DETERMINATION OF SHAPE FORMATION OF ELECTROCHEMICALLY DEPOSITED COPPER MICROSTRUCTURES BY PROGRESSIVE BOUNDARY UPDATE METHOD

R.A. Said
United Arab Emirates University
Electrical Engineering Department, P.O. Box: 17555,
Al-Ain, United Arab Emirates

A model of deposition profile, based on progressive mass transport calculation due to localized electric field, is presented to describe the formation behavior of copper microstructures.

EXPERIMENTAL TECHNIQUE & RESULTS

Copper microstructures are deposited using a localized electrochemical deposition technique (1) described in Fig. 1. A microelectrode is placed near a conducting substrate and an electric potential is applied between them through a plating solution of $CuSO_4$. The highly confined electric field in the region between the microelectrode and the substrate localizes the deposit. Moving the microelectrode appropriately produces copper microstructures with cross sectional area equivalent to that of the microelectrode. The deposit at the start location, however, has larger dimensions, as observed in the deposit formation shown in Fig. 2. This could highly affect the performance of deposited devices. Thus, modeling the deposit profile is required to understand and control the formation of deposited structures.

MODELING AND SIMULATION

The main factors affecting the deposition rate and in turn the deposit profile are electron transfer rate and mass transport (2). At potentials used in localized deposition, 4 - 5 V, mass transport is the process-determining factor (1). Due to the highly localized field beneath the microelectrode, migration is the dominant mechanism of mass transport in localized deposition processes that can be described as

$$J_a \propto -\nabla\varphi = E\,, \qquad [1]$$

where J_a is the flux of species a, φ is the electric potential, and E is the electric field. Thus, a prediction of the deposit profile can be obtained from the electric field calculation. This was conducted using a boundary element approach (3), applied on the electrode-substrate geometry shown in Fig. 3. A progressive boundary updating method, illustrated in Fig. 3, was also implemented to take into account the interaction of electrode with new deposited material. The details in Fig. 3 demonstrate a coarse spacing, *h*, between the electrode and the substrate, where the calculation of several incremental deposition steps are allowed during one cycle of electrode positioning. Figure 4 shows deposition profiles evaluated using the above procedures, where h=5µm and an incremental deposit calculated every 1µm.

ACKNOWLEDGMENT

This research was financially supported by the Scientific Research Council at the United Arab Emirates University.

REFERENCES

1. J.D. Madden and I.W. Hunter, J. Microelectromechanical Systems, **5**, 24(1996).
2. A.J. Bard and R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley, New York (1980).
3. C. A. Brebbia, The Boundary Element Method for Engineers, Pentech Press, England 1984.

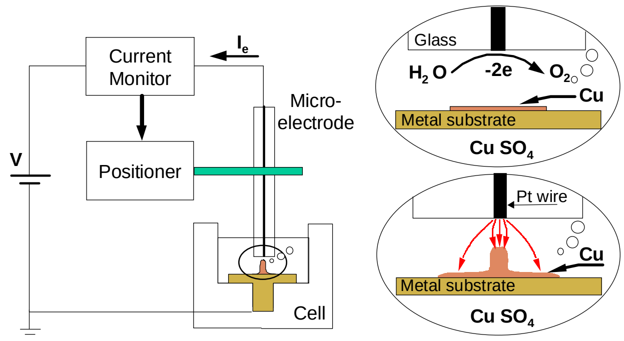

Fig. 1: Schematic diagram illustrating the setup used in electrochemical deposition of copper columns microstructures.

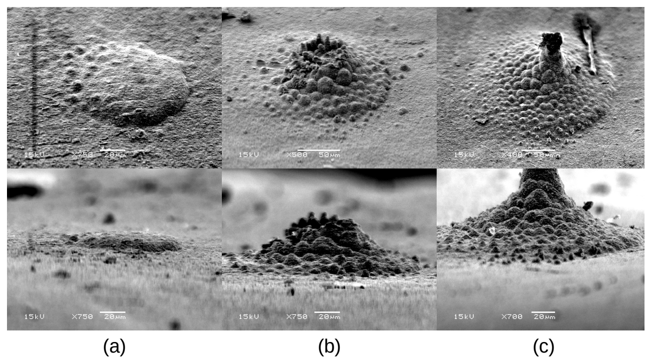

Fig. 2: SEM images showing the top and side views of the evolution of a copper column formation at the different stages (a), (b), and (c).

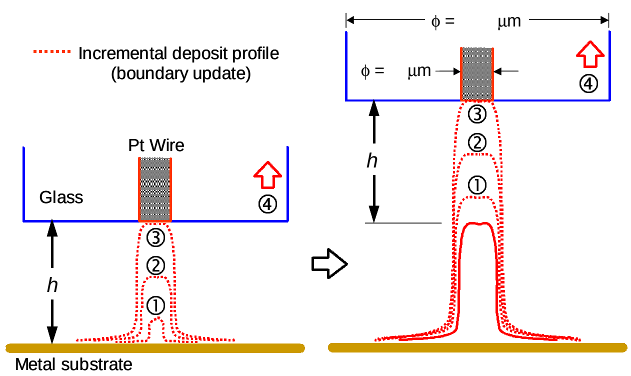

Fig. 3: A drawing illustrating the progressive boundary updating method used in the electric field and deposit profile calculation.

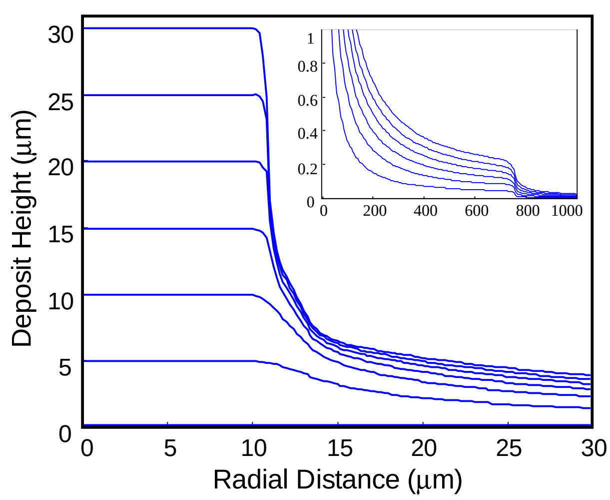

Fig. 4: Evaluated deposition profile using progressive boundary updating of the electric field calculation of the geometry in Fig. 3.