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Thin Films with Controlled Thickness Gradient – the direct "one-stop" multi-calibration vehicle for etching

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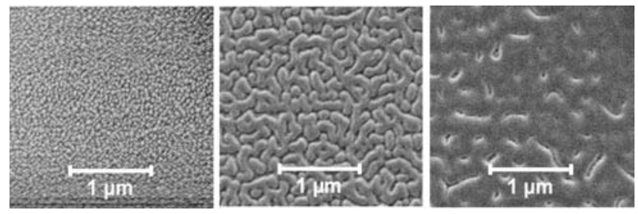
A novel approach for the local deposition of thin films on a local scale is described. As this method provides control over the chemical vapor deposition down a sub-micro meter range also layers of different thickness may be processed on the same substrate. Although only reasonable for small areas this approach facilitates to deposit layers of different thickness next to each other resembling a layer with a thickness gradient. This opens an exciting new possibility to deposit a layer with a controlled thickness gradient – a unique feature of this method not accessible with traditional blanket CVD deposition. The localized formation of material may also be used to fabricate functional elements for the repair of multi-level-metal interconnect layers of integrated circuits. We have used the layers with a well-defined thickness gradient for calibration of plasma etching processes to optimize the processing time.

The unique feature of the described approach is that a focused beam was used to trigger a chemical vapor deposition on a locally confined position. The fundamental process of chemical vapor deposition is identical to blanket deposition in a plasma or a thermal reactor. However, with a focused electron or ion beam initiating the reaction a material deposition in the sub-100nm range could be achieved. Scanning the focused beam over an selected region provided areas up to several 1000 µm². Repeated scanning would provide an increased layer thickness. By conscientiously varying the scan repetition number within the deposition area thin material films with a thickness gradient were obtained.

Thin films of tungsten and of silicon oxide were deposited by this CVD method. Fabricated layer thickness was in the range from several nm up to 2 µm. However, with ultrathin films island formation was observed within the initial phase of layer growth. The thin films consisted of amorphous material and had a surface roughness in the range of 3 nm to 10 nm. The surface roughness of these thin layers could be influenced by varying the pixel spacing of the beam scan raster. With differently thick layers the simultaneous testing of material properties was feasible with only a single further lithography step. The conductivity of metal films (Van-der-Pauw setup) and the resistivity of dielectric layers (capacitor setup)could be measured for layers with an alternating thickness on the same sample. The statistic variation between process steps is avoided this way and results in much more accurate results. Test vehicles with different layer thickness were fabricated for simultaneous characterization of devices.

These films with a thickness gradient also provided an valuable test device for the plasma etching of these CVD-layers. The total removal of a specific layer thickness in combination with the residual film of a initially thicker layer provided accurate means for the etch rate measurement. Concluding the gradient thickness of deposited films renders this new approach an ideal test vehicle for rapid device testing with different layer thickness. The gradually changing film thickness has also been successfully used to determine the etching rate.



(a) (b) (c)

Fig. 1 Thin films of tungsten during focused ion beam induced deposition from $W(CO)_6$ imaged during the initial stage of chemical vapor deposition. At an ion exposure of (a) and (b) a metal island film is observed while higher ion doses than (c) result in a homogeneous film,