A fab approach to precision on glass

HIGH-TECH MANUFACTURING ON GLASS. Micro-optical components, arrays thereof or even complex lab-on-a-chip systems justifiably play an increasingly vital role in technology. For many system integrators, there is no longer an ›if‹ to their adoption, rather a ›how‹ to their manufacture.

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The photonic industry is undergoing an important transition from ›new world R&D‹ to being a mainstream, comprehensive and widely useable toolset for industrial manufacture. This usability extends from the integration of photonic sub-components and sub-systems at various levels into complete solutions, to the utilization of photonics-based tools in the manufacturing process itself, and finally to the utilization of photonics-based instrumentation in the process control.

Many products would not be economically feasable, or their manufacture not technically possible, were it not for the capabilities provided by photonics [1]. This increasing breadth of dependence upon photonics in manufacture, and indeed its recognized role as a key enabling technology in addressing many societal challenges [2], comes as part of the need to achieve greater process efficiency, for example in manufacture. Parallel to this, there is the demand for more feature-rich and capable components and sub-systems in ever more compact formats – not only for consumer goods, but also in measurement technology and in diagnostic and sequencing devices.

For many of the latter (that is, measurement technology and consumables for Life Science), precision microstructures at the sub-µm level on and in glass (**Figure 1**) – from micro-optical components or arrays through to complex lab-on-a-chip systems – play an increasingly vital role. IMT Masken und Teilungen, based in Greifensee in Switzerland, already specializes in this field, but has now set itself the goal of making this technology decidedly more accessible.

Increasing integration

The large majority of the developments within the photonics industry go hand in hand with increasing levels of integration and miniaturization, both of which then also enable high levels of parallelization. Much as was the case for IC development some four or five decades ago, photonics manufacture is rapidly moving toward the adoption (where appropriate) of wafer-level processes to enable miniaturization and volume production at attractive costs. Ready examples can be found by looking to, for example, the incorporation of optical components at the pixel level on CMOS image sensors, or the utilization of photonic integrated circuits (PICs) for data- & telecom components. But while it is the smartphone and internet applications that drive the trend toward integrated functional optoelectronic components, the demands of clinical and environmental diagnostics and sequencing are meanwhile driving the need for accurate, reliable, feature-rich, yet cost-effective lab-on-a-chip systems for point-of-care and other diagnostics.

The current state of play for photonics integration is that, while many of the technological hurdles for achieving suitable levels of integration have already been overcome, what is still missing is the so-called ›fab eco-system‹ as well as the necessary level of demand to support that eco-system [3] – the classic chicken and egg scenario. That is, sufficient infrastructure must be available within the industry so that access to (fab-based and thus cost-effective) manufacture is guaranteed for sufficient numbers of (fab-less) companies so as to make business viable for both parties. One finds an exact analogy of what is required in photonics by looking to the modern-day manufacture of image sensors by a relatively low number of fabs, where the sensors have been designed by a much larger number of ›design houses‹ operating as solutions providers to systems integrators.

Many international projects both EU-wide and worldwide are addressing the aspect of optoelectronics integration – the future of PIC technology will most likely center around silicon and InP photonics [4], as well as hybrid approaches. Certainly within Europe, the few PIC developers and recognized technology leaders in the field are setting themselves up to be the PIC fabs of the future, providing design tools and manufacturing capability to those SMEs seeking to utilize integrated components within their products. Even EU funding is being geared to support adoption of this approach [5].

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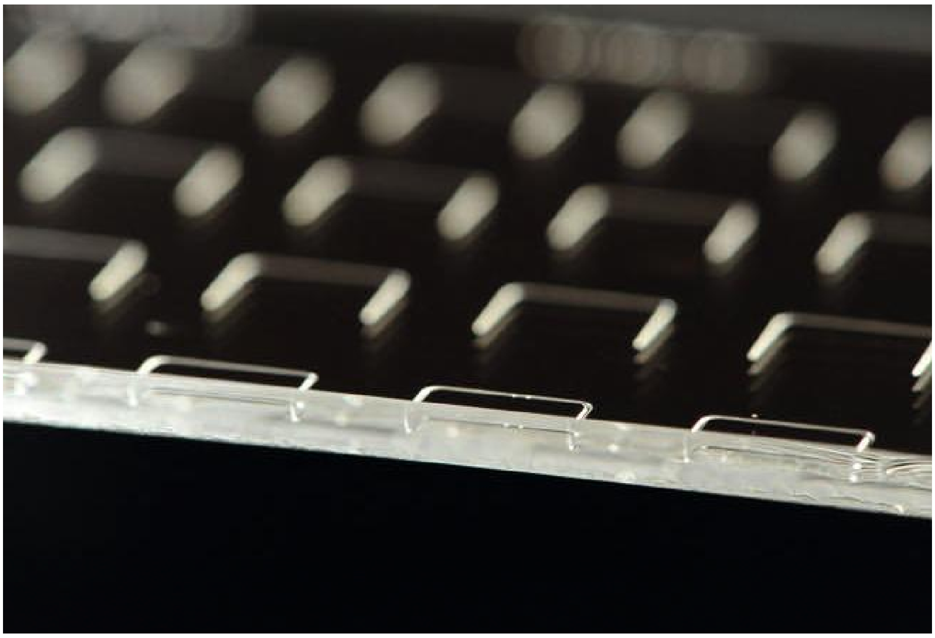
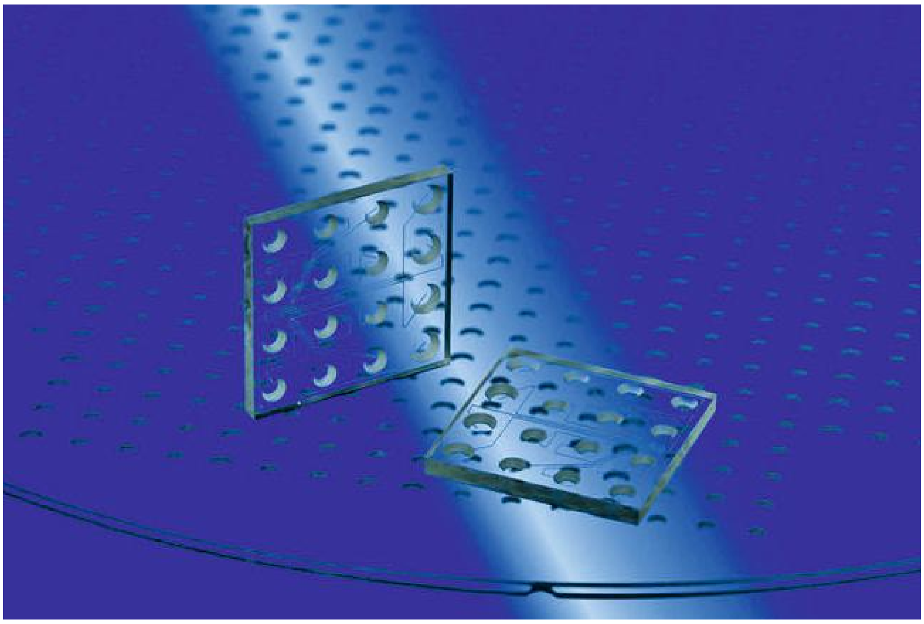


1 This image details a section through a microfluidic channel in glass. However, modern manufacturing on glass allows much more functionality to be attained than just simple channels.

IMT's fab approach for precision on glass

As already mentioned, it is not only integrated optoelectronics components and systems (PICS) that are required. For the aforementioned clinical and environmental applications, the call is much more for cost-effective high-end components in glass that employ multiple technologies (microfluidics, microelectronics, micro-optics, waveguides et cetera) to achieve reliable and complex functionality in a compact format. Some of the required components might even be considered consumables, for whose manufacture the concepts of volume production and wafer-level manufacture and assembly represent the only feasable approach (**Figure 2**).

To make this technology more accessible, IMT has thus chosen to mimic the fab approach – such as that employed in the image sensor industry – for the manufacture of current and future delineated and etched glass components. More exactly, a recent multiple million Euro investment in top-of-the-line fabrication capability will allow the company to act as a fabrication center for a wide range of complex precision on glass systems – designed either internally by IMT itself together with its customers, or by external clients wanting to exploit the fab-less approach for the manufacture of their own component designs. IMT expects that many of the latter will be for high-end, even cost-sensitive (and glass-dependent) photonic and Life Science applications.



2 Consumables for high quantity applications manufactured at the wafer level.

Fabrication systems

At IMT all processes used for the manufacture of glass components and consumables employ equipment that is equally at home in the semiconductor industry. This in turn means that many of those manufacturing aspects so critical to the semiconductor industry – cleanliness, high volume and high yield in combination with cost-effective manufacture, singulation capability et cetera – are also common to IMT's workflow.

3 Automated fabrication and handling systems – here the load-lock of the sputtering system – mean that many of those manufacturing aspects so critical to the semiconductor industry – cleanliness, high volume and high yield in combination with cost-effective manufacture, singulation capability et cetera – are also common to IMT's workflow. (Source: Evatec)

For products displaying two parallel surfaces (for example, a lab-on-a-chip component), the base material is a 200 mm wafer in the specified glass material. Depending on the dimensions of the final component, a 200 mm wafer may contain from four up to several hundred components. For components with different dimensions, special chucks and holders have been designed that, to a very large extent, allow use of automated equipment.

In the initial cleaning process, wafer scrubbers originally designed for the cleaning of silicon have been adapted for cleaning glass wafers, and thus ensure the highest level of surface cleanliness before application of process coatings (for examples, metals and photoresist). This step utilizes automated sputtering chambers (**Figure 3**), processing 16 wafers simultaneously.

The subsequent lithographic processes apply automated mask aligners with a throughput of up to 100 wafers/hour. Automated etching systems allow critical fine etching of metal layers and into glass as well as the removal of the photoresist in tied-in processes.

Final dicing of the glass dies out of the wafer also utilizes automated or semi-automated wafer saws to achieve a dicing accuracy identical to that which is common in the semiconductor industry. Last but not least, proper handling of the wafers early in the workflow, and of individual components later in the workflow, is instrumental in achieving a cleanliness of the finished products that, while standard for semiconductor processes, is still rare for optics and opto-electronics.

Although IMT is already a recognized leader for the manufacture of reticles and gratings, optical coatings, biochip and delineated optical components on glass, these new capabilities will enable the company to offer a greater breadth of services and expands the current capacity from 1.4 million components shipped in 2012 to several million components per year.

Where to manufacture – keep it local

While component integration and miniaturization are certainly one of Europe's major R&D strengths, for some time now conventional wisdom has been that cost-effective volume production and rapid time-to-market can only be achieved by utilizing manufacturing and packaging services based ›abroad‹ (outsourcing). If this is the case, is there any commercial logic in trying to estabish the same type of service in Europe?
There are, however, other aspects to outsourced manufacture that have an indirect cost impact and that critically influence the experience and the practicality. Some of these center primarily around cultural and regional proximity, and are particularly important for the manufacture of cutting-edge components, where the skill set, technology understanding and the working time-zone of both partners need to be at least comparable to ensure both a timely resolution to problems and a guaranteed time-to-market [3].
The reality is that the high-end manufacture of critical components within Europe is anything but ›expensive‹ when all factors are considered. The skill set and technology understanding in photonics in Europe is as high as anywhere else in the world. IMT is just one of the examples where modern automated manufacturing processes are employed in Europe to achieve competitive pricing for high-end consumables for Life Science and for components for optoelectronics exhibiting a leading technical edge.

Summary

Increased levels of integration will be a common feature of future photonics and all other high-tech components and solutions. Establishing various eco-systems within Europe to support diverse approaches to integration is critical to maintaining cutting-edge development, in particular where Europe already has, and certainly intends to maintain, the technological lead. For precision on glass applications – for optical and Life Science applications requring feature-rich systems on and in glass – this eco-system is already being put into place. ■

References

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3 ›Manufacture of Photonics Components: A European Perspective‹, Harlin, prepared for EPIC (*www.epic-assoc.com*).
4 See ePIKfab (*www.epixfab.eu*), EuroPIC (www.europic.jeppix.eu) and PARADIGM (*www.paradigm.jeppix.eu*). All funded by the FP7 ICT programme.
5 ›EC details 80bn Euro innovation proposal‹, optics.org, December 1, 2011 (*optics.org/indepth/2/12/1*). Also see ACTMOST on the web (*www.actmost.eu*).

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