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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.
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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.

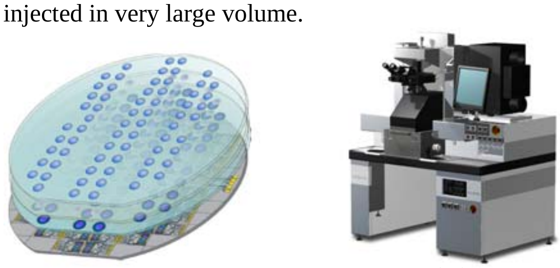

Fig.2 (left) Wafer-level CMOS imager[2,3]. (EU-IST-2001-35366 WALORI); (right) New Mask Aligner MA8E for high precision UV replication of microlenses on 8'' wafers (SUSS MicroTec).

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.

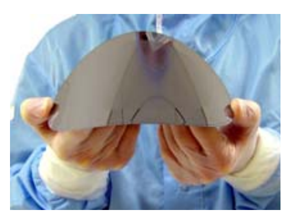

Fig.3 Microlens wafer (Ø 200mm, Silicon) thinned to 140µm thickness.

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.

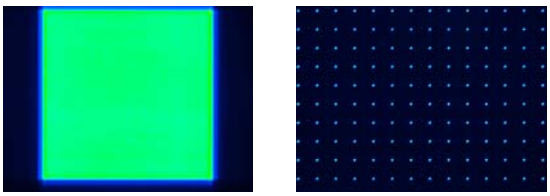

Fig.4 (left). Intensity distribution in the Fourier plane of a microlens homogenizer; (right) A microlens array generator transforms a gaussian laser beam into a matrix of sharp spots.

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.

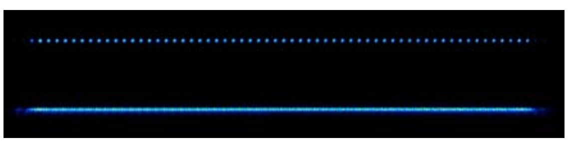

Fig.5 (top) spot pattern from 1D homogenizer and (bottom) using additional linear random diffuser for smoothing.

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

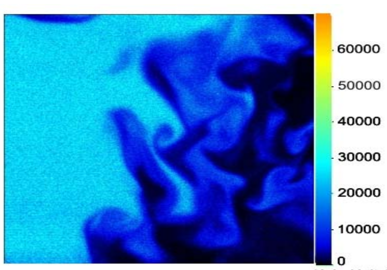

Fig.6 Laser sheet homogenizer: RMS image of the normalized fluorescence signal. Tracer-LIF measurement of mixing field of two different turbulent flows [Courtesy LTT, Erlangen, FRG].

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

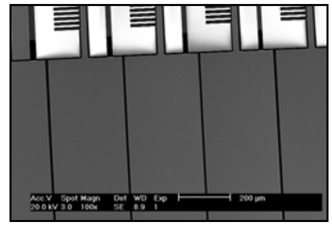

Fig.7 Dynamic Laser Diffuser. SEM image shows linear micromirror arrays with integrated actuators [CTI-Project No. 9143.1 ALBS, Switzerland].

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.

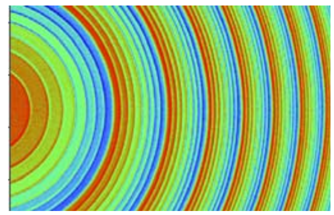

Fig.8 Fresnel-type diffractive optical element.

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.

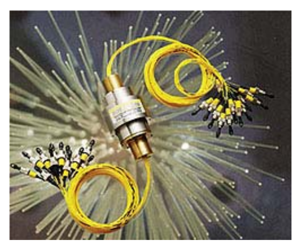

Fig.9 Rotary joints rotating at 100 rpm allowing >10 GBits per channel transmission at < 2dB loss by using mono-mode fibers, microlens arrays and a Dove prism. [Photo by Schleifring]

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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Micro-optics (or microoptics) is the field of optics dealing with particularly small optical components. The small physical dimensions have various implications concerning fabrication techniques, usable optical materials, relevant physical effects, performance limitations and the practical handling. The article is meant to provide an overview on such aspects. Fabrication of Micro-optical Components.Â Note that such a kind of lens is not a separately used optical component, but becomes the inseparable part of some larger devices. That is a typical aspect of micro-optics: most micro-optical elements are not fabricated and sold separately, but rather fabricated as parts of some larger optical microsystems, usually containing multiple components. Due to their unique advantages such as low threshold, parallel operation, symmetrical and circular beam, on-wafer test capability, and high bandwidth modulation, VCSELs now constitute strategic light sources for photonic applications, ranging from optical communications to instrumentation as well as optical storage or printing [1]. Current research on these devices concerns enhancement of emission performances by means of novel confinement designs, spectral.Â In Sections 2 and 3, we review different fabrication methods for passive micro-optics integration on VCSELs, from hybrid report to direct fabrication on device surface. In Section 4, we describe recent advances in the field of active micro-optics for VCSEL beam adaptation to a dynamic environment. Optics on request. Developing micro-optics for new photonic processes can often take multiple iterations of designing, prototyping, trial and error, with each cycle requiring expensive fabrication equipment and many weeks to complete. While this is not an issue for the R&D labs of large optics firms designing new families of products for their customers, university researchers and smaller companies often lack the resources or time to experiment with new micro-optical designs in an efficient and cost-effective way. To address these issues, Dr Matthew Currie, applications engineering manager at PowerPhotonic, a spin-out micro-optics firm from Heriot-Watt University, chose to develop an automated rapid prototyping process for freeform micro-optics as the final project of... Micro optics -custom spectacles make lasers brighter. PowerPhotonic is an Innovative Scottish technology company who design and manufacture custom micro-optics for beam enhancement of laser diode arrays in bars and stacks, providing unique optical solutions using rapidly manufactured optical components. The next generation of optical data storage and solid state laser pumping have contributed to laser diodes becoming a billion dollar industry. The ability to offer increased brightness, wider operating temperature range, and higher efficiencies has also enabled penetration into the defence and ...Â The fabrication of the optical component for this application was carried out by PowerPhotonic Ltd. Bulk optical lenses can focus or collimate an optical beam but there are very few techniques available for the fabrication and integration of scaled down versions of these refractive lenses for use in micro-optics. These techniques are fairly new and werenâ€™t available until more than a decade back. Very thin Diffractive elements can help achieve the same objective.Â Microlithography has been extensively studied in the IC industry and is the process of choice for fabrication of micro optics [1-7]. The process usually starts by exposing a wafer coated with a photoactive polymer through a mask. This polymer is called the photoresist and it can be of two types namely positive and negative tone resists.