Micro- and Nanomachining for Optics

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The roadmap in microelectronics seems to define the requirements for the next generations of microlithography, however, other applications have taken key positions, too. In this trend, optics is both, a beneficiary and a pushing field as well. Based on applications and visions, the talk wants to give an insight into challenges and limitations and how the micro- and nanomachining technologies can enable the optics for giving further contributions to technical progress.

Passive refractive or diffractive optical elements are usually realized by forming a surface profile in a material of fixed index (gradient index optics excepted). Even artificial materials can be made on the base of surface profiles with sub-wavelength resolution. Thus, because of the huge variety of optical functions needed for applications, highly different binary, multi level and continuous surface profiles in different materials are of interest. As a consequence micro- and nanomachining is challenged to realize complex micro-optical elements as well as special material properties completely on the base of 2 and 3D microstructures. Figures 1–8 show examples of different optical microstructures made by lithographic techniques. In order to fabricate such optical elements, special demands of optics on lithography or micro- and nanomachining arise from the wave nature of light. This refers to the accuracy, as well as to special 2 and 3D fabrication techniques.

As an example, a grating of 220 nm lines and spaces, 3500 nm depth acting as a artificial birefringent material, has to be fabricated with ±1% accuracy for duty cycle and depth. With a knowledge of the correspondence between geometry and optical function, special technologies (e.g. regeneration of etching mask) can be developed to fulfill the optical specifications without a fulfilling of the tightly demanded geometrical accuracy.
Another example is the continuous profile fabrication by gray tone lithography and proportional etching transfer into glass for refractive lens arrays. This technology requires a very precise exposure dose control for realizing the resist profile (0.2 % achieved by e-beam lithography) and a very stable or controlled etching ratio for the transfer of the resist profile into glass. In this case problems arise from relative depth accuracy of the analogue lithographic process and the absolute wavelength scaled profile accuracy required from optics. This usually prevents the use of such a technology for optical profiles with large depths (> 50 µm). For special surface profiles it is possible to overcome this limitation by the technique of analogue lithography on pre forms.

In summary the micro- and nanomachining for optics, including characterization, should be seen as a special field with own problems and solutions, which is promising and challenging as well.

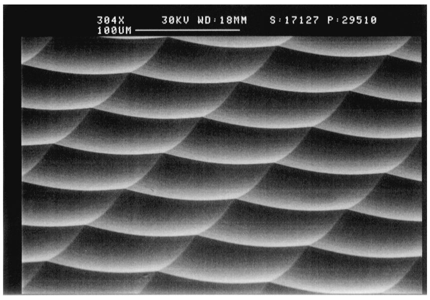

Fig. 1: Concave micro lens array
Single lens 100 µm x 100 µm

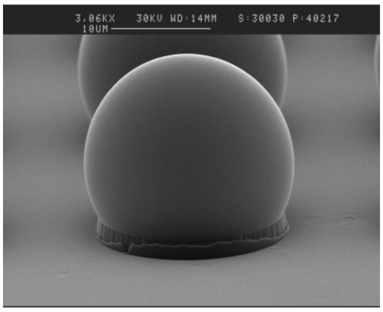

Fig. 2: Quartz ball lenses on a quartz substrate, diameter 20 µm

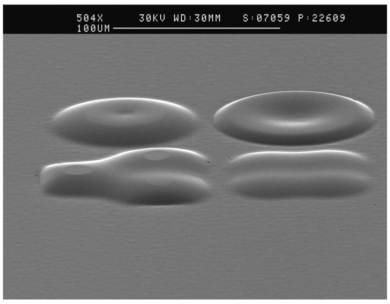

Fig. 3: Refractive beam shaping elements in glass

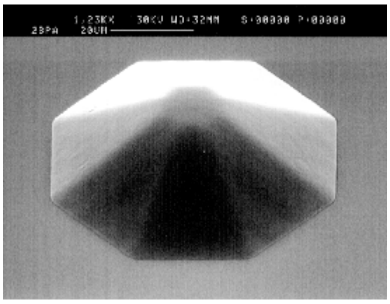

Fig. 4: Multifaceted micro prism
20 µm height

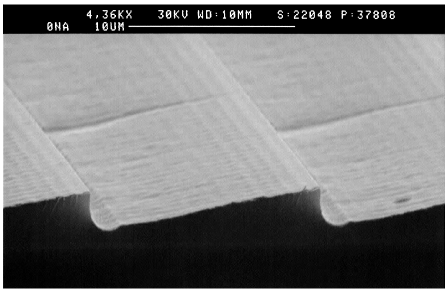

Fig. 5: Blazed grating in resist,
12.5 µm period

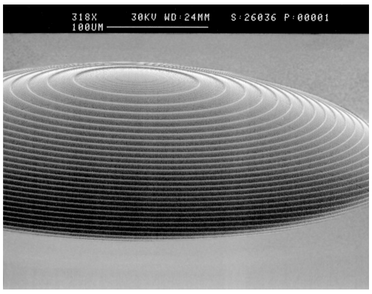

Fig. 6: Diffractive lens on a refractive lens, 50µm height

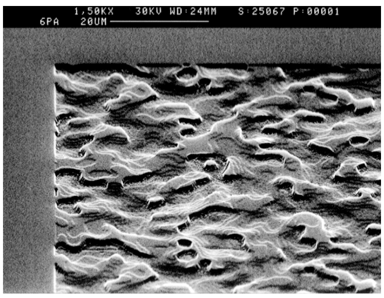

Fig. 7: Diffractive optical element
8 level, 250 nm pixel size

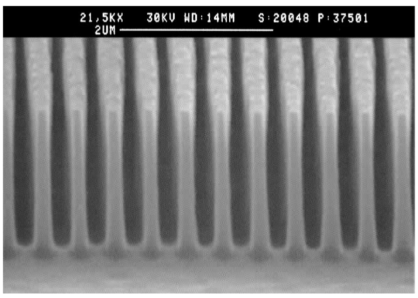

Fig. 8: 440 nm period grating in quartz, 2000 nm depth