Etch Study of Zirconium Oxide Nanoparticle Photoresist

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Abstract:

As feature sizes continue to decrease, the need for high etch-resistance photoresist becomes more apparent. Using thin films creates lower aspect ratio patterns and effectively prevents pattern collapse. However, due to poor etch-resistance, achieving deep trenches on thin films can be difficult, as one will often etch through the photoresist before etching the substrate as desired. A promising potential solution lies in inorganic resists. This study looked at one such resist, a zirconium oxide (ZrO_2) nanoparticle-based resist. These zirconium oxide nanoparticles are surrounded by methacrylic acid ligands, where the inorganic core has high etch-resistance and the photochemical reactions can occur at the organic ligands. This project looked at the effects of different lengths of oxygen plasma cleaning before etching to see its effects on etch-resistance of the nanoparticles in tetraflouromethane (CF_4) and sulfur hexafluoride (SF_6) gases. The oxygen clean appears to have little effect on the etch-resistance of the film.

Introduction:

Many processes today implement photolithography to create features. This process involves exposing a photo-active coating to light in order to create a pattern [1]. The coating acts as a protective layer, allowing for etching of the pattern into the substrate. These photo-active compounds are the source of much research as they can continue to be improved.

One such material is an inorganic complex consisting of zirconium-based nanoparticles. These nanoparticles have high etch-resistance, a desirable trait when making small features. High etch-resistance allows for one to use thinner films, as one needs less photoresist (the photoactive compound) during the etch phase [2]. Thinner films prevent the patterns from failing by avoiding tall and narrow structures that would be prone to defects.

This study examined the properties of this complex process. In particular, it sought to optimize the etch step of the resist by looking at the effects of various oxygen plasma clean times on the etch properties of thin films of the particles in CF_4 or SF_6 plasma etches.

Procedure:

The nanoparticles were synthesized and processed according to literature [2]. The wafer was exposed to light using the ABM contact aligner at the Cornell NanoScale Science and Technology Facility (CNF). The wafer was exposed under 254 nm light using contact lithography.

The wafer was then cut into fragments and exposed to either CF_4 or SF_6 plasmas in the Oxford 81 and PlasmaTherm PT72 respectively (also at the CNF). The samples were exposed for thirty second intervals, up to two and a half minutes. The thickness of the remaining films was then measured using spectroscopic ellipsometry.

Results and Conclusions:

Figure 1 shows the change in thickness due to the oxygen clean. The thickness decreased at an exponential rate. The decrease in etch time could represent the oxygen consuming all of the organic compounds on the surface of the film and then its inability to etch into the zirconium oxide. Further study should be done to confirm this theory, looking at the composition of the film before and after the etch.

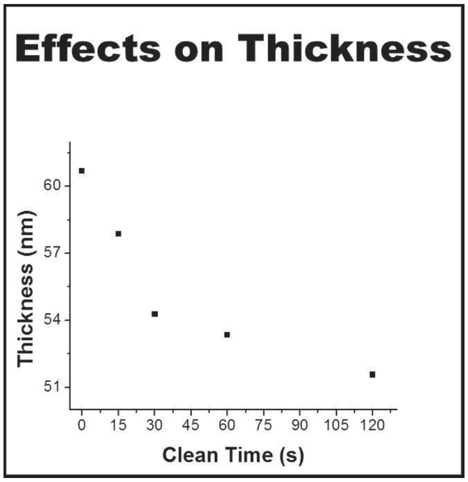

Figure 1: The change in thickness as a result of the oxygen clean.

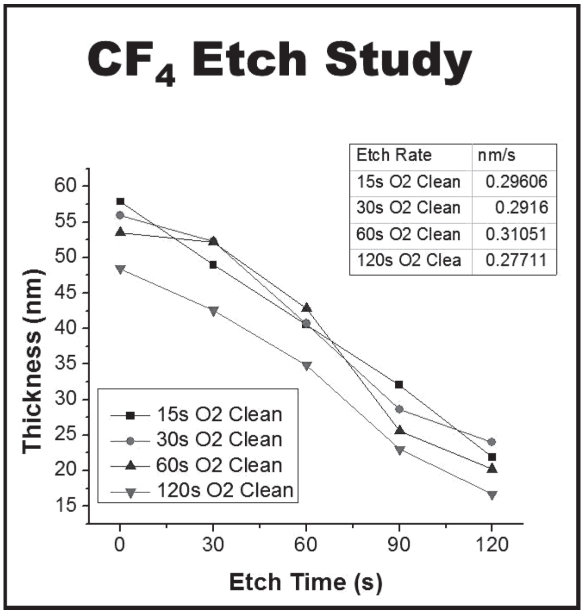

Figure 2: The results of etch study performed in CF_4 gas with various O_2 clean times.

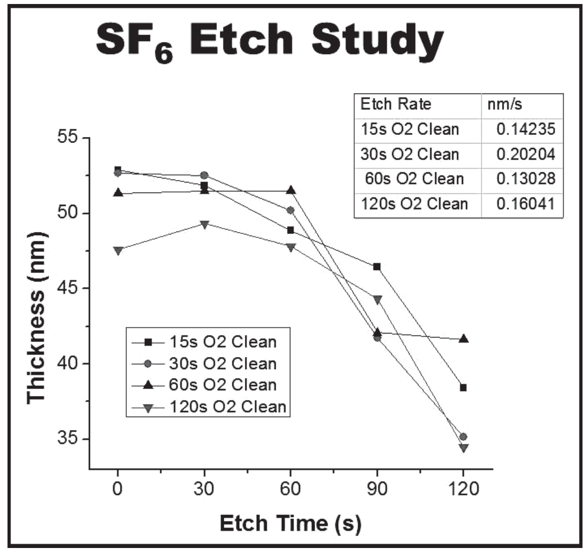

Figure 3: The results of etch study performed in SF_6 gas with various O_2 clean times.

Figure 2 shows the effects on the film in a CF_4 plasma etch. Overall, other than a thickness decrease, not much change was seen in the etch resistance of the film. Figure 3 shows the effects on the film in a SF_6 plasma etch. Although, the 30s etch appeared to have a much faster etch rate, this could just be due to artifacts in the data. It does not appear that the oxygen clean step had a significant effect on the etch rate. In the end, further study should be done to confirm these results and help further optimize etching.

Overall, the research proved that the photoresist is for the most part unaffected by the oxygen clean in these processes. In neither process was a noticeable difference apparent in the etch step. The photoresist held up well in both plasma etches, giving fairly consistent etch rates. These positive results lend evidence to the durability and strength of the resist.

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References:

[1] Ito, H.; "Chemical Amplification Resists for Microlithography"; Advanced Polymer Science, 172, 41-53 (2005).

[2] Trikeriotis, M, Krysak, M, Chung, Y. S., et. al.; "A new inorganic EUV resist with high-etch resistance"; SPIE, 8322, 1-6 (2012).