HBr Plasma Based Copper Etch Process

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The HBr plasma-copper reaction that is the base of a new copper etch method was studied. The reaction product's morphology and structure has been investigated and discussed. The result shows that this is a potentially important copper etching method.

Copper is an ideal interconnection material for VLSI and many other microelectronics devices (1). However, it is difficult to etch copper into fine lines using a conventional plasma etching method under mild plasma conditions. Recently, authors developed a new plasma-based copper etching method that showed a high etch rate at room temperature and a vertical profile pattern using HCl or Cl_2 feed gas with a parallel-plate type conventional plasma reactor (2,3,4). The plasma-copper reaction is the key of the success of this method. Instead of evaporating the copper compound during plasma processing, copper was converted into solution soluble product accumulated on the substrate. The reaction product was subsequently removed with a dilute acid solution. In this paper, we investigate the plasma-copper reaction process using HBr as the feed gas. The reaction product's morphology and structure are discussed.

A parallel-plate plasma reactor in the RIE mode was used for the copper etch reaction. The experimental set-up was described in detail previously (2-4). Experimental data was interpreted with plasma phase chemistry and ion bombardment phenomena and the reaction product was analyzed by SEM, EDX, XPS, and XRD.

Figure 1(a) shows an example of the patterned Cu sample after being exposed to the HBr plasma. The originally smooth Cu surface becomes rough and the layer is swollen. Figure 1(b) shows the copper pattern after the removal of the reaction product layer with the HCl solution and the photoresist layer. Therefore, copper can be etched with this plasma process. The HBr exposed copper film is granular and porous. Its XRD pattern shows a polycrystalline structure. These results are similar to those of the HCl or Cl_2 plasma processes although the detailed film morphology and structure are not exactly the same.

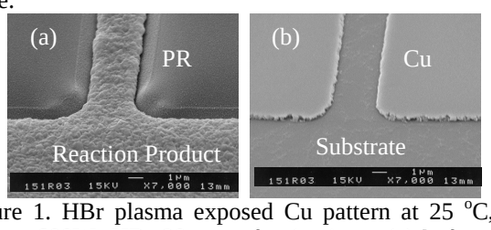

Figure 1. HBr plasma exposed Cu pattern at 25 ^{o}C, 20 mTorr, 600W, HBr 20sccm, for 1 minute (a) before and (b) after the removal of the reaction product and photoresist layer.

The XPS spectra of the copper compound surface are shown in Figure 2(a) and (b). They contain CuBr and Br peaks. Separately, it was confirmed from the Auger Cu LMM spectrum that Cu was in the $CuCl_x$, instead of the metallic Cu, form. The exact composition of $CuBr_x$ depends on the process condition.

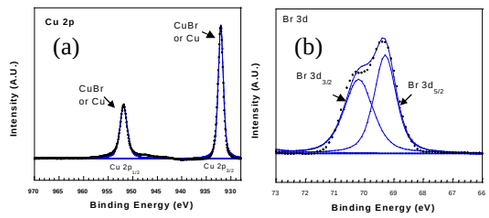

Figure 2. XPS spectra of the HBr exposed copper surface at 25 ^{o}C, 20 mTorr, 600W, HBr 20sccm, for 2 minutes, (a) Cu 2p and (b) Br 3d core level

In the process study, we conclude: 1) a high copper consumption rate, e.g., > 400 nm/min, could be obtained, 2) the reaction rate increases with the increase of pressure and plasma power, and 3) the Br concentration, which was estimated with the actinometry method, increases and the ion bombardment energy, which was represented by the cathode self-bias voltage ($-V_{dc}$), decreases with the increase of pressure. The reaction rate is more influenced by the Br concentration than the ion bombardment energy. No copper corrosion was observed when the etched pattern was rinsed with DI immediately after the reaction.

References

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