Micro-interconnections Using Single Crystals

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Electrodeposition has been widely used in the electronics manufacturing industry for producing micro- or nano-components of electronic devices. Deposits of a wide variety of microstructures ranging from single crystal to nano-crystal can be obtained using different deposition parameters and/or with various assisting techniques. Microstructure has a significant effect on the electrical and mechanical performance of a plated deposit. In this project, we have explored the growth history of electrodeposited copper columns by kinetic Monte Carlo (KMC) simulations and characterization of electroplated copper columns - in terms of microstructure, crystal structure, surface morphology and interfaces, by a range of techniques in order to tailor the microstructure for specific applications.

A two-dimensional cross-sectional KMC (2DCS-KMC) model has been developed to simulate the electrocrystallization of single crystal copper. The entire growth history from the deposition of the first atom until 100 equivalent mono-layer atoms can be reconstructed and visualized by simulation, as shown in Figure 1. The model has proved capable of capturing the effects of deposition parameters, including applied electrode potential, concentration of the electrolyte and temperature [1]. Further to this single-lattice model for treating single-crystal growth, we have developed an advanced 2DCS poly-lattice KMC model to simulate the electrodeposition of polycrystalline copper. To our knowledge, this is the first such poly-lattice KMC model for electrodeposition of polycrystalline materials. The evolution of the microstructure, texture development, grain growth statistics and grain boundary misorientation have been explored by simulations using this model. Figure 2 shows the simulated microstructure of copper deposit on Cu and Au substrate respectively. The simulation results agree qualitatively with our experimental observation.

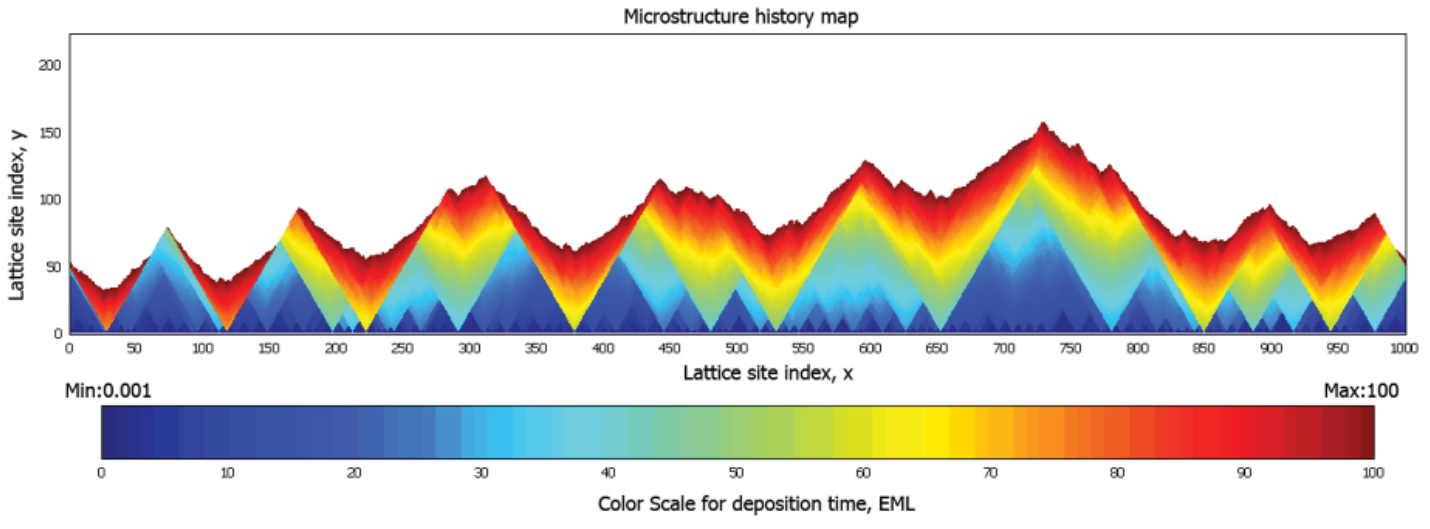

Figure 1: The microstructure history map showing the entire growth history of electrodeposition of single crystal copper

Copper columns plated for different times, representing the different times over the deposition of one column, have been characterized to explore the growth history experimentally. It was found that the electroplated copper columns show a microstructure with bi-modal or tri-modal grain size distribution, i.e. large grains on the top and preferably the edge (Mode I), ultrafine grains near the deposit/seed layer interface (Mode III) and a mixture of columnar grains and twins, having undergone growth, simultaneous recrystallization and spontaneous self-annealing after plating.

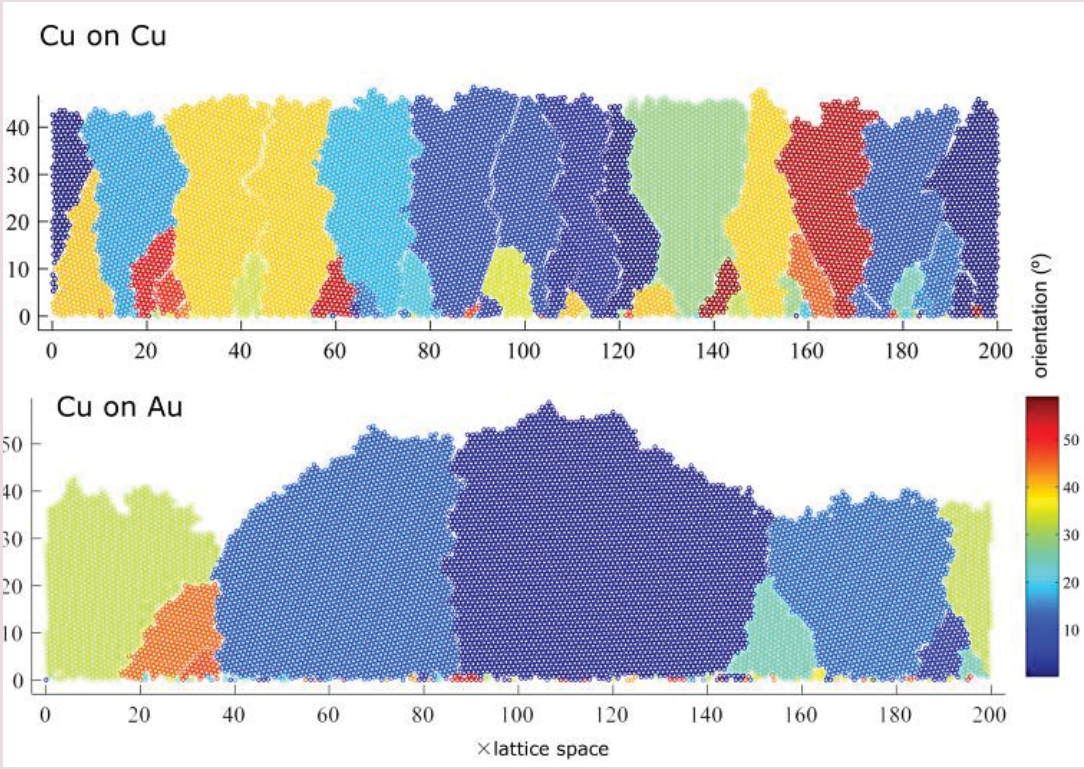

Figure 2: Snapshots of the microstructure of electrodeposited Cu on Cu and Au substrate on deposition of 50 equivalent monolayer atoms