Fabrication of 10 nm Metal Lines with Low Resistivity by Helium Ion Beam Induced Deposition

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Abstract As the dimensions of integrated circuits, data storage and biological/medical devices continue to shrink, conventional technologies, such as gallium focused ion beam (Ga-FIB), photo-lithography and electron beam lithography, are approaching their limits. A helium focused ion beam, with a smaller probe size relative to that of the electron beam and Ga-FIB, has the capability of fabricating sub-10 nm patterns at high densities, providing a possible solution for future nanofabrication. Here, He ion beam induced metal line deposition is described. This not only enables the fabrication of 10 nm metal lines with good repeatability, but also with extremely high purity, no gallium and carbonaceous contaminations. The metal lines were deposited on Zeiss test structures for electrical measurements to calculate their resistivity and contact resistance. The resulting metal deposits were directly inspected for their geometry and size by helium ion microscopy (HIM) because of its high imaging resolution, and further characterized by high resolution transmission electron microscope (HR-TEM) and electron energy-loss spectroscopy (EELS). Electrical property measurements show these metal lines have less than 100 μΩcm resistivity and less than 100 Ω contact resistance on gold pads. HR-TEM images reveal that these metal lines are composed of 5-10 nm crystallite grains; and EELS analysis shows that no measurable carbon signal was observed. By reducing the size of the beam limited aperture, 10 nm metal lines at 25 nm half pitch were deposited by He ion beam. Single-line and multiple-line patterns were prepared to examine overspray around the metal line depositions. Both HIM imaging and electrical measurements of those patterns verify that the overspray between individual lines is minimized. Finally, factors determining ultimate line width using He ion beam are discussed.