

Patterned Multilayers for the Formation of Sub-Lithographic Features

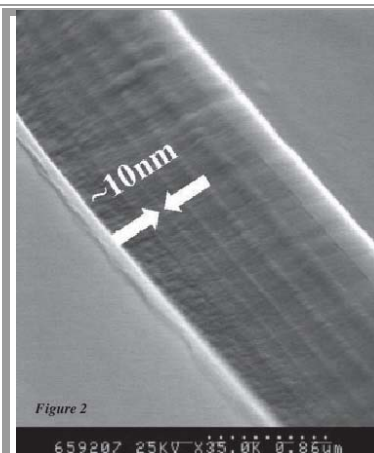
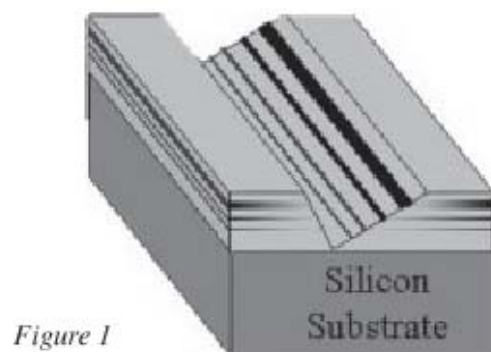
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The current level of optical lithographic techniques for producing nanoscale structures is reaching a fundamental limit of roughly 200 nm. In order to explore new methods of producing structures smaller than this limit, we attempted a novel approach for creating chemically patterned surfaces for producing gold wires of roughly 10-100 nm in size. Our method consisted of depositing a multilayer film (~10 nm up to 100 nm) of alternating amorphous silicon and amorphous gold/silicon alloy layers onto a silicon wafer. The structure was pattern-etched and then annealed to induce segregation of the gold from the Si. It was expected that surface energy considerations should drive the gold to the exposed edge of the multilayer, resulting in gold nanowires. In this work, we varied anneal temperature and thickness in order to investigate this process. Results were analyzed using SEM and TEM.

Following etching, SEM images were taken of the prepared surface grooves. This imaging revealed that we had in fact achieved our first goal of producing a chemically patterned surface with sub-lithographic scale patterning (represented in fig. 1.) Following etched sample imaging, the sample was annealed and imaged again to look for the formation of gold surface features on top of the chemically patterned surfaces. Fig. 2 is a (35,000X) SEM image of one of the many patterned grooves on the surface of the multilayer film (identical orientation to fig. 1). Visible within the groove are four bumps on the surface, the smallest of which is ~10 nm wide. These bumps were not present prior to annealing at 250°C. While SEM imaging did reveal that we had in fact produced surface features similar to what we were looking for, the composition of these features had to be determined by other means.



Following SEM analysis, two cross-sectional TEM samples were prepared to qualitatively determine whether the observed surface features were actually gold or not. One TEM image was taken prior to annealing (Fig. 3) and one image was taken of the post-annealed sample (Fig. 4). In fig. 3, the dark horizontal bands correspond to Au₂₅/Si₇₅ alloy layers while the light bands correspond to amorphous silicon layers. In the post-annealed image (Fig. 4), rather than segregating to the surface, the gold preferentially segregated into the amorphous Si. This result was unexpected and indicated that the surface features observed in fig. 2 were not composed of gold, as we had suspected.

SEM imaging of the post-annealed surface features led us to conclude that segregation of gold from the gold/silicon alloy to the exposed surface of that alloy was not preferential to segregation into the surrounding amorphous silicon, and that the observed surface features were believed to be an oxide formation. However, we did in fact create a chemically patterned surface with feature resolution well beyond the limit of current optical lithography (~10 nm). This process may be useful for producing surface features for controlling and observing chemical reactions along a nano-scale interface.

