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Pioneering 3D photonic integrated circuits

HITTING THE SPOT: PRECISION FIBER ALIGNMENT

Laser-induced selective etching can be used to manufacture tightly-toleranced 2D hole arrays and, unlike rival methods, offers the kind of adaptability the industry craves.

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Just as the semiconductor industry is struggling with demands to pack transistors on chips at densities previously thought impossible, the fibre optics industry is grappling with the need for ever higher capacity data transmission. A key difficulty in this task is accurately connecting large numbers of often densely packed fibres to the next link in the chain. 2D hole arrays manufactured using laser-induced selective etching offer the ideal solution.

2D hole arrays – into which the end faces of multiple optical fibres are inserted for high-precision fiber alignment – are a key low-loss coupling technology enabling numerous applications, including datacentre interconnects, optical switching hardware, such as reconfigurable optical add drop multiplexers (ROADMs), and coupling to free-space optical systems and photonic integrated circuits.

At present, 2D hole arrays can be fabricated using various methods and materials. For example, a range of lithographic techniques can be used to manufacture precision hole arrays with high levels of positional accuracy. But it can be difficult to control absolute hole diameters, sidewall angles and geometric profile throughout the depth of the material. CNC milling is another option. However, this technique suffers from tolerancing and tooling limitations, especially in achieving the desired aspect ratios for smaller holes, and it is relatively slow in brittle materials such as glass.

RIE or laser processing?

The two techniques best equipped to produce tightly-toleranced 2D hole arrays at scale are silicon patterning and laser-induced selective etching. Currently popular in the industry, silicon patterning involves the same process used to manufacture silicon MEMS devices; reactive ion etching removes silicon material which is masked appropriately to form the shape of the array required.

Meanwhile, laser-induced selective etching is a novel two-stage microstructuring process in glass that uses a focussed ultrashort pulsed laser to induce subsurface material patterning, localised to the focus of the laser beam. By rapidly scanning a 3D shape within the glass, regions of enhanced etch rate are created, such that upon exposing the substrate to a wet chemical etch, the irradiated regions etch preferentially.

Both techniques offer significant advantages over rival methods, including their ability to produce high-density optical ports as well as their inherent speed and scalability. Both methods provide tight control over positional accuracy of the fiber hole center (<0.5µm tolerances) and hole diameter – important factors in reducing insertion loss and ensuring excellent 2D array performance.

Flexible frontrunner

Where silicon patterning and laser-induced selective etching primarily differ is in their adaptability – a crucial factor in a rapidly advancing industry. For example, because silicon patterning relies on existing MEMS technology and fabrication facilities, the tools used to manufacture 2D arrays can only produce standard silicon wafer thicknesses, typically 650 microns thick. Given 2D arrays require thicknesses in the 2 mm range, to provide the mechanical rigidity and integrity to hold the optical fibers in place, three silicon-patterned 2D arrays are often stacked and bonded together to produce the required thickness. This not only creates an additional unnecessary processing step and cost, but also introduces a potential new stackup misalignment error. In contrast, laser-induced selective etching can be performed on substantially thicker glass substrates, such as 2mm.

Another important feature highlighting the adaptability of laser-induced selective etching is the technique's freeform control of hole shape throughout the volume of the substrate. A crucial advantage this brings and a capability silicon patterning does not provide is the ability to form holes at arbitrary angles to the surface of the glass – providing the opportunity to minimise back-reflections, for example. Freeform 3D control also means the hole entrance can be modified to any desired shape. Though silicon patterning can produce a flared hole to allow simple fiber insertion, the flare must be a standard-sized cone shape. Laser-induced selective etching can yield curved or conical flares, of various lengths depending on requirements.

Finally, laser-induced selective etching can produce fiducials anywhere on the glass and in any shape desired. Alignment fiducials etched on the glass can enable automated vision-based alignment, thereby totally eliminating the need for slow and costly active alignment.

About Optoscribe Ltd

Formed in 2010, Optoscribe uses its innovative laser direct write technology to manufacture glass-based photonic components primarily for the telecommunications and data communications markets. Optoscribe's technology allows for 3D waveguide formation and 3D laser induced selective etching with unprecedented design freedom.

Optoscribe's Precision Fiber Alignment Structures (OptoArray™) are capable of solving many of the challenges with the drive for high density optical connections.

The company is located in Livingston, UK, where it has a state-of-the-art manufacturing facility.

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