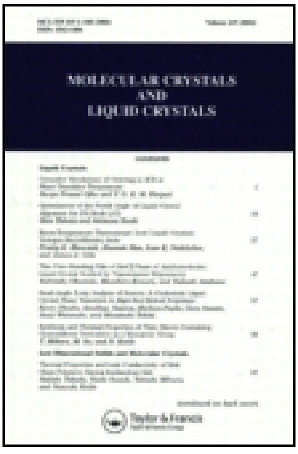

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Development of Sub-half Micrometric Structures with High Aspect Ratio Using a Multi-layer Lithography e-beam Process and Plasma Dry Etching

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In this work we are using the AR-P 322 (*All Resist GmbH*) DQN-novolac photoresist, with 3μm resolution specified by the manufacturer in the development of sub micrometric structures with high aspect ratios (10:1). In order to obtain these structures (sub-half micrometric and nanometric) we are studying the possible application of electron beam lithography and plasma etching. The resolution limit of the photoresist AR-P 322 is increased to 0.25 μm (nanometric resolution), using an electron beam spot size of 50 nm and dry development.

Keywords: e-beam-lithography; nanolithography; nanostructure; novolac; plasma etching; high aspect ratio structures.

INTRODUCTION

In this work we are using a DQN-novolac based polymer in the development of sub micrometric structures with high aspect ratios. In order to obtain these structures (sub-half micrometric and nanometric) we are studying the possible application of electron beam lithography and plasma etching.

The DQN-novolac system is the most important polymer system used in microelectronics. It's a very resistant polymer and its photo sensibility and contrast are high, which results in good definition of device structures.

In this study we increase the resolution's limit of the AR-P 322 (*All Resist GmbH*) DQN-novolac type photoresist from 3 μm specifited by the manufacturer to 0.25 μm (nanometric resolution), using an electron beam spot size of 50 nm and dry development by plasma etching. The plasma etching development is important to obtain the best resolution and resistance of the lithographic patterns.

The main application of microlithography is the development of silicon structures for micromachines and the microelectronics' structures with other materials: SiO_2, aluminum, etc. The study of resistance of these resists is fundamental [1]. The main advantages of using the photoresist with e-beam lithography is the possibility of increasing its resolution, adherence to metals and SiO_2 films, high wet resistance, high sensibility and low cost. An oxygen plasma etching is necessary for anisotropic etching of the resist [3]. With these two techniques it is possible to obtain anisotropic patterns with sub micrometric dimensions and high aspect ratios (10:1).

The sub-half micrometric structures were obtained using a trilayer lithographic process [2]. (The bottom layer of ARP 322 resist has 20 μm thickness, the isolation layer is aluminum with 100nm thickness and the top layer is OFPR 800 photoresist with 4 μm thickness). The exposure of the top layer is done in a SEM Philips 515 at 70 $\mu C/cm^2$ dose and 30 keV beam energy. After the development of this sub-micrometric structures in the top resist, we performed the wet etching of the aluminum layer; this layer was used subsequently as a mask for the oxygen plasma etching of the bottom layer resist.

The dry development in oxygen plasma etching of the samples (bottom layer) were performed in a home build *Reactive Ion Etching* system.

EXPERIMENTAL

We used 3 in (three inches) p type bare silicon wafers with (100) orientation. Before the polymer deposition we cleaned the samples in a "Piranha"clean followed by HF solution dip

For the tri-layer structure preparation we used the process sequence of Figure 1: deposition of the adhesion promoter (HMDS) (2000 rpm, 10s), deposition of the AR-P 322 (2000 rpm, 40s, 20μm), baking at 200°C, thermal evaporation of the thin aluminum layer (thickness of

200 nm), deposition of the adhesion promoter (HMDS) (2000 rpm, 10s), deposition of the optical resit OFPR 800 (*novolac*) from TOKYO OHKA (4000 rpm, 20s, 4 μm), baking at 90°C, optical exposure of the resist OFPR 800 wet development of the resist OFPR 800, baking at 90°C, wet etching of the aluminum layer and dry development with oxygen plasma of the thick resist layer.

The dry etching of the thick polymer was carried in a home built Reactive Ion Etching (RIE) etch reactor (ref.) with oxygen plasmas.

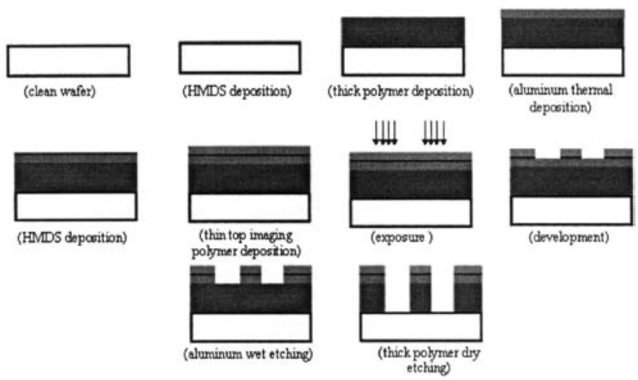

FIGURE 1 Sequence of the tri-layer fabrication process.

RESULTS AND DISCUSSION

Contrast curve

The contrast curve is the main function used for resist characterization, since it is possible to obtain the dose necessary for best exposure of a resist.

The contrast curve for the AR-P 322 resist was made measuring first the film thickness after development of the e-beam exposed resist, as shown in Figure 2. The first exposure project was made for e-beam doses from 0.7 to 168 $\mu C/cm^2$ and the second exposure project from 1 to 240 $\mu C/cm^2$.

Figure 3 shows the contrast curve itself, where the minimum dose necessary to sensibilize the photoresist (D_0) by e-beam is shown to be 70 $\mu C/cm^2$, and the energy for complete exposure (D_{100}) of the AR-P

322 is 150 $\mu C/cm^2$. The slope of this curve gives the contrast of the resist (γ) which in this case is 3.02. This shows the possibility of application of the optical resist in an electron beam process.

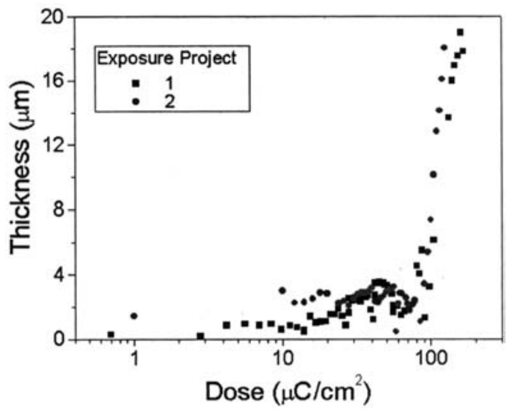

FIGURE 2 Measurements of AR-P 322 resist thickness as a function of exposure dose by e-beam exposure.

Resist etching rate

The dry development of the thick resist AR-P 322, was made in a RIE (Reactive Ion Etching) plasma system, with oxygen plasmas. The process pressure was set at 15, 30, 60 and 120 mTorr and the RF power at 50, 100, 150 e 200 W.

After 30 minutes of process we measured the height of topography with a height step meter to determine the etching rate, which is shown in Figure 4 as a function of power and pressure. We also analyzed the profile of the samples in a SEM (Scanning Electron Microscopy) to determine its anisotropy. With these measurements we conclude that the best condition (high anisotropy) is achieved at 30 mTorr of pressure and 50 W of RF, with an etching rate of 0.54 μm/min.

The structures obtained after dry development are shown in Figure 5, where we observe the high resolution (0.4 μm) and high aspect ratio (10:1) of the three layer process.

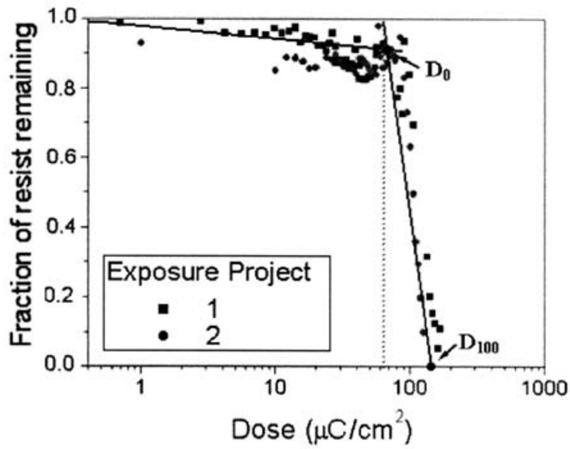

FIGURE 3 Contrast curve (fraction of resist remaining).

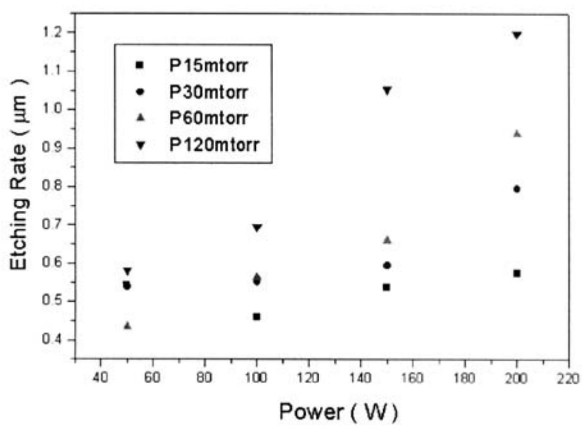

FIGURE 4 Thick polymer layer etching rate as a function of power and pressure.

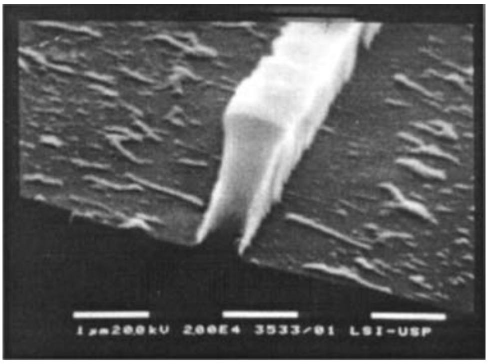

FIGURE 5 SEM photograph of sub-half micrometric (0.4 μm) line obtained by e-beam and dry etching process for AR-P 322 optical resist.

CONCLUSIONS

This work shows a new possibility of lithography processing with decrease in cost of nanostructure development, using a conventional photoresist for advanced applications in micromachining silicon process with high aspect ratio (10:1). This result is possible using the dry plasma development and e-beam lithography process.

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