Fabrication Technology for Sub-100 nm Semiconductor Devices

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For rapid prototyping of modern sub-100 nm devices a method for the direct deposition of nanostructures of material was developed This direct-write lithography is a maskless technology and requires only a single process step. By local deposition of silicon oxide and tungsten rewiring of chips and reverse engineering becomes feasible. This position-controlled local fabrication of sub-µm dielectric structures opens a versatile alternative for backend processing. Chemical vapor deposition of silicon dioxide induced by a focused ion beam was used to obtain material deposition confined to µm and sub-µm dimensions. Using metal-insulator-metal test vehicles the deposition rate and insulating properties of obtained materials were investigated. Dielectric breakdown of thin layers is correlated to impurities in the deposited material. Material properties appear to respond sensitively towards a change of process parameters such as the composition of the precursor gas. With an appropriate process control this method can provide interconnect and interline dielectrics for advanced rapid prototyping and multilevel rewiring of integrated circuits.

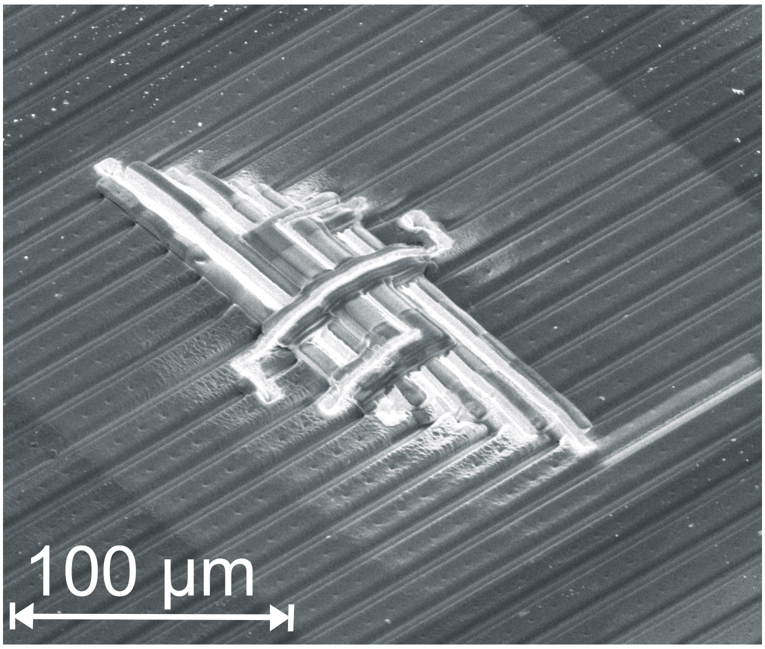

Fig. 1: Typical lines of an interconnect layer with FIB processed multilevel rewiring.

A research topic focusing on industrial fabrication technology of semiconductor devices is the development of a repair method for photomasks. Phase shift masks (PSM) are an enabling technology in lithographic fabrication of modern integrated circuits (IC) with a feature size below 250 nm. Phase shift technology allows to obtain a small structure size remaining under the wavelength of the light source used for the lithographic exposure. Alternating aperture phase shift masks consist of a flat reflective chromium mask and a 3-dimensional structured quartz substrate. The production of phase shift masks is cost intensive and the yield is low due to defects in the quartz substrate or the chromium layer. Focused Ion Beam (FIB) technology offers a versatile repair method allowing a locally confined deposition of material utilizing chemical vapor deposition (CVD) initiated within the scanned area.

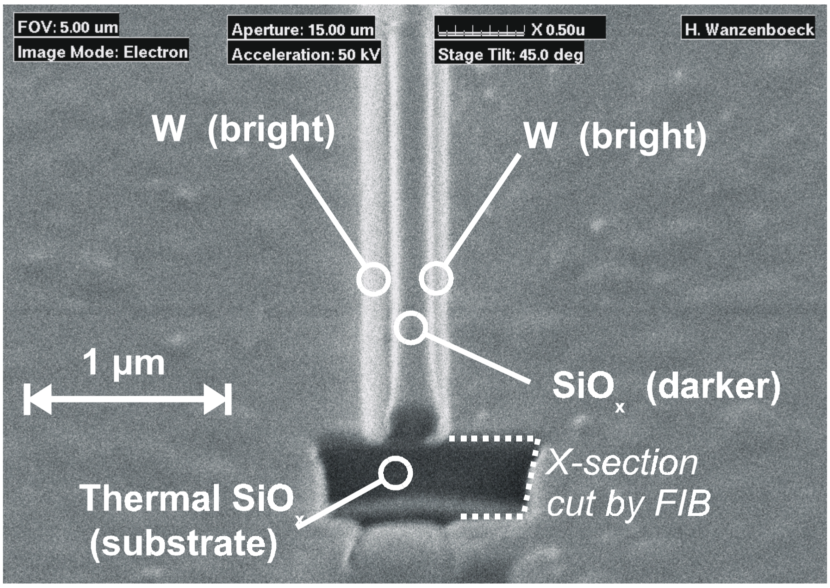

Fig. 2: FIB deposited structure showing two bright W wires (120 nm width) and a darker silicon oxide line (200 nm wide) in the middle. The sample is 45° tilted for this image. A hole is milled into the substrate displaying the cross-section of the deposited structures.

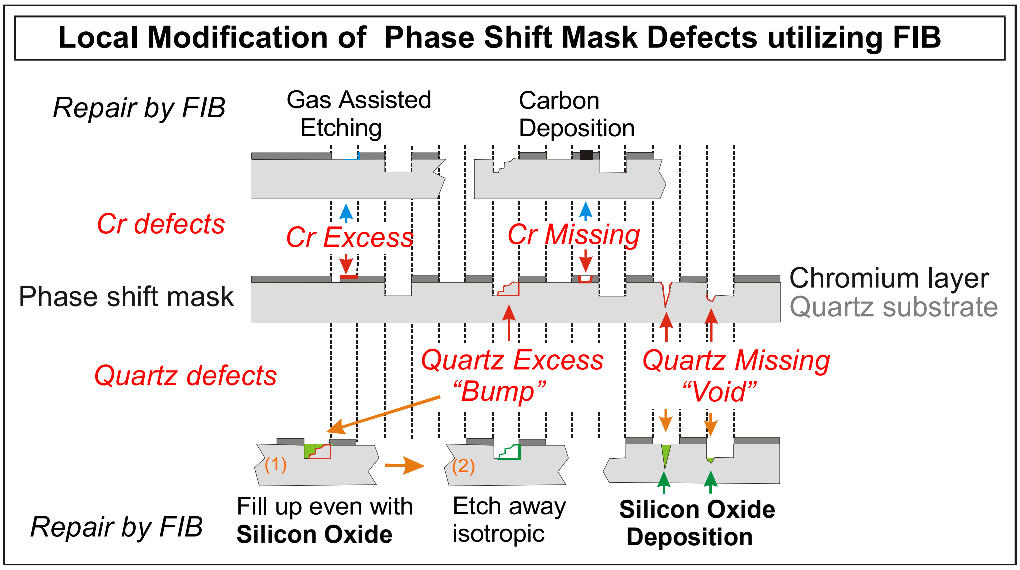

Fig. 3: Schematic illustration of different defect types of alternating aperture phase shift masks and corresponding repair strategies.

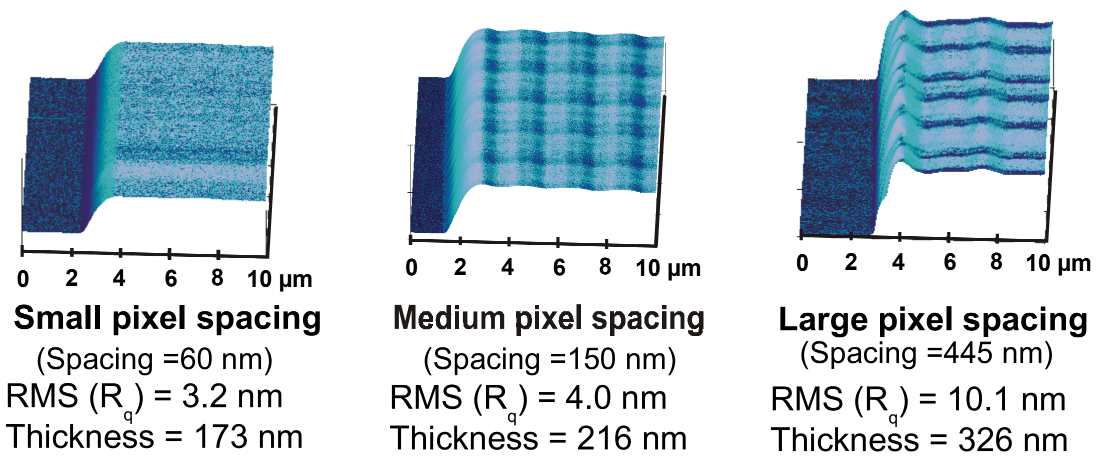

Fig. 4: Surface topology of silicon oxide deposited by FIB was imaged by AFM. The same total ion dose and the same gas composition was used. The varying pixel spacing resulted in a different surface roughness and geometry (image 10 x 10 µm).

The proposed repair strategy for quartz defects utilizes the local deposition of CVD silicon oxide as this material is most similar to the quartz of the original photomask. Silicon oxide structures down to 200 nm can be deposited with this method. The chemical composition of the deposited material was found to vary with the process parameters. The surface roughness and the potential of this process for phase shift mask repair was investigated.