

Micro-patterning of Copper Based on Photolithographed Self-assembly Monolayers

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Abstract: A new method has been developed for fabrication of copper micro-pattern by selective chemical copper deposition based on photolithographed (3-mercaptopropyl)-trimethoxysilane (MPTS) self-assembly monolayers (SAMs). As confirmed by scanning electron microscopy (SEM), Cu closely replicated the mask features. The present approach makes this technic to be cheap and may be applicable to assembly of microelectronic circuits.

Keywords: Micro-pattern, deposition, photolithograph, SAMs, MPTS, SEM.

Self-assembled monolayer (SAM) films containing thiol or amine functional terminal groups are useful in surface-modification strategies to synthesize nano-particulate micro/nano-structures owing to diversified useful reactions such as covalent bonding¹⁻³. UV exposure of MPTS SAMs causes –SH terminal groups oxidized¹. Thereby patterned selective chemical deposition can be carried out onto a surface template of reactive –SH functional groups through patterned exposure.

A silica-coated single crystal silicon wafer was used as the substrate. It was pretreated in chromic acid to produce hydroxyl groups in the SiO₂-coated substrates surface. Self-assembly was done by immersing the cleaned substrate into a dehydrated benzene solution containing 1×10^{-5} mol/L of MPTS for 6 h at room temperature. MPTS monolayers were formed through covalently bonding of methoxysilane with the hydroxyl groups. Covered by transmission copper grid, the MPTS-coated substrates were irradiated with 253.7 nm UV light held 6 cm from the surface of the substrate in air under ambient conditions for 2 h. The –SH terminal groups of the MPTS monolayers in

Figure 1 Schematic representation of self-assembly patterned Pd on photolithographed MPTS monolayers

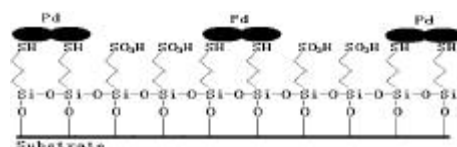
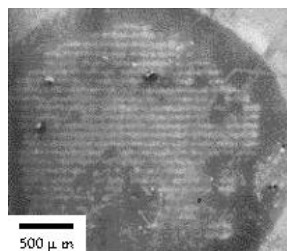


Figure 2 SEM image of copper micro-pattern using selective chemical copper deposition onto the photolithographed MPTS monolayer using Cu mask



the exposed region were oxidized to $-\text{SO}_3\text{H}^+$. **Figure 1** shows the representation of Pd onto the photolithographed MPTS monolayers.

Next, the substrates were immersed into the activator solution mainly containing PdCl_2 in order to adsorb Pd. Pd, the catalyst and nucleating site of electroless metal deposition, is strongly fixed on the thiol groups in the unexposed areas while it is weakly attached to the exposed areas and thus can be easily rinsed off⁴. The chemical deposition was performed in the electroless plating solution, composed of NaOH 12 g/L, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ 13 g/L, $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ 29 g/L, HCHO 95 mL/L for 10 min at 28°C. The product was ultrasonicated in twice-distilled water for 10 s to wipe off the copper physically absorbed in the exposed regions. Thus, Cu appears only in the unexposed areas and the regular Cu micro-patterns are formed.

A SEM image of the micro-pattern shown in **Figure 2** was obtained on a Hitachi S-450 type scanning electron microscope operated at 15 kV. The copper films closely reproduced the patterns of the grid masks. The bright areas correspond to the regions of the photolyzed MPTS monolayers, while the dark areas to the regions of the copper films. The EDAX analysis results show that the unexposed area is covered with Cu films. This approach is simple, inexpensive and convenient. It may be applied to fabrication of microelectronic circuits.

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