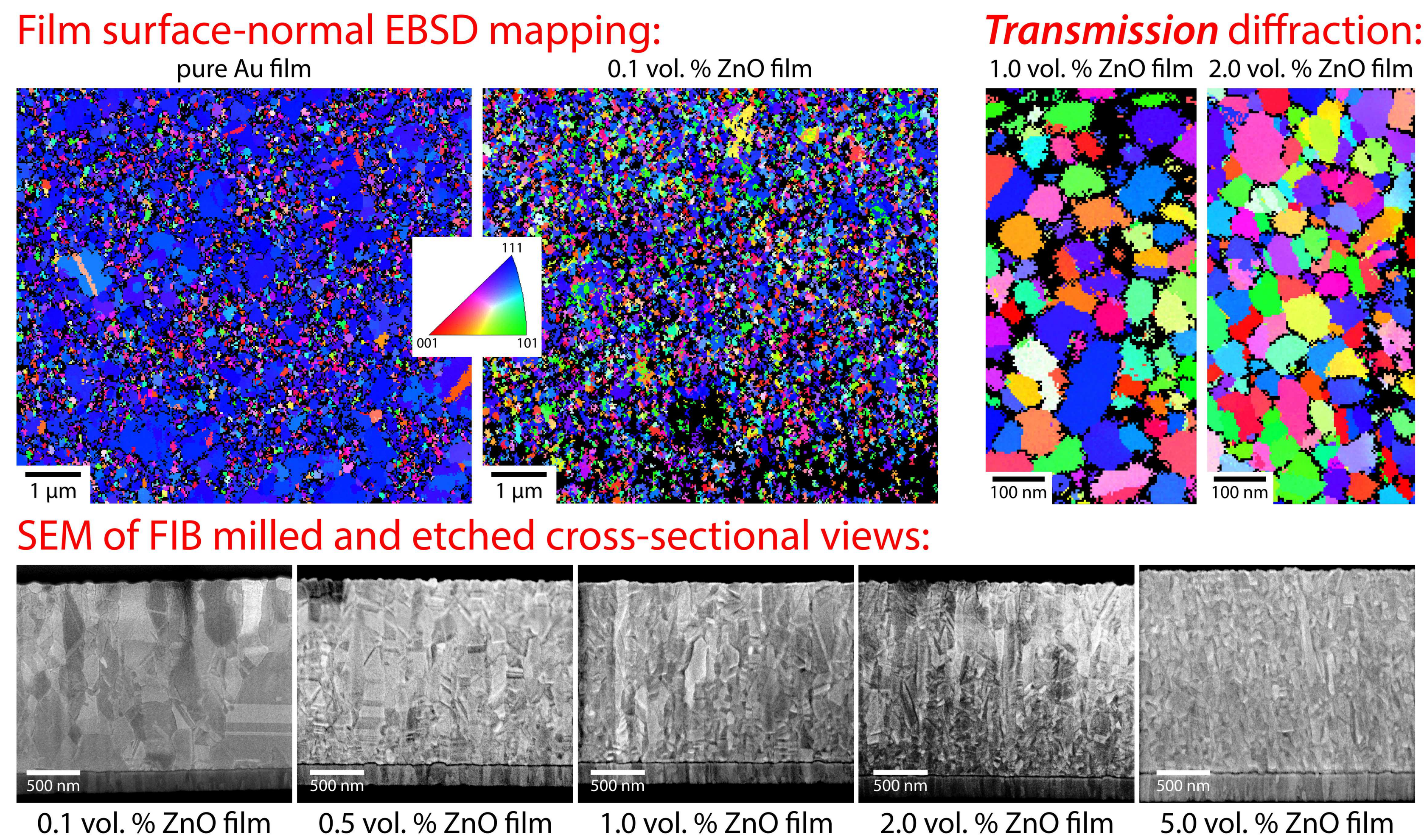

Figure 2. "Kitchen-sink" microscopy (XRD was inconclusive...) utilized to determine grain size vs. composition.

... used to determine deposition quality, hardness and wear resistance was developed. The method is insensitive to twins and to bimodal grain size distributiona. In situ resistivity annealing and ex situ microscopy have recently been used to demonstrate thermal stability up to 250°C for days.

More stable refractory metal oxides, carbides and nitrides are being explored as superior GB mobility stabilizers, as well as deposition via additive manufacturing routes.

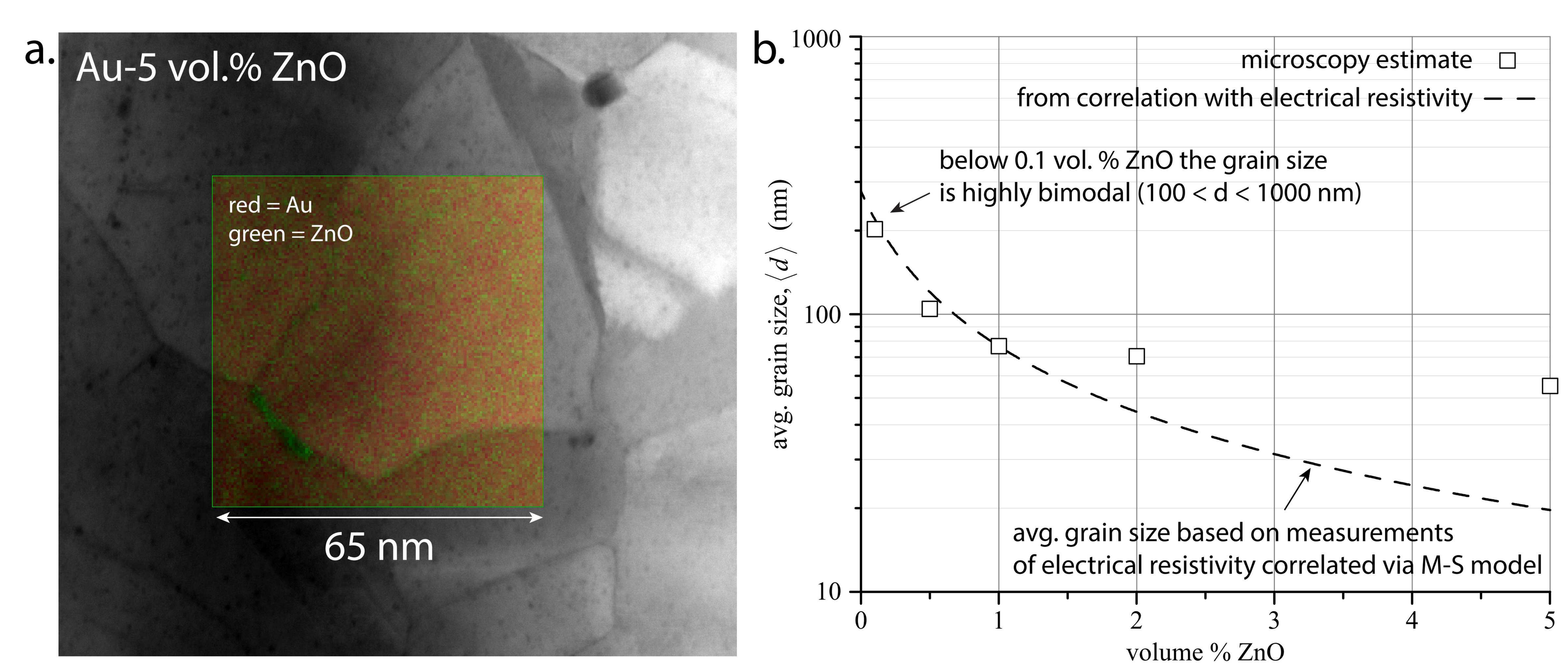

Figure 3. (a) HAADF TEM reveals GB segregated ZnO; (b) grain size as a function of ZnO concentration and empirical model fit.

Mayadas-Shatzkes model (electron scattering at GBs):

$$\frac{\rho}{\rho_o} = \left[1 - \frac{3}{2}\alpha + 3\alpha^2 - 3\alpha^3 \ln\left(1 + \frac{1}{\alpha}\right)\right]^{-1}$$

Scattering parameter:

$$\alpha = \frac{\lambda}{d}\frac{R}{1-R}$$

Empirical relationship between scattering parameter and composition is linear:

$$\alpha = 43.19 f + 0.165$$

Between 0 and 30 vol. % ZnO, M-S seems to fit well, corresponding to a range:

$$0.1 < \alpha < 10$$

An inverse empirical correlation between ceramic phase concentration and grain size appears to exist for e-beam codeposited Au-ZnO. This correlation may extend to a broader number of material systems, especially in the composition regime of interest for electrical contact applications (approx. < 1.5 wt. %)

Summary

E-beam deposited dispersion strengthened gold is an environmentally friendly alternative to traditional electrodeposition, with tribological characteristics exceeding ASTM/Mil-Spec "hard gold".

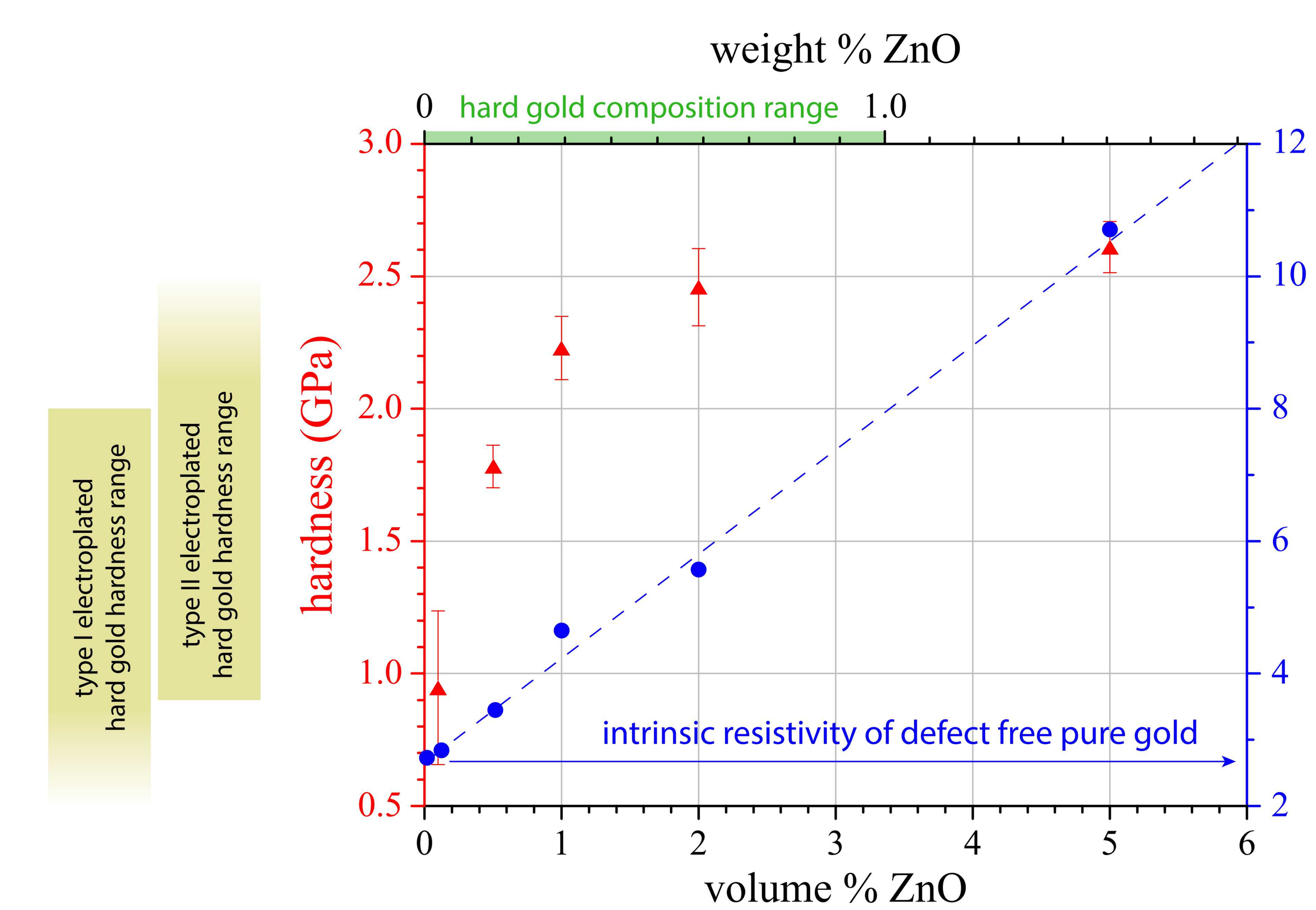

Figure 4. The increase in hardness and electrical resistivity of Au-ZnO are both primarily due to Hall-Petch strengthening; Au-ZnO is a suitable alternative to electrodeposited "hard gold" (ASTM B488).

Acknowledgments

From SNL: Paul Kotula (TEM), Bonnie McKenzie (SEM), Michael Rye (FIB-TKD)

National Nuclear Security Administration
U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. DOE's NNSA under contract DE-AC04-94AL85000

UUR - SAND No. 132746