ROUGHNESS SCALING OF CYCLICAL ELECTRODEPOSITION/DISSOLUTION OF COPPER

Afua Osafo-Acquaah, Jacob Jorne and Yonathan Shapir*
Department of Chemical Engineering,
*Department of Physics & Astronomy,
University of Rochester, Rochester, New York 14627,
USA

The understanding of the individual deposition/dissolution processes and their combined effects during multiple cycling is fundamentally important for both technological applications and natural phenomena. Previous studies of surface roughness dealt with a single process of growth and recession, however in many natural phenomena and technological applications, both processes of deposition and dissolution alternate to generate a rough surface. The scope of this work include extending the study of kinetic surface roughness in two interesting directions, namely the effect of the number of cycles on surface roughness and the effect of the relative duration on the individual processes within each cycle.

The kinetic roughening of copper during cyclical electrodeposition/dissolution in $CuSO_4$ solution is experimentally studied. The scaling exponents α and β of the primary processes are determined (Fig.1) and compared to those obtained from cycling (Fig.2). The cycling mode is characterized by deposition and dissolution time. In the early time regime, the roughness is predicted to grow as n^{β}, where n is the number of cycles [1,2]. The roughness saturates to a value that scales with, L the system size as L^{α}. α and β are the roughness and growth exponent, respectively. The roughness is found to increase as a power law of n, consistent with the scaling behavior anticipated theoretically [1,2]. The scaling exponents of the cyclical process are theoretically expected to be determined by those of the primary process with the smaller dynamic exponent $z = \alpha/\beta$. Experimentally, the scaling exponents are found to be affected by both primary processes.

At long deposition and cycle times, the morphology changes from self-affine (Fig.3) to mounded (Fig.4). The transition in growth exponent β is observed in (Fig.1) and (Fig.2), as the surface roughness reaches a critical value, beyond which lateral and vertical growth occurs simultaneously.

Acknowledgement: This work was supported by the Office of Naval Research, Grant No: N00014-00-1-0059

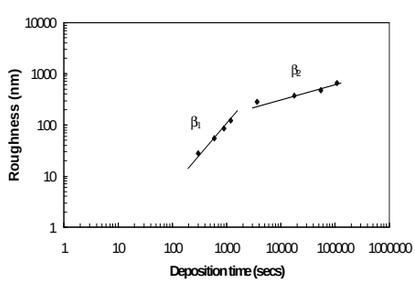

Figure 1. Crossover of growth exponent β from self-affine (β_1) to mounded (β_2) morphology after long times of copper deposition.

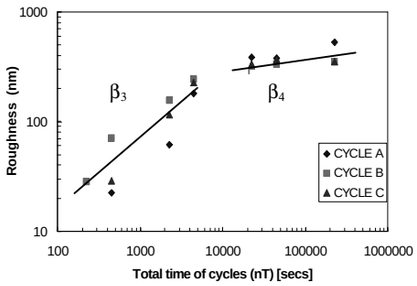

Figure 2. Crossover of growth exponent β from self-affine (β_3) to mounded (β_4) morphology observed after long cycling time in all 3 cycling modes. Cycle A: (300s/150s), Cycle B: (30s/15s) and Cycle C: (6s/3s)

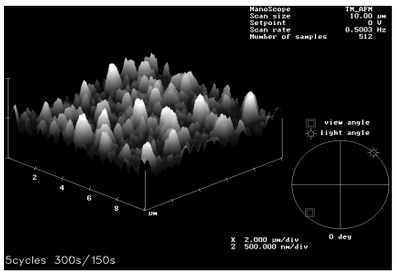

Figure 3. AFM image of copper surface after 5 cycles of (300seconds deposition/150seconds dissolution) in acidic copper sulfate solution. The current density is 0.8mA/cm^2. The area size is 15x 15μm^2 with a vertical scale of 0.5μm.

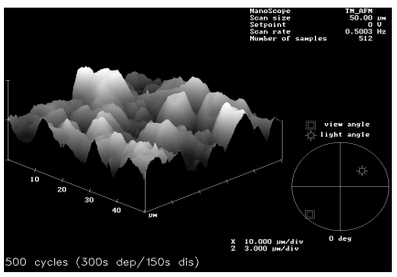

Figure 4. AFM image of copper surface after 500 cycles of (300seconds deposition/150seconds dissolution) in acidic copper sulfate solution. The current density is 0.8mA/cm^2. The area size is 100x 100μm^2 with a vertical scale of 3μm.

References:
1. S. Raychaudhuri, Y. Shapir, D. G. Foster, and J. Jorne Phys. Rev. E. **64**, 256 (2001)
2. S. Raychaudhuri, Y. Shapir, D. G. Foster, and J. Jorne Phys. Rev. Lett. **84**, 14 (2000)