

Fabrication of Aspherical Microlenses in Fused Silica and Silicon

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Abstract

We report on the manufacturing, testing and packaging of microlens arrays and micro-optical systems. We will present applications in photolithography, miniaturized imaging systems, optical networking and sensors.

Microlens Fabrication

Different suitable manufacturing techniques for refractive microlens arrays have been proposed. The most promising technique is the reflow or melting resist technique.[1,2] It uses solely standard semiconductor equipment and processes like wafers, resist coating, photolithography, wet processing, etching, etc. and allows to manufacture large microlens arrays of excellent optical quality and uniformity for wavelengths from the deep ultraviolet to the far infrared.[3]

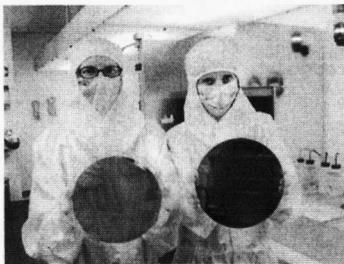
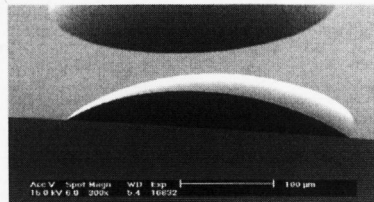


Figure 1. Cleanroom for fabrication of microlens arrays in Quartz and Silicon (200mm wafer size).



Picture by J.C. Roulet, IMT Neuchâtel

Figure 2. Refractive microlens manufactured by reflow technique and RIE.

A thick layer (typically 1 μm to 50 μm thickness) of positive photoresist is coated on top of a fused silica or silicon wafer using a Spin Coater. A chromium-on-glass mask is contact copied in a Mask Aligner. The exposed resist is resolved in a standard developing process. An array of photoresist cylinders is obtained. The resist cylinders are melted at a temperature of 100 to 150°C on a hot plate or in an oven.

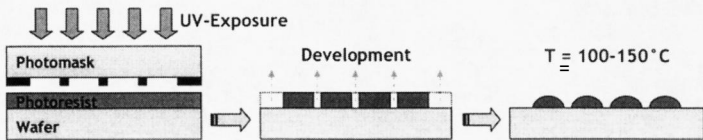


Figure 3. Fabrication of refractive microlenses by photolithography and reflow.

The resist lenses are transferred in fused silica by reactive ion etching (RIE). Atoms from the resist surface and the fused silica are simultaneously removed by energetic ions until the lens shape is completely etched into the substrate. Aspherical lens profiles are obtained by varying the etch rate during the RIE transfer.

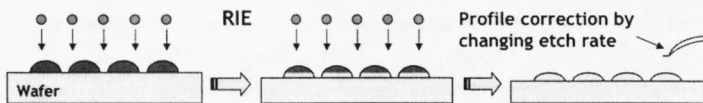


Figure 4. Transfer of the resist microlenses into the substrate by reactive ion etching.

Photolithography, deposition and lift-off techniques are used to manufacture alignment marks, pupil arrays and metal pads on both wafer surfaces.

Interferometrical Testing

A Twyman-Green interferometer [4] is used to test the microlens profiles. The Twyman-Green interferometer measures the deviation of the surface profile from an ideal sphere and the radius of curvature at the vertex. A Mach-Zehnder interferometer [4] is used to test the wave aberrations of microlenses. The Mach-

Zehnder interferometer measures the wave aberrations and the paraxial focal length. Wave aberrations of 0.02λ (rms) and 0.12λ (p-v) corresponding to a Strehl ratio up to 0.99 are achieved.

APPLICATIONS

Wafer Level Packaging for CMOS Imagers

Microlens-based camera systems are currently investigated within the EU-IST Project WALORI.[5] A bio-inspired design approach using multiple imaging channels and a spatial superposition is investigated.[6] Wafer-scale lens manufacturing and wafer-level packaging are the key objectives.

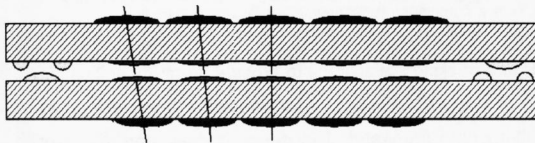


Figure 5. Wafer-level packaging of a microlens-based multi-channel camera systems.

The precise alignment of the different optical layers is performed in a Mask Aligner.

Microlens Projection Lithography

Microlens Projection Lithography is a contact-less photolithographic technique that has been developed for Süss MicroTec Mask Aligners.[7] Microlens Projection Lithography uses an ultra-flat microlens-based projection system consisting of some 100.000 identical micro-objectives side-by-side. Each micro-objective consists of 4 microlens layers. Wafer-level packaging of the different optical layers ensures a precise alignment of the projection system. A fully symmetrical optical design eliminates coma, distortion and lateral color.

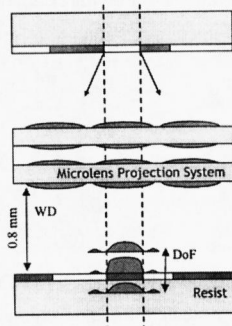


Figure 6. A microlens-based projection system projects a photomask onto a resist layer. Each micro-objective images a small part of the photomask pattern onto the wafer. The partial images overlap consistently and form a complete aerial image of the photomask on the wafer.

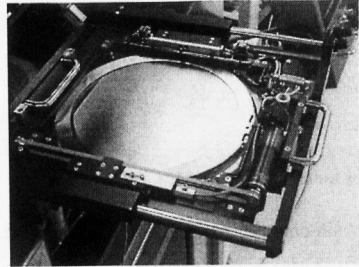


Figure 7. Ultra-flat microlens projection system integrated into a SUSS MicroTec Mask Aligner MA150-MPL. Microlens Projection Lithography allows photolithography on curved or non-planar substrates, in V-grooves, and holes.

The lens system is frontal- and backside telecentric to provide a unit magnification (+1) over the whole depth of focus (DOF). Each micro-objective images a small part of the photomask pattern onto the wafer. The partial images from different channels overlap consistently and form a complete aerial image of the photomask. Microlens Projection Lithography provides a working distance (system-to-substrate) of $WD = 0.8 \text{ mm}$ and a depth of focus $DOF > 50 \text{ }\mu\text{m}$ for a resolution of $5 \text{ }\mu\text{m}$. Due to the extended DOF and the telecentricity Microlens Projection Lithography allows photolithography on curved or non-planar substrates, in V-grooves, and holes.

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 - 2) H. P. Herzig (editor), "Micro-optics", Taylor & Francis, ISBN 0-7484-0481-3 (1997).
 - 3) R. Voelkel, M. Eisner, K. J. Weible, "Fabrication of aspherical microlenses in fused silica and silicon", *SPIE* 4400, 40-43 (2001).
 - 4) Prof. Schwider, University of Erlangen-Nuernberg, Germany
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 - 7) W. B. Hugle, R. Dändliker, H. P. Herzig, "Lens array photolithography", GB patent appl. 9224080.3 (1992), U.S. pat. 08/114,732 (1993).