SPRAY COATING NEGATIVE TONE RESISTS

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1. INTRODUCTION
Spray coating is an essential coating technology for depositing resists across deeply etched structures, such as a MEMS device etched deeper than 100 µm. Conventional spin coating has limitations when processing structured wafers with severe topography. Spin coated resist often fills the entire structure. This leads to difficulties in the following lithography steps. Thus, industry requires a method to apply resist conformally. Spray coating technology is an effective method for performing conformal coating over deep etched structures.

In view of conformal coating, positive tone resist is desirable, as already adopted for many applications such as etch mask or electroplating. An important property of positive tone resists – such a DNQ/Novolak resist - is the comparably high glass transition temperature that is above the soft bake temperature. During soft bake the resist thickness changes depending on corner angle and location. Typically the resists thickness reduces at the top corner and increases at the bottom corner. However, when using positive acting resists, reasonable conformal coating can be achieved. The negative tone resist is a UV plastic material that is hardened during UV exposure. Unlike the previous case, during the soft bake step, the resist becomes soft and surface tension deteriorates the conformality of the resist layer. Often only a very thin residual resist coverage or no resist at all is observed on the top corner after soft bake. For these reasons, industry preferably adopts positive tone spray resists. Nevertheless, using negative tone resists is still important for some specific applications. Examples are the SU8 resist from MicroChem/ Nippon Kayaku and the THB 151N resist from JSR. SU8 is often used as a permanent resist structure and THB151N is an important plating resist.

2. PERMANENT LAYER (SU8)
Conformal coating with SU8 is frequently requested for many MEMS applications. SU8 has very unique properties, making it excellent dry etch resistant and enabling high aspect ratio imaging. Several process evaluations have been made using different topographic structures.

2.1 SPRAY COATING
2.1.1 POPPING DEFECTS
Bubble popping defects are observed during the soft bake step when diluted SU8-50 is spray coated as a layer thicker than 5 µm. Multiple coatings are thus required to apply a SU8-50 layer thicker than 5µm. This problem was solved by changing to the SU8-3000 Series. SU8-3050 allows, without popping defect, reaching already on a single coat, more than 20 µm of resist thickness. This is due to the fact that the SU8-3000 series contains Cyclopentanone, while the SU8 series contains gamma-Butyrolactone. Since the boiling point of Cyclopentanone is 131°C and the boiling point of gamma-Butyrolactone is 205°C, using a lower boiling point solvent might help to reduce the stress accumulation during the soft bake step and therefore helps to avoid popping defect.

2.1.2 CONFORMAL COATING
To achieve conformal coating, many tests have been done by changing spray coating parameters. However, SU8-3050 flows to the bottom of the topography, leaving the top corner exposed after the soft baking step, as shown in Figure 2. This phenomenon is observed with different series (SU8 2000 / KMPR series). Surface tension generated during the soft bake step acts so that the thickest part (bottom corner) pulls resist from all other the regions. The glass transition temperature of unexposed SU8 film (60°C) is lower than soft bake temperature (95°C). Thus,
SU8 becomes liquid and it is pulled into the bottom corner during soft bake by the surface tension. As shown in Figure 1, the thickness of the resist at the bottom corner is significantly thicker than at any other location. Changing the spray coating process parameter is not an efficient approach. For this reason, SU8-3050 needs to be UV processed before thermal processing step. Process sequence is modified as below: Exposed SU8-3050 layer becomes harder by cross linking during post exposure bake. This prevents the SU8-3050 layer from flowing into the bottom corner while maintaining the coverage at the top corner. Figure 2 shows images of the inverted process. Approximately 1.1 \(\mu\)m resist is observed on the corner after post exposure bake at 95°C for 180 seconds.

### 2.2 Lithography

Lithography test is done to verify that inverting the process steps has no influence on the lithography property. The process is then qualified by comparing its results to the ones from the conventional process. Figure 3 shows two SEM images from both processes after development. No influence is observed such as poor adhesion, worse resolution or requiring a different develop time as compared to the conventional process. During the exposure step, the SU8-3050 layer surface is sticky since it is not soft baked. Therefore, a contact between mask and coated wafer must be minimized in order to avoid mask and coated wafers sticking to each other. The SUSS MicroTec global WEC or NCGS (Non Contact Gap Setting) options are therefore in this case ideal. The exposure energy affects the resist thickness at the top corner. As shown in Figure 4, there is hardly any resist on top corner when exposing with a dose of 100mJ/cm². Resist coverage, however, becomes sufficient when exposing with a dose of 250mJ/cm². Higher exposure dose is thus critical in order to initiate a more effective cross linking.

**Process detail:**
- **Resist:** Diluted SU8-3050
- **Spray coating:** Arm speed 120 mm/sec./Chuck Temp. 60°C/Nitrogen 0.1 MPa
- **Exposure:** SUSS MA/BA 6 Gen2 / LGO optics / 250mJ/cm²
- **Soft/Post Exposure Bake:** SUSS HP8 TT / 95°C for 180 sec
- **Develop:** Immersion develop with PGMEA 180 seconds and IPA rinse

### 3. Bump Mold Resist (THB 151N)

THB 151N is used as bump mold for solder bump application in the advanced package technology. The same phenomenon as for the SU8 resist is also observed in this case.

#### 3.1 Spray Coating

The same evaluation performed as for the SU8 resist, comparing standard and inverted process sequence, was carried out in the THB 151N case. As shown in Figure 5, the inverted process helps to keep the resist on corners after the soft bake.

### 4. Conclusion

Inverting the process sequence is an efficient approach and allows spray coating any resist with a glass transition temperature lower than its soft bake temperature. Exposure initiates cross linking and changes the material properties, helping to minimize the resist deformation due to the surface tension during the soft bake step. Process optimization is strongly dependent on the structure design, i.e., a smaller process window is expected with vertical etched topography.

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