FABRICATION OF 3D-STRUCTURES IN SU-8 RESIST USING AN E-BEAM LITHOGRAPHY SYSTEM AND 3LITH CALCULATION AND SIMULATION TOOL

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E-Beam lithography (EBL) is a common tool for R&D applications and master copy fabrication, which allows to generate structures below 10 nm. Due to its high resolution and its flexibility, EBL is frequently used for prototype development, e.g. for integrated optical devices with Bragg gratings as wave selective elements. Processes for planar applications like microelectronic devices are fully developed and a large variety of different EBL systems exist, differing mainly in working principles, capabilities and price.

Whereas two-dimensional patterning is sufficient for the production of microelectronic devices, microsystems with micromechanical and optical elements include three-dimensional structures. Anisotropic wet etching of silicon can often be used for applications in this area. In case the restricted geometry of anisotropic etching techniques does not meet the desired structure, 3D direct laser writing might be applied for the fabrication of structures in the 1 µm range. However, some components of recent devices need a higher resolution. Especially diffractive optical elements (DOEs) like highly efficient couplers require sub-µm accuracy due to sub-optical-wavelength feature sizes.

In order to meet these needs, we have developped a 3D e-beam lithography tool called "3LITH". 3LITH allows to produce artificial 3-dimensional structures with continuously variable remaining resist thickness, e.g. as a master for replicating technologies. The resist structures can be defined by greyscale TIFF images, where the brightness corresponds to the desired remaining height, or by GDSII[1] files, where doses or layer numbers correspond to the wanted remaining height. Alternatively 3D structures can be defined by analytical formulas.

As a result, taken into account proximity effect correction (based on system scattering parameters) and resist behaviour, a final output file for all these structures, suitable for direct exposure by EBL, is created automatically.

In order to evaluate the general utility of special software for the generation of 3-dimensional structures, standard PMMA resist with a thickness of 2.4 µm was used during first tests. The fabrication of 3D structures was in principle possible with this resist. Nevertheless, a smooth resist surface could not be obtained with PMMA (see figure 3). For this reason, SU8 resist has been tested for 3D EBL applications as an alternative. This negative resist was originally used for high aspect ratio applications in UV photolithography. Nevertheless, a modification of SU8 can be applied as negative resist for electron beam lithography. Besides its high sensitivity, one interesting feature is that the contrast curve can be controlled by postexposure bake time (Fig.1). Thereby,

[1] Hierarchical layout database used within Raith's EBL software. GDSII is the registered trade mark of Calma GE.

low contrast values, which are required for 3D EBL, can be obtained. Moreover, smooth resist profiles after developing were easily achieved with SU8 resist. In order to evaluate SU8 for the fabrication of large area optical devices, 3D Fresnel lenses have been exposed in addition with a RAITH150 EBL system. Some results are shown in Fig.2. SU8 has been found especially useful for this kind of application, both due to its high sensitivity and its low contrast, and a smooth resist surface after developing.

Fig.1 Contrast curve of SU8 resist with and without postexposure bake. For measuring this contrast curve, the pattern above has been exposed several times with different overall dosefactors.

Fig.2 Fresnel lens with a size of 1024 × 1024 µm^2: a) gdsII pattern, and corresponding b) optical microscope images of results in 2.4 µm thick SU8.

Fig.1

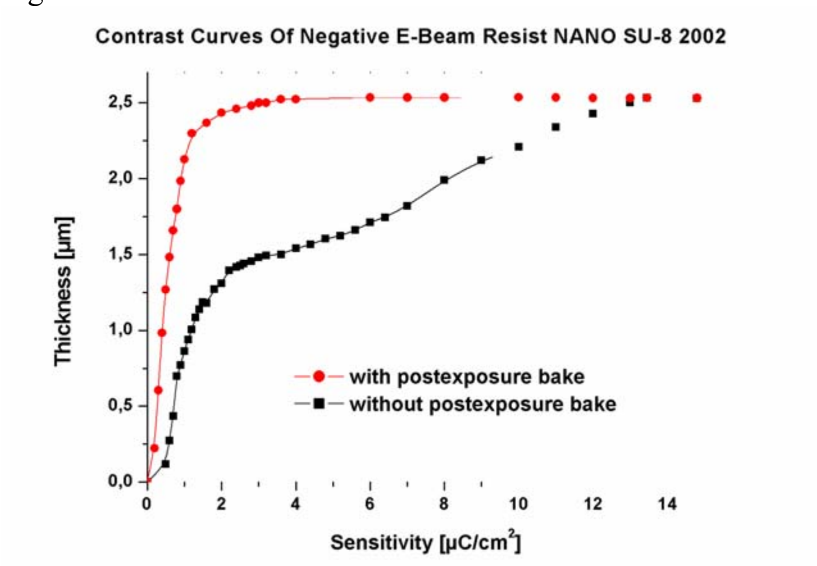
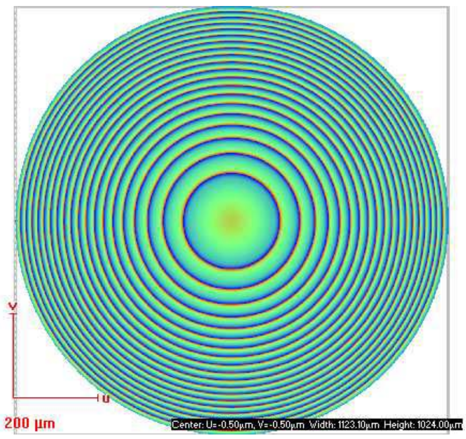
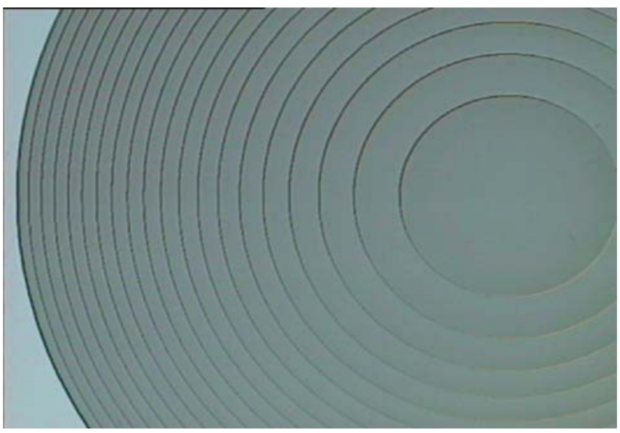


Fig.2



a)



b)