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Characterization of the Surface Layer of Ag/W Electrical Contacts

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Materials for electrical contacts in circuit breakers must meet a stringent set of property requirements including excellent thermal conductivity, electrical conductivity, corrosion resistance and arc erosion resistance [1]. In most cases, no simple metallic alloy can meet these requirements, and metal-matrix composites must be used instead. The metallic matrix phase in such composites is usually silver, due to its excellent electrical properties, and the most common reinforcements used are Mo, W and WC [2]. The properties of the composite depend critically on microstructural parameters such as phase volume fractions, morphologies and distributions. Here we present data from our studies on Ag/W composite contacts and some of the potential complications in the characterization of such materials are discussed.

A series of commercial powder-processed Ag/W contacts was evaluated using electron microscopy techniques. Particular attention was paid to the character of the contact surface since this dictates the arc erosion behavior during switching [3]. The contact surfaces were examined using backscattered electron (BSE) imaging in a JEOL 6335F field-emission SEM to reveal the distribution of the Ag and W phases. The results were found to be remarkably sensitive to the accelerating voltage used as shown in Figure 1. This figure is a selection of four BSE images obtained from the same region of a contact surface at different accelerating voltages. The bright regions are the W, the darker regions are the Ag, and the black features are residual surface porosity from the powder processing. The surface porosity is revealed most clearly at the lowest accelerating voltage (5kV, Fig 1a) as expected due to differences in the excitation volume. Surprisingly, there are also dramatic differences in the apparent volume fraction of the W phase. There appears to be far more W at 20kV (Fig 1d) than at 5kV (Fig 1a), although in all cases this is significantly less than the nominal volume fraction of 50% for this contact material.

The origins of this effect are revealed clearly in cross-sectional SEM and TEM images (e.g. Figs 2 & 3, respectively). The BSE SEM images obtained from metallographic cross-sections through these contacts reveal the presence of an Ag layer up to 5 µn in thickness covering most of the contact surface. Thin sections were cut from the surface using FEI Strata 400S DualBeam FIB and imaged in a JEOL JEM-2010 FasTEM at an accelerating voltage of 200 kV. The TEM images show that the Ag surface layer has a much finer grain structure than the Ag regions within the composite and that even the "exposed" W is covered by a nanocrystalline Ag layer of up to 50nm in thickness. Thus the apparent variation in surface W content also arises due to differences in excitation volume with accelerating voltage (e.g. [4]). [5]

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[5] This work was supported by a grant from GE Energy Management.

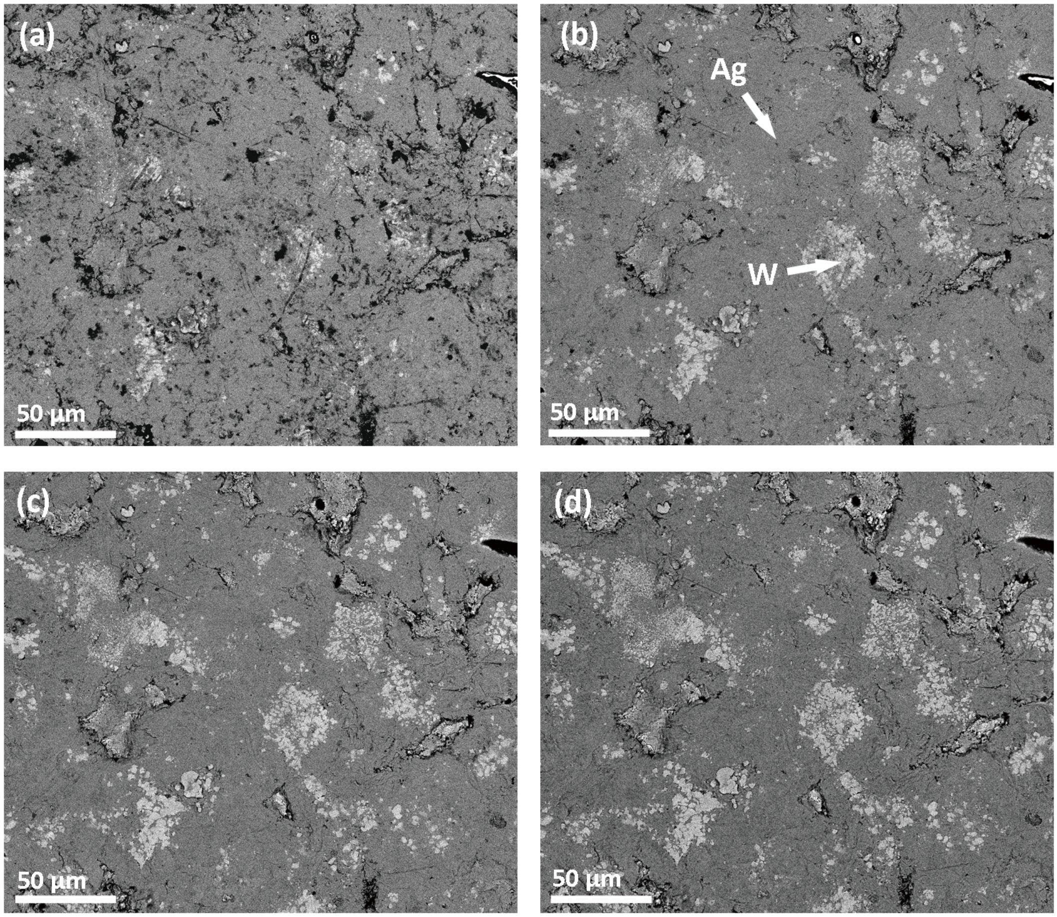

Figure 1. BSE SEM images of the surface of an Ag/W electrical contact obtained at accelerating voltages of: (a) 5 kV, (b) 10 kV, (c) 15 kV and (d) 20 kV.

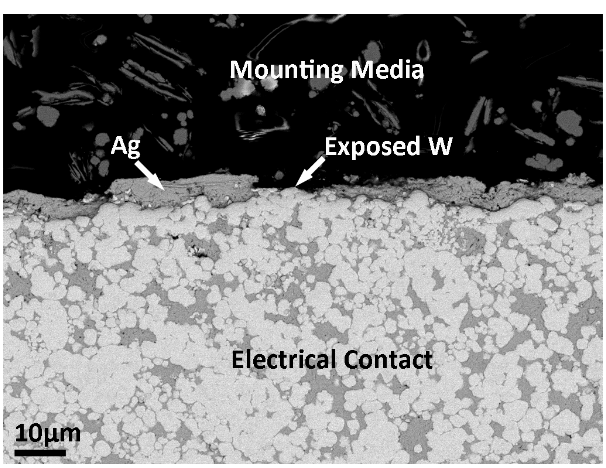

Figure 2. BSE SEM image of a cross-section from the surface of an Ag/W electrical contact.

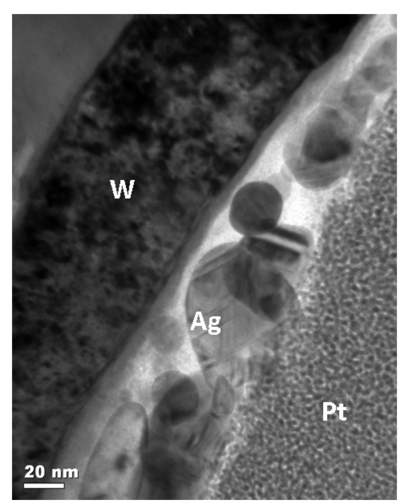

Figure 3. Bright field TEM image of a FIB-cut cross-section.

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