Abs. 2291, 206th Meeting, © 2004 The Electrochemical Society, Inc.

Magnetic field effects during electrochemical processes at micro structures

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It is well known that a magnetic field which is applied perpendicular to the current lines can enhance the mass transport towards an electrode. The main origin of this enhancement are Lorentz forces that induce a forced convection (magnetohydrodynamic or MHD effect). Besides the Lorentz forces effects from concentration gradients of paramagnetic ions are discussed in the literature. It seems promising to use magneto-hydrodynamic effects to enhance the mass transport in electrochemical reactions at microstructures. This paper will discuss some recent results from the authors' lab dealing with magnetic field effects at microelectrodes and microstructures.

The question if a magnetic field influences the kinetics of the electron transfer reaction is discussed controversially in literature. To address this issue the effect of an external magnetic field (up to 1 T) on the electron transfer kinetics was studied at disk microelectrodes (diameter ca. 50 μm). For an outer sphere system (Ir(IV)/Ir(III)) the effects on the exchange current density and the transfer coefficient were found to be small.

Furthermore, the influence of a magnetic field on dissolution and deposition of copper microstructures (Fig. 1) was investigated. Dissolution experiments with different orientations of the magnetic field relative to the working electrode were performed (Fig. 2). One important result was that the magnitude of the magnetic field effect strongly depended on the orientation. By rotating the magnetic field in steps of 90 degrees increases as well as decreases of the current density could be achieved. It will be shown that magnetic field effects in electrochemical reactions are a complex interplay of Lorentz forces, paramagnetic gradient forces and natural convection.

Finally, the effect of a magnetic field to enhance the mass transport during electrodeposition in confined geometries (aspect ratios up to 2) will be addressed.

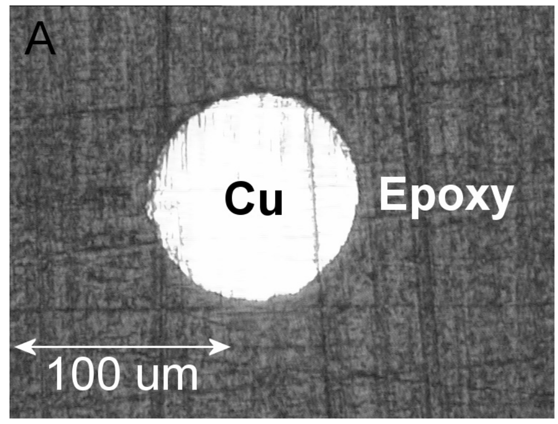

Fig. 1: Microscopic image of the lab made micro electrodes. Cu wires (diameter 100 μm) were embedded in epoxy resin, cut and polished.

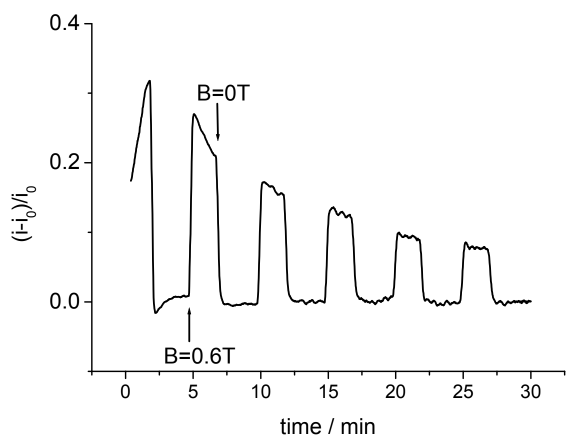

Fig. 2: Relative increase of the current density for the electrochemical dissolution of Cu micro-structures (Fig. 1) in the presence of a magnetic field. The field was periodically switched on and off. The effect decreases because the aspect ratio (depth/width) of the structure increases.