FOCUSED ION BEAM INDUCED CHEMICAL VAPOR DEPOSITION (FIB-CVD) FOR LOCAL NANODEPOSITION OF DIELECTRIC MATERIAL

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In this work a focused beam induced chemical vapor deposition is presented, that simultaneously allows depositing material and at the same time to obtain the structures required for functional microelectronic devices. This sophisticated technique finally closes the long endured gap between the demand for high-quality dielectric material on one hand and a quick prototyping technique for device development on the other hand.

Chemical vapor deposition is acknowledged as a highly versatile process in microelectronic fabrication. However, the requirement for specific shapes of dielectric material in specific functional units has lead to the fact that structuring the layer fabricated by CVD is as crucial as the deposition process itself. For structuring, optical lithography followed by chemical etching is the predominantly used methodology. Not only that etching raises the critical issues of material selectivity and etch stop layers, the lithographic approach requiring a specific photomask for every design is very inflexible and time consuming before the first device can be produced. For mass production the lithographic approach remains unmatched in high throughput and economical value. For rapid prototyping and for 3-dimensional devices, however, an alternative strategy has been sought a long time.

Focused beam induced CVD utilizes a focused ion beam with a spot size in the nm regime to initiate the deposition reaction on an arbitrary surface. This maskless direct-write technology facilitates the additive fabrication of dielectric material and structuring towards functional units within a single process step. By guiding the scanned beam the CVD can be used to deposit pattern designs. Due to the small spot diameter, material deposition can be restricted to the nanometer range so that 3-dimensional nanostructures can be fabricated.

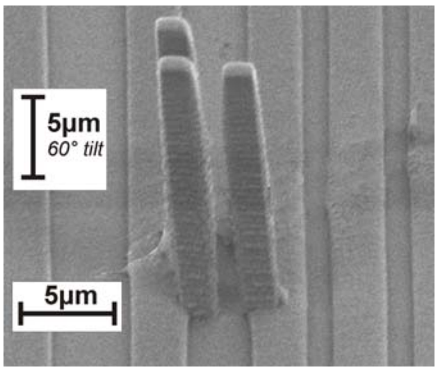

Figure 1. Three pillars of deposited silicon oxide.FIB-CVD allows to fabricate 3-dimensional structures of silicon

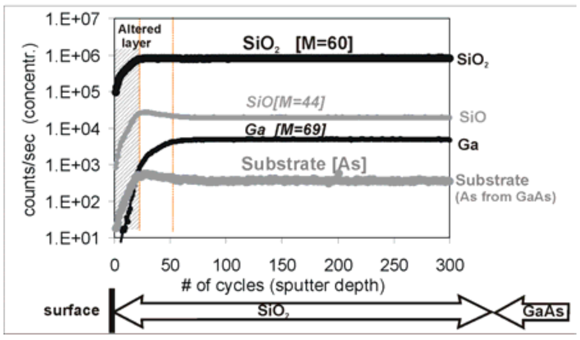

Figure 2. SIMS depth profile of a thick silicon oxide film deposited by FIB-CVD on top of a GaAs-substrate.

This unmatched combination of direct-write deposition of dielectrics bears the potential of becoming a key technology for rapid prototyping of electronic devices as well as for the development of micromechanical systems and for the repair of optical components and photomasks.

A gas mixture of siloxane (tetramethyl-cyclotetrasiloxane) and oxygen has been used as precursor system to facilitate the deposition of silicon oxide. A focused ion beam of Ga^+ ions has been employed to induce the chemical reaction of the components adsorbed on the substrate surface. As the maintenance of a focused particle beam requires vacuum condition (base pressure 10^{-6} mbar) the components were introduced via a micro-nozzle system positioned in close vicinity to the deposition area. The coadsorbed components are decomposed under formation of silicon oxide by the secondary ions and secondary electrons generated by the impact of the 50 kV Ga^+ ions.

Primarily the deposition process itself and the influence of chemical parameters - such as the gas phase composition and the total pressure - and the effect of scan parameters - such as pixel spacing and local exposure time (dwell time) - have been investigated. All parameters were observed to have an influence on the chemical composition of the deposited silicon oxide as assessed by Auger electron spectroscopy. The optimum process parameters have been identified and silicon oxide near the stoichiometric composition of SiO_2 with only negligible contaminations of Ga - originating from the ion beam - and carbon - from an incomplete decomposition of the organometallic precursor - has been deposited.

Furthermore, the electrical properties of the deposited silicon oxide have been tested employing metal-insulator-metal structures as capacitor test vehicles. The insulating properties were found to depend on the deposition parameters as mentioned previously. The interface between substrate and deposited material is effected by ion implantation and amorphization by the focused ion beam. The extent of the up to 100 nm thick intermixing layer was studied by transmission electron microscopy of cross-sections. Secondary ion mass spectroscopy was used for depth profiling and demonstrated a uniform composition of the deposited material until the intermixing region was reached.

Based on the fundamental understanding of this advanced CVD technique exemplary prototypes have been fabricated to demonstrate the application of this technology for fabrication of nanostructured materials, in micromachining, MEMS and for modification of interconnects of microelectronic circuits.

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