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Micro-Optics Fabrication and Applications

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Abstract: Demand is growing for micro-optics in 200mm wafer technology. Well-established processes from Semiconductor industry allow cost-efficient manufacturing of almost any micro-optics structure shape.

Keywords: Micro-optics, microlens arrays, microfabrication technology, optics, array optics, beam shaping, beam homogenizer, wafer based manufacturing of optics, wafer level packaging

1. Introduction

Driven by the practical need to miniaturize and by the desire to establish flat and lightweight optics with novel functionality researchers started to focus on micro-optics in the early 80s. The peak of R&D was in the 90s, when a variety of novel fabrication techniques for high- and low-quality micro-optics were developed. Consequently, a number of micro-optics companies appeared. The telecom boom emphasized commercialization. Today, micro-optics fabrication is divided into two parts: niche players supplying key components in low volume for laser, telecom, medical and metrology; and companies supplying high-volume and low-costs micro-optics for the consumer market.

2. Micro-Optics Markets

Most niche players achieved a healthy double-digit annual growth in the last years. In this market, the micro-optics component is a small key element of a bigger device or machine. The quality of the micro-optics has a significant influence on the overall performance and lifetime of the machine. Fortunately, customers are willing to pay reasonable prices.

Fig.1 Microlens arrays for laser beam shaping and fiber coupling.

For consumer market applications, the situation is quite different. Here, costs per unit are the one and only driving force. Micro-optics is printed, moulded or injected in very large volume.

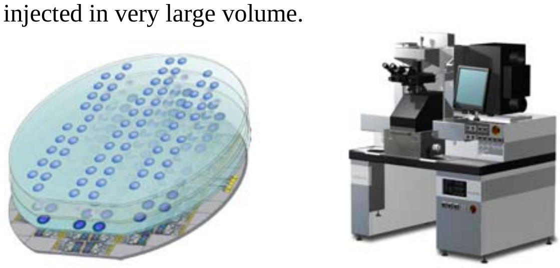

Fig.2 (left) Wafer-level CMOS imager[2,3]. (EU-IST-2001-35366 WALORI); (right) New Mask Aligner MA8E for high precision UV replication of microlenses on 8'' wafers (SUSS MicroTec).

Venture capital is investing in micro-optics companies and CMOS fabs are trying to establish micro-optics know how and capabilities in-house. However, lens material stability during reflow, yield problems in full wafer UV replication technology and patent restrictions bear a certain risk.

In both market segments, the availability of standardized "off-the-shelf" micro-optics is poor or not existing. Most micro-optics is OEM, manufactured on customer's request. Optical engineers seeking for suitable micro-optics have to invest much time and money on the definition, purchasing, packaging and system integration. It is difficult to find the appropriate manufacturer or vendor who supplies micro-optics with good quality and short delivery time. Optical shop testing requires special equipment and training. A key component with a narrow supplier base means high costs and high risks. Therefore, the long-term success and the future growth of the micro-optics markets will depend on education of the customers, availability, and quality and reliability of micro-optical products.

2. Wafer-Based Manufacturing of Micro-Optics

Manufacturing of micro-optics in 200mm wafer technology relies on standard technologies from semiconductor industry, like resist coating, lithography, reactive ion etching, deposition, sputtering, and lift-off. These well-established technologies allow the manufacturing of almost any micro-optics' structure shape on wafer level. As all processes are well established, the quality is merely a question of expertise and budget. Key applications for wafer-based high quality micro-optics are in telecom, laser industry, imaging, inspection systems, and data storage.

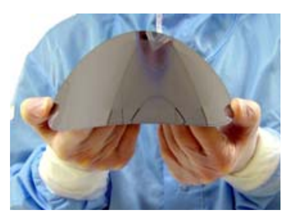

Fig.3 Microlens wafer (Ø 200mm, Silicon) thinned to 140μm thickness.

3. Micro-Optics Testing and Characterization

For characterization and testing, the current situation is different. Neither the test equipment used by semiconductor industry nor the test equipment from classical optics manufacturing is suitable for micro-optics testing.[1] Most test instruments used for micro-optics were developed by research institutes or by the manufacturing companies themselves. As micro-optics remains a niche market, all instruments are built in small series. This lack of suitable test equipment is a major problem for micro-optics manufacturing today.

4. Laser Beam Shaping and Array Homogenizers

Microlens array homogenizers[4] in a so-called fly's eye condenser arrangement are widely used for laser beam shaping. From DUV lithography steppers to IR laser machining the microlens homogenizer provides uniform "flat-top" illumination independent from the laser intensity profile or temporary laser fluctuations.

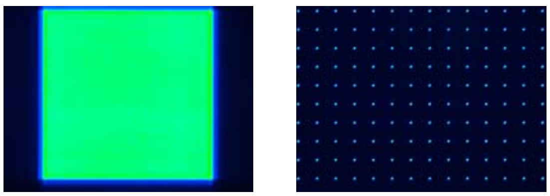

Fig.4 (left). Intensity distribution in the Fourier plane of a microlens homogenizer; (right) A microlens array generator transforms a gaussian laser beam into a matrix of sharp spots.

Array generators allow drilling of thousands of identical small holes in parallel with a single laser pulse. Typical applications are perforating plastic foils in packaging industry and medical applications like skin treatment and cosmetics.

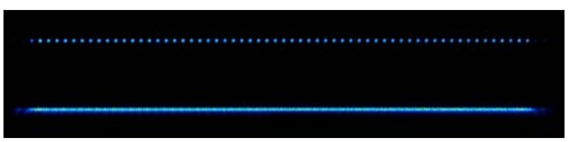

Fig.5 (top) spot pattern from 1D homogenizer and (bottom) using additional linear random diffuser for smoothing.

For laser thermal annealing of amorphous silicon a sharp laser line with uniform intensity is required.

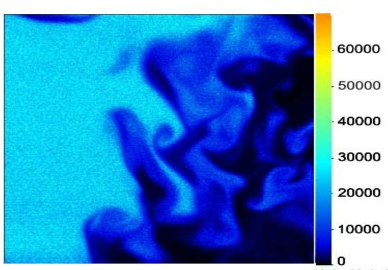

Fig.6 Laser sheet homogenizer: RMS image of the normalized fluorescence signal. Tracer-LIF measurement of mixing field of two different turbulent flows [Courtesy LTT, Erlangen, FRG].

Static and dynamic linear random diffusers are used to improve the uniformity of line homogenizers and laser sheet homogenizers.

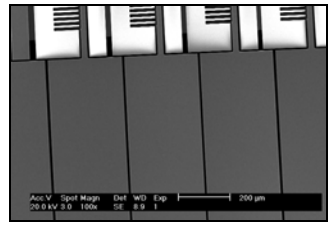

Fig.7 Dynamic Laser Diffuser. SEM image shows linear micromirror arrays with integrated actuators [CTI-Project No. 9143.1 ALBS, Switzerland].

Diffractive optical elements are manufactured in 200mm wafer technology and well suited for high efficient beam shaping of monochromatic laser light from the DUV to the IR wavelength range.

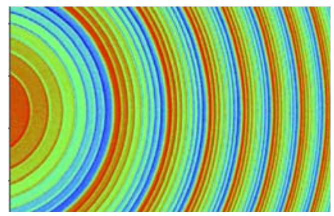

Fig.8 Fresnel-type diffractive optical element.

5. Fiber Coupling - Rotary Joints

Microlens arrays are widely used for fiber-coupling and collimation. Recently compact 2D fiber collimator arrays for data transmission between rotating systems, e.g. radar antennas or for undersea cable installation ships were presented.

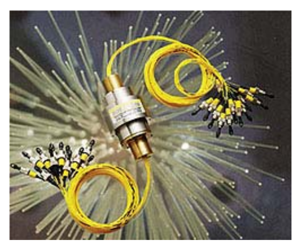

Fig.9 Rotary joints rotating at 100 rpm allowing >10 GBits per channel transmission at < 2dB loss by using mono-mode fibers, microlens arrays and a Dove prism. [Photo by Schleifring]

6. Conclusions

Technology for micro-optics fabrication on 200mm wafer level is well established today. Despite of this, micro-optics is not available off-the-shelf and it remains difficult to find appropriate suppliers for low and high-volume applications.

7. References

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