Dry-film Photoresist Processing

A. El Hasni and U. Schnakenberg

schnakenberg@iwe1.rwth-aachen.de

The application of SU-8 is today one of the key technologies for developing microelectromechanical systems (MEMS) and especially for microfluidic systems. Complex three-dimensional multilayered resist structures can be realized on the one hand by repeating liquid resist deposition, resist drying and lithography steps. Unfortunately, these sequences are highly time-consuming and can last several days to reduce mechanical stress in the SU-8 layers. Structured substrates or free-standing devices of considerable height cannot be easily coated with a liquid photoresist.

To overcome these drawbacks, dry film photoresists (DFR) are favorably be used. Combined with lamination or wafer bonding processes, this technology shows significant advantages over liquid photoresists, such as robust and simple processing, good conformability and uniformity, no mechanical stress, as well as no formation of edge beads. The film lamination on flat and structured substrates with high topographies is possible and beneficial when bridge-type devices or closing of channel structures are realized by multilayer lamination. In order to meet the specific requirements for a dry film photoresist, a new DFR on epoxy resin basis was developed by microresist technology GmbH (Berlin, Germany).

In the project, IWE1 develped the lamination process [1]. The new developed DFR was laminated using a Royal Sovereign RS-382S (Royal Sovereign International Inc., USA) roll laminator. Before lamination, the top protection liner was peeled off. To achieve optimal performance, only the roller temperature (upper and lower roller) and roller pressure were adjusted. In Table 1, the parameters are summarized. The lamination speed (roller rotation) was increased from 0.9 to 1 m/min after the first lamination step. After lamination, the laminated wafer cooled down to room temperature. After removing the carrier liner, lithography including i-line exposure was performed followed by a post-exposure bake on a standard hotplate for crosslinking of the irradiated dry film. The PEB step is critical for the fabrication of multilayer devices with embedded micro channels, because potential reflow of uncrosslinked dry film resist would lead to microchannel clogging. Therefore, the PEB temperature was modified after the first lamination. The resist development was carried out in mr-Dev 600 developer.

Table 1: Process parameters used for multilayer lamination of DRF.

Process	Parameter	First layer fabrication	Subsequent layer fabrication
Lamination	Roller temperature (upper and lower roller)	95°C	45°C
	Speed	0.9 m/min	1 m/min
	Pressure (roller gap)	3 bar	3 / 2.6 bar
Exposure	Exposure dose	500 mJ/cm²	500 mJ/cm²
PEB	Temperature	90°C	60°C
	Time	5 min	10 min
Development	Time	10 min	10 min

For the multilayer lamination process, it was necessary to reduce the lamination temperature from the second layer on to prevent liquefaction or sagging effects.

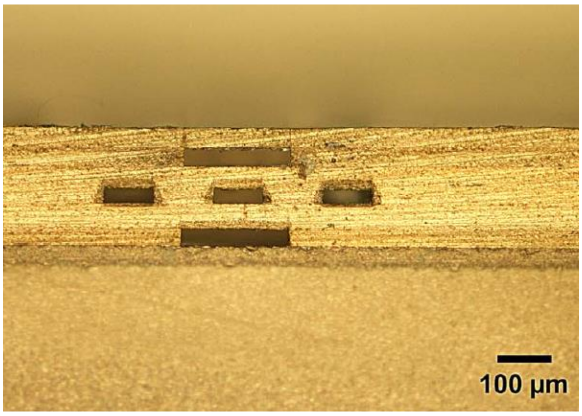

Fig. 1: Photo of cross-section of six laminated DFR layers. The total stack thickness was determined to be 213 µm.

As shown in Figure 1 six DFR layers with a mean film thickness of 33 µm were laminated. The roller gap had to be adjusted for the lamination of the last layer to avoid sagging of the laminated DFR in the junction region which exhibits a significantly larger microchannel width. A total processing time of approximately 30 min was needed for fabricating a single layer.

In Figure 1, the embedded micro channels in the different layers of the device are clearly visible. The rectangular channel geometries are observed without deformation of the different DFR layers indicating optimum lamination. In addition, devices using 65 µm thick DFR layers were fabricated by applying the same lamination parameters. In this case, sagging and deformation of the laminated layers were observed in some areas of the devices. Here, a further tuning of the lamination parameters is required. Nevertheless, clogging of micro channels was not observed when using the thick DFR, so fully operable devices could be fabricated.

To conclude, the new dry film photoresist show with beneficial properties with high aspect ratios of 6:1 for freestanding structures and excellent bonding strength performance. A simple lamination process enables a high processing speed and a high degree of versatility. We have proven the capability of the DFR to fabricate complex microfluidic structures with three-dimensional functionalities by applying a multilayer lamination process. The proposed epoxy-based negative-tone DFR enables a robust, simple, and fast fabrication of multilayer microfluidic devices.

Acknolwdegements
This work was funded by the German Federal Ministry for Economic Affairs and Energy, ZIM program, Grant KF 3147402CK3.

Project partners

- micro resist echnology GmbH, Berlin, Germany
  http://www.microresist.de

- Fraunhofer Research Institution for Microsystems and Solid State Technologies, Munich, Germany
  https://www.emft.fraunhofer.de/en

References

[1] A. El Hasni, S. Pfirrmann, A. Kolander, E. Yacoub-George, M König, C. Landesberger, A. Vogt, G. Grützner, U. Schnakenberg : Six-layer lamination of a new dry film negative-tone photoresist for fabricating complex 3D microfluidic devices. Microfluidics and Nanofluidics 21 41 (9pp) (2017), doi: 10.1007/s10404-017-1877-8