Three-dimensional nanometrology of microstructures by replica molding and large-range atomic force microscopy

We have used replica molding and large-range atomic force microscopy to characterize the three-dimensional shape of high aspect ratio microstructures. Casting inverted replicas of microstructures using polydimethylsiloxane (PDMS) circumvents the inability of AFM probes to measure deep and narrow cavities. We investigated cylindrical deep reactive ion etched cavities in silicon wafers and determined the radius of curvature (ROC) of the sidewalls as a function of depth. Statistical analysis verified the reliability and reproducibility of the replication procedure. The mean ROC was determined as $(6.32 \pm 0.06)$ μm, i.e., with 1% accuracy, while the ROC linearly increases by $(0.52 \pm 0.03)$ μm from the top to the bottom of the sidewalls. Nanometer sized surface defects are also well replicated. In addition, the method allows combining multiple features from differently processed wafers into a single sample, accelerating characterization in process optimization tasks. To access the sidewall shape samples needed to be cleaved. The method was applied to study X-ray refractive optics, whose performance is crucially affected by their three-dimensional shapes.