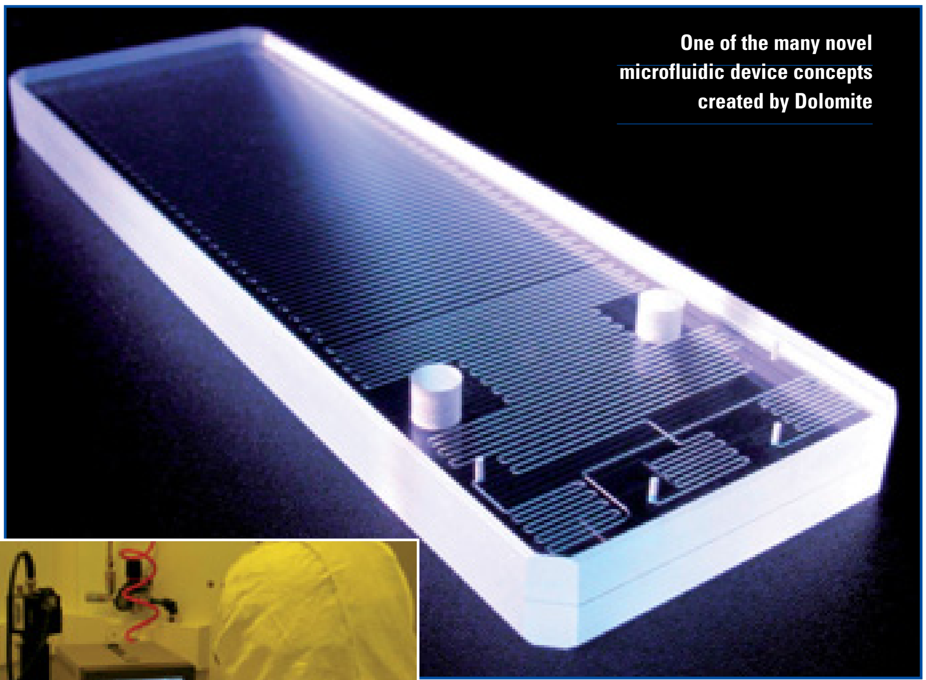
Challenges in new device fabrication

Gillian Davis, commercial director of The Dolomite Centre, looks at some of the requirements and challenges faced in creating a cleanroom capability suitable for realising the commercial potential of microfluidic systems



One of the many novel microfluidic device concepts created by Dolomite

Microfluidic channels viewed on a monitor

Imagine being able to analyse DNA at a crime scene or to have your illness diagnosed at the doctor's surgery without having to wait for samples to be sent away for analysis. These are just some of the revolutionary ideas that may become reality with the advances currently being made in the field of microfluidics. This exciting multi-disciplinary field involves the formation of micron-sized channels and novel features in chemically-resistant wafers. Fluids are then introduced into the channels and moved to regions of the wafer that perform functions such as mixing, filtering, reaction, heating, product separation, isolation and analysis – functions that are currently performed by skilled laboratory technicians as several distinct and time-consuming steps.

The use of microfluidic devices and instruments offers many potential advantages over conventional analytical chemistry practices; including improved reproducibility, faster and more efficient processing, lower sample and reagent consumption, more accurate and faster temperature control and the possibility of realising portable, on-site analysis. The potential to realise such advantages is fuelling growing interest in microfluidics across a broad range of new applications in areas such as environmental monitoring, clinical diagnostics, food and beverage, cosmetics, pharmaceuticals and chemical analysis.

The field of microfluidics is, however, still very much in its infancy, with few commercial applications yet having been realised. The Dolomite Centre, the first Microfluidic Application Centre in the world, is focused on working with clients to turn their concepts for microfluidic systems into commercial products. With its understanding of chemistry and the life sciences, combined with its expertise in glass microfabrication and microfluidics, Dolomite offers a complete service, from device fabrication through to full instrument development.

Complex structures

Key to the development of microfluidic devices is the use of microfabrication techniques capable of creating micro-channels and complex structures in materials suitable for handling chemicals without influencing the analysis process or being attacked. Although there is a wealth of expertise and a wide range of microfabrication tools available for processing complex structures in silicon, its limited chemical stability and lack of optical transparency do not make silicon the material of choice for microfluidic devices.

It is this requirement for chemical inertness and optical transparency that has led to the use of glass and polymers for microfluidic devices. Some of the tools and processes designed for fabricating devices in silicon can be adapted for use with these materials, although some additional processing techniques have had to be brought in from other disciplines or developed from scratch.

Dolomite has chosen to specialise in making devices from glass, since the inertness and biocompatibilty of this material together with its optical properties make it ideal for use in an extremely broad range of applications compared with other materials. However, glass, being susceptible to breakage, cracking, scratching and chipping, is a difficult material to process and handle and this is one of the reasons why there are few suppliers of glass microfluidic devices.

Dolomite has more than 50 years' experience in conventional precision solids-processing of glass, including cutting, grinding, optical polishing, drilling, and thermal bonding. Combining this with more recent photolithographic and wet etching expertise, as well as microfluidic device and instrument design capabilities, gives Dolomite a unique combination of skills to offer its customers.

Development to assembly

A typical series of steps are involved in the fabrication of a glass microfluidic device (see figure 1). The first step is usually to design the components of the chip, including channels, mixers, valves, pumps, separators, and heaters. This requires the use, and frequently the development of software design packages capable of modelling the behaviour of fluids flowing in small channels. Dolomite has proprietary software tools that, together with its expertise in microfluidic systems, facilitate the design of novel devices for customers.

Once the device has been designed, a chrome-on-quartz mask, suitable for use with standard optical photolithographic tools, can be produced. Since typical device features in microfluidic devices are of the order of 5-100μm, proximity lithography can be used to illuminate the layer of photoresist spun onto the metallised glass wafer. Conventional lithographic techniques of exposure, baking, development and etching are used to pattern the photoresist and to provide a mask for the subsequent glass etching step that removes the exposed glass areas.

Over the past few years, demand for deep microfluidic channels has risen significantly, with channels deeper than 50μm often being requested. To meet this need, Dolomite has developed a proprietary acid etch process that can routinely produce channels with depths of up to 300μm and with optical quality surface profile.

Designated clean areas

To ensure device quality, the whole lithographic fabrication process described above is performed in Dolomite's purpose-built class-1000 cleanrooms (see figure 2). Specific areas designated for cleaning and assembly have class 100 status.

Once the microfluidic wafer has been created, conventional solids-processing steps such as drilling, dicing, grinding and polishing are performed. The final step involves sealing the cleaned microchannel using a second glass wafer that is brought into optical contact and thermally fused with the patterned glass wafer.

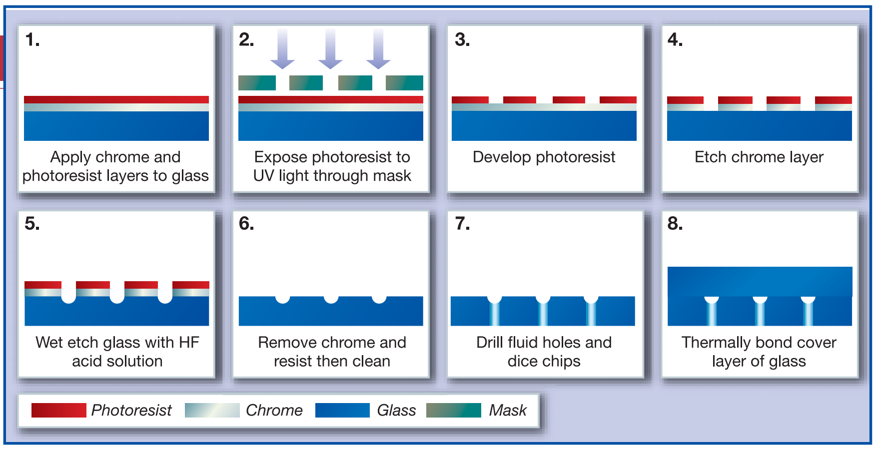
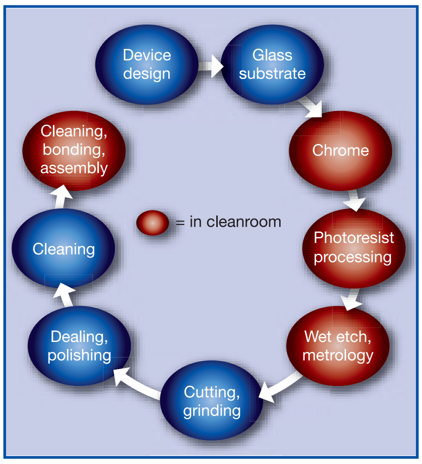


Figure 1 (above): The series of steps involved in the fabrication of a glass microfluidic device
Figure 2 (right): A schematic of the production flow, showing the different fabrication processes that require cleanroom facilities



To fabricate chips with increased fluid volumes or more complex channel geometries, Dolomite has perfected the design and manufacture of what it calls 'double-etched' chips. These chips are generally 2-layer devices with etched features on both layers. One of the challenges of fabricating such 'double-etched' chips is the need to align the features on the two patterned layers before bringing them into optical contact and thermally bonding them to create the microfluidic device.

It was found that standard Flip-Chip techniques didn't have the accuracy needed, and normal mask alignment methods didn't have the flexibility required. To solve this equipment shortfall, Dolomite had to build its own proprietary flexible non-contact alignment method.

Instrument design

The main picture opposite shows some of the novel high quality chips created by Dolomite that are helping customers commercialise their microfluidic device concepts. Realising the device alone is, however, only part of the solution. In contrast to the somewhat similar field of micro-electronics, where component devices are sold into a well established electronics market familiar with integrating such components into products, there is no such established knowledge, capability or market for microfluidic devices themselves.

Customers for such devices often have neither the specialist knowledge of fluid handling required to successfully introduce fluids into or remove fluids from the devices, nor knowledge of the pumps, detectors, heating modules and control systems frequently required to create a fully functioning microfluidic system. Dolomite therefore offers a complete service, from device fabrication through to full instrument design and development.

This article has provided a brief introduction to the growing field of microfluidics and has explored the advantages that the ability to perform complex chemical tasks in a cheap, reliable, portable manner could bring. But despite its similarity to the field of microelectronics, microfluidics has additional unique multi-disciplinary challenges that must be addressed before the full commercial potential of this field can be realised.

With the keen interest currently being shown from the pharmaceutical and chemical industries that see microfluidics as a means to increased speed and automation, wide commercialisation of microfluidic devices may not be so far away.

As a subsidiary of Syrris, a leading provider of productivity tools and flow reactor technologies to r&d chemists, Dolomite is able to combine an in-depth understanding of chemistry and the life sciences with expertise in glass microfabrication and microfluidics to offer a complete service, from device fabrication through to full instrument design and development to its customers. ■

CONTACT

Gillian Davis, commercial director
The Dolomite Centre Ltd
Unit 1 Anglian Business Park
Orchard Road, Royston
Herts SG8 5TW
UK
T +44 1763 242 491
F +44 1763 246 125
www.dolomite-centre.com