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Utilisation of JSR and BCB resists for the construction of gray scale microstructures

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Abstract

This paper reports on the use of two well-known photoresists, the JSR and BCB for the construction of gray scale structures which have a wide range of applications in the semiconductor/electronics industry. Reactive ion etching experiments were carried out in order to define the etching rate of the resist JSR and cyclotene using a combination of two different gases. Argon and Oxygen were used separately in order to determine the etching rate of the photoresist and the cyclotene by changing the following parameters: concentration, gas pressure and power of the RF unit. New reactive ion etching experiments were performed using combinations of the two gases in order to establish the optimum ratio of the two gases for accomplishing the desirable gray scale structures.

Keywords: gray scale, BCB, JSR, microstructures, characterisation.

1. Introduction

Optical lithography using grayscale masks is the main high-throughput process that can be used to create complex tapered microstructures for optical and fluidic applications [1], [2] and [3]. This makes grayscale mask fabrication the most critical and expensive step in the process. The basic fabrication process using gray scale lithography is schematically illustrated in Figure 1.

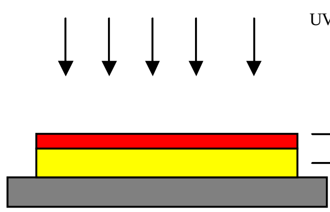

Fig. 1: Fabrication process using gray scale lithography

Spinning curves as well as softbaking conditions were defined.

2. Experimental work

Initially, a calibration plate with the gray scale structures was used only the photoresist JSR was applied without the cyclotene layer. The test patterns on the calibration plate are useful for calibrating photoresist thickness versus mask optical density (OD), as can be seen in Figure 2. The first part of the calibration plate has 200 gray levels, and each gray level consists of three test strips, 204.8 εm x 819.2 εm in size. The 200 gray levels are determined by the optical density values, according to the

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equation D= 0.152 + 0.009286i, where i = 0, 1, 2é 199. Thus, by using this equation, the minimum and maximum optical density (OD) can be determined to be 0.152 and 2.0 respectively. This part is useful for matching photoresist heights with specific optical densities in the mask in order to build a calibration curve. The second part is utilised to determine the number of gray levels required to fabricate a smooth surface figure for a 3D structure (Figure 2).

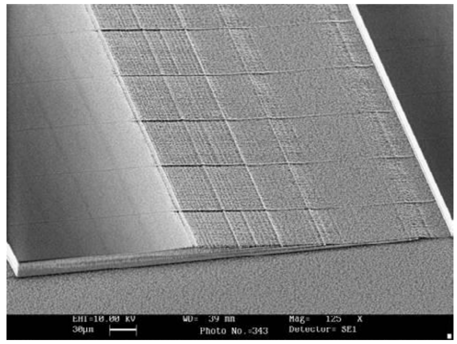

Fig. 2: Gray scale structures using JSR and BCB resists.

3. Results and discussions

Characterisation experiments for the resists JSR and the BCB (cyclotene - BCB) [4] were carried out. Spinning curves as well as softbaking conditions and exposure times were defined as can be observed in Figures 3 and 4.

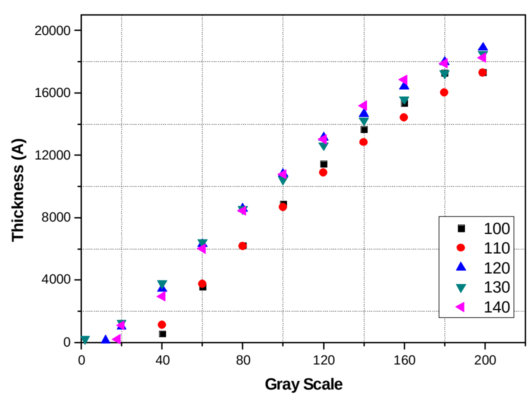

Fig. 3: JSR resist using different softbaking temperatures (100 °C, 110 °C, 120 °C, 130 °C, 140 °C).

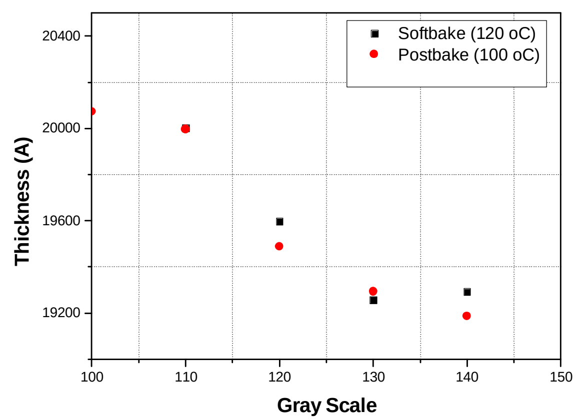

Fig. 4: BCB resist using using 120^{o}C softbaking temperature and 100^{o}C postbaking temperature.

Reactive ion etching experiments were carried out in order to define the etching rate of the resist and cyclotene using a combination of two different gases, as can be seen in the Figure 5. Initially, gas1 and gas2 were used separately in order to determine the etching rate of the photoresist and the cyclotene by changing the following parameters: concentration, gas pressure and power of the RF unit (Figures 6 and 7).

Subsequently, using combinations of the two gasses new reactive ion etching experiments were performed as can be observed in Figure 8. The target of these experiments was to establish the optimum ratio of the two gases (10:1) for the desirable gray scale structures. At this stage, the main problem was that the gases were influenced by each other resulting in different etching rates than when they were used separately. Further experiments need to be carried out in order to investigate and solve or find alterative solutions for the current problem.

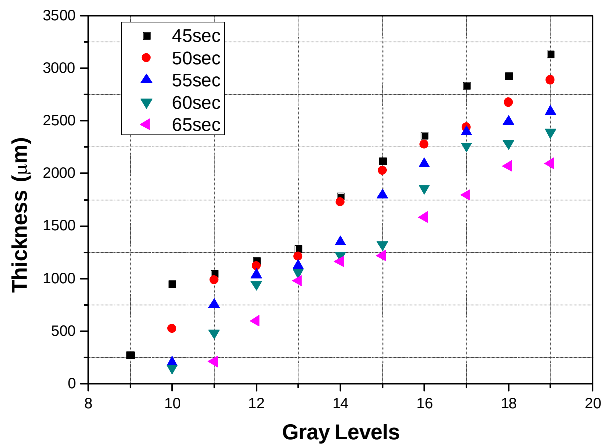

Fig. 5: JSR resist using different exposure times

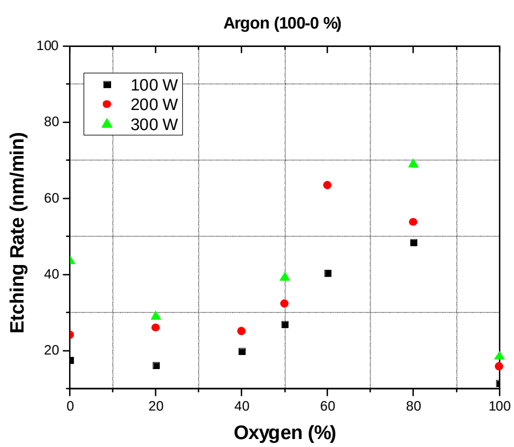

Fig. 6: JSR etching rates using: Ar and O_2 with the following conditions:gas5 sccm max, pressure 20 mTorr conditions:gas5 sccm max, pressure 20 mTorr and power 100W, 200W and 300W.

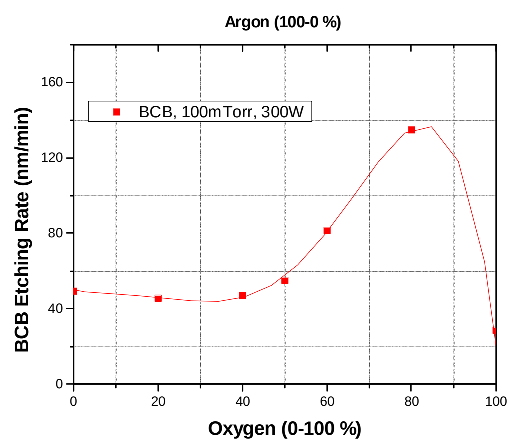

Fig. 7: BCB etching rates using: Ar and O_2 with the following conditions:gas 5 sccm max pressure 1000 mTorr and power 300W.

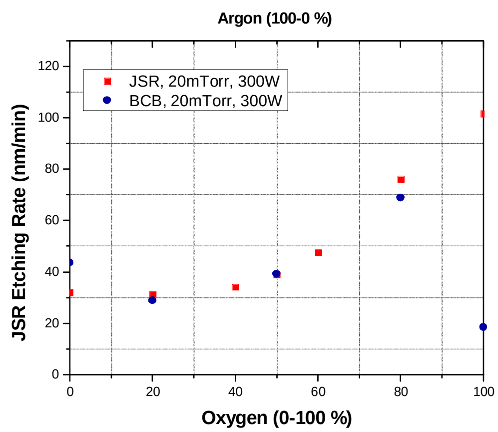

Fig .8: Comparison of JSR and BCB etching rates using:
Ar and O_2 with the following conditions:
pressure 20 mTorr and power 300W.

4. Conclusions

In general, based on the experimental work, encouraging results have been obtained that demonstrate the feasibility of creating gray scale structures in BCB using ion reactive etching techniques with a very accurate and repeatable control of the thickness distribution. However, further experimental work needs to be carried out in order to fully prove the concept and fulfill the specific requirements. More experiments are required for studying the effect on surface roughness of BCB after the ion reactive etching step. In addition, a different type of instrumentation for the ion reactive etching experiments could be used with a larger chamber, where more homogeneous etching rates could be accomplished. For the current experimental work the chamber has the size of holding only one wafer. Finally, it is worthy investigating alternative types of negative resists e.g. SU-8 for replacing the BCB resist.

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