The *Wander*ful Worlds of Materials Science: A Multidisciplinary Trail from Room-Temperature Cu Recrystallization to Thermoelectric Energy Conversion and Points In-Between

Dr. Mihal E. Gross
Office of Naval Research

The radical shift from Al to Cu interconnect metallization just about ten years ago and the impending applications of high performance thermoelectrics can be traced to fundamental studies in the design and control of micro/nanostructures and the role of minor variations in chemical composition on materials properties. The switch to Cu was driven by electromigration problems in Al related to grain structure and orientation at sub-micron line widths. The switch to Cu essentially inverted the entire interconnect fabrication process and resurrected the seemingly outdated wet process of electroplating in an updated guise. Not, though, before a three-way race was run with PVD and CVD (once known as vapor plating) processes. The key advantage of electroplated Cu has served interconnect reliability well, but now dimensions have shrunk enough that Cu is demonstrating some of the same issues as Al did not that many device generations back. That poses an interesting challenge that will undoubtedly call upon all the multidisciplinary resources available.

A different class of materials and devices, namely thermoelectrics and Peltier/Seebeck coolers/generators, offer interesting historical and state-of-the-art materials comparisons and challenges. Control of heteroepitaxial nanostructures and compositions rather than grain structure has heralded a new generation of higher performance semiconductor thermoelectrics. Phonon scattering at coherent nanostructure interfaces demonstrated both in MBE-grown pnictide films and furnace tube/elemental reaction-grown bulk ingots provide a means for starting to decouple phonon and electron transport. But reduction of thermal conductivity has a finite limit and new directions are approaches are beginning to emerge to increase power factors and take the next step up in performance.

Stepping beyond the fundamental materials performance, device integration of both Cu interconnect metallization and thermoelectric energy conversion devices require additional materials expertise for low parasitic, robust contacts that pose another set of interesting materials challenges. This multidisciplinary talk is intended to be highly interactive to address those aspects of greatest interest to the audience, with the Cu and thermoelectrics programs reflecting the different perspectives of a then-Bell Labs researcher to current ONR Program Officer.

“Brief” Bio

Dr. Mihal Gross joined the Office of Naval Research (ONR) in 2003 as a Program Officer in the Physical Sciences Division, now part of the Naval Materials Division, following a twenty year research career at Bell Laboratories. The scope of Dr. Gross programs encompasses basic and applied research in Functional Solid State and Nanoscale Materials Science for the Navy and Marine Corps, with a current focus on the design and synthesis/growth of semiconductor nanocomposites with decoupled control of electronic, phononic, and/or photonic transport properties to significantly advance thermoelectric and related performance.

Dr. Gross is the author of over 50 scientific publications and the inventor of 8 issued patents in semiconductor and microelectronics-related thin film materials research, including MOCVD precursor chemistry and mechanisms of film deposition, laser- and focused ion beam direct–write metallization, room-temperature recrystallization mechanisms of electroplated Cu interconnect technology, and MEMS optical router metallization.

Dr. Gross received her B.Sc. degree from the Massachusetts Institute of Technology and M.Sc. and Ph.D. degrees from Northwestern University. She has served on the Board of Directors of the Materials Research Society and the Executive Committee of the Advanced Metallization Conference and was responsible for initiating the “Chemical Perspectives of Microelectronic Materials” symposia at MRS, which spawned several more focused symposia that are still running. She has also chaired the Gordon Research Conference on the Chemistry of Electronic Materials.

Immediately prior to joining ONR, Dr. Gross was awarded the 2002-2003 AAAS/RAND Science and Technology Policy Fellowship, working with the White House Office of Science and Technology Policy.

Dr. Gross currently serves as the ONR representative to the interagency Nanoscale Science, Engineering, and Technology Subcommittee that is responsible for coordination of the National Nanotechnology Initiative and is the founder and chair of the Interagency Advanced Power Group-Direct Thermal-to-Electrical Energy Conversion Panel.