

Preface

Copper has lower resistivity than aluminum and can be electrodeposited easily. Hence, copper can be used for chip wiring. In 1998, the copper damascene on-chip interconnect process was introduced commercially and became the first industrial nanofabrication process. This nanofabrication technology relies on electrodeposition of copper to fill cavities or vias of diameters less than 0.1 μm . This process has now been adopted worldwide for advanced semiconductor manufacturing and has branched into several industrial applications: Damascene metallization, through-silicon via metallization, interstitial via hole build-up in printed wiring boards, and both sides smooth Cu foils for collectors in Li-ion batteries.

However, no comprehensive books have been published on Copper Electrodeposition for Nanofabrication. The Part I of present book introduces the reader to fundamental aspects of copper electrodeposition. This is followed by details of additive chemistry, suppression effects (due to PEG additive), and acceleration effects (due to SPS additive), leading to filling mechanisms. Mathematical models for superfilling, continuum models for nucleation and growth, Kinetic Monte Carlo simulations, and shape evolution are then reviewed.

The Part II of the book covers two specific challenges facing nano-interconnect fabrication in the coming decade, i.e., direct electrodeposition on noble metal barriers and liners and microstructure evolution in electrodeposited Cu nanowires and its impact on Cu resistivity. The part starts with a critical overview of the specific scaling challenges foreseen in damascene interconnect fabrication. It also outlines the current challenges to the two technologies, such as direct plating, electroless deposition, and theory-guided molecular design of additives in electrochemical systems. This introductory chapter is followed by a comprehensive study that discusses the evolution of microstructure in electrodeposited Cu nano-interconnects. A hallmark of this study is the development of metrology techniques (SIMS) to probe patterned metal lines. Finally, the part ends with a contribution documenting mechanisms involved in direct plating of Cu on noble metals such as ruthenium (Ru).

In Part III of this book, emerging applications of electrodeposition are outlined: through-silicon vias (TSVs), printed wiring boards, copper foils for Li-ion battery current collectors, and through-hole filling. TSVs are used for fast conduction of digital signals from one chip to another chip in advanced packaging solutions in smart phones, high speed image processing, and capsule endoscopes. In interstitial

via hole build-up printed wiring boards, the interstitial via holes are filled by copper electrodeposition. Then, the individual board layers are piled up so that the via holes interstitially connect the wiring in the vertical direction. The primary application of this technology recently has been in smart phones. Smooth copper foils serve as electric collectors for the anode of Li-ion batteries. In order to coat the carbon on both sides of the copper foil, the foil must be smooth and thus coated with electrodeposited copper. Through-hole plating is an emerging technology in printed wiring board manufacturing.

Kazuo Kondo was very much astonished when he visited the IBM Watson Research Center in 1999 and Drs. M. Datta and J. Dukovic kindly showed him their lab and red copper wafer electrodeposited by copper. Drs. Datta and Dukovic are team members for the development of the damascene on-chip semiconductor wiring process. This experience gave Kazuo Kondo the initial motivation to start research in copper electrodeposition.

We hope that this book benefits scientists, engineers, and academicians working in the field of copper electrodeposition. We are grateful to all the contributors for their time, commitment, patience, and feedback. Through our interactions with the contributors, we have learned a great deal. We sincerely hope the readers enjoy the chapters. Finally, we would like to acknowledge the opportunity given to us by K. Howell of Springer to edit this book.

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