LASER MICROFABRICATION OF MULTIFUNCTIONAL DEVICES

Andy Goater, Gary Owen, Julian Burt & Nadeem Rizvi

UK Laser Micromachining Centre

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BIOTECH CHIPS

Complex multifunctional devices used in:

- Cell manipulation & detection
- Drug discovery
- Chromatography
- Virus detection
- Microarray technology
- Proteomics
- Genomics
- Blood analysis
- Microbiology
- Many aspects of personal healthcare

Development phase requires evaluation of numerous designs and concepts → LASERS
Medical devices → Stringent validation and regulatory qualifications (high costs to market)
Mature products → Ultrahigh volume production

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Laser microfabrication allows rapid implementation of design concepts.
Typical chip contains:
- Micro-electrodes
- Micro-channels
- Micro-holes
- Micro-optics

Common Materials:
- Polymers
- Thin metal film
- Glass
- Composites
ELECTRODE LAYER

- 100nm gold on PC (glass is also commonly used)
- Various electrode designs for different functions
- UV laser patterning used to remove gold from substrate
- Different mask projection methods used depending on designs
- All masks made using laser cutting of polymers/metals

Polynomial electrodes  Levitation electrodes  Castellated electrodes
PATTERNING OF ELECTRODES (1)

Stage 1

Details:

- Multiple masks used
- Mask dragging & synchronised mask scanning used

Polynomial Electrodes

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Stage 1: Levitation Electrodes

Details:
- Single mask used
- Mask dragging method produces sets of finger electrodes

Levitation Electrodes 100um
Stage 1

Details:

- Multiple masks used
- Step-and-Repeat method used to cover large area with repeating pattern

100um gap
CHANNEL LAYER

- 250um thick polyester with adhesive on each side
- Different thickness can be used
- Typical channel widths range from 100um – 1mm
- Channel cut in polymer using direct writing

Example of high quality cutting of polyimide

Channel layer after laser cutting
ENCAPSULATION LAYER

- 1mm thick glass slide with through holes
- Different thicknesses can be used (down to ~50-100um)
- Typical holes size ~1mm (100um to 2mm holes also used)
- Holes cut in glass using direct writing
- Edges of glass also profiled to allow for electrical connections

Example of high quality drilling of glass slide

Glass slide after laser drilling and profiling

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ASSEMBLY OF CHIP

- Electrical connections are made with electrodes.
- Continuity and shorting tests are conducted.
- Channel layer is aligned and bonded to electrode layer.

- Encapsulation layer is cleaned and port assemblies are prepared.
- Port assemblies are bonded over holes in glass.

- Encapsulation layer and channel layers are aligned and bonded together.
- Complete chip is tested for leaks and flow.
COMPLETED DEVICE

Assembled prototype device during final testing phase.
Devices can also incorporate optical elements (e.g. microlenses, waveguides) for interrogation of chip performance and enhanced functionality.

50μm diameter microlenses in polycarbonate made with UV excimer laser.

100μm wide waveguide with lenses on each side, machined in polymer layer.

Courtesy D.Morris & J.Burt, UWB (Optical Biochip project).
PROTOTYPE TO PRODUCTION

All elements of prototype chip can be automated for high volume production

- **Gold coating of substrates**
  Batch process, can be made on wafer scale.

- **Patterning of electrodes**
  High-speed laser patterning (or photolithography).

- **Channel layer**
  High-speed cutting of polymers (reel-to-reel system).

- **Encapsulation layer**
  Cutting and drilling using high power (speed) lasers.

- **Alignment & bonding**
  Automated pick and place equipment can assemble devices.

- **Electrical connections**
  Automated wire bonding.

- **Inlet/Outlet ports**
  Automated handling and alignment systems place and bond.

- **Testing**
  Fluidic and electrical tests can be conducted automatically.
SUMMARY

The prototyping of a multi-level device has demonstrated:

- Ability of lasers to machine variety of materials and structures with high precision and quality.
- Great advantages of lasers during prototyping phases to evaluate designs quickly and cost-effectively.
- Implementation of multiple micromachining strategies in a single device to produce different features.
- Scalability – the process development work carried out can be used for automated manufacturing (i.e. laser processing is not ‘dead-end’).
CONTACT

Dr. Nadeem Rizvi
E: n.rizvi@uk-lmc.co.uk
T: +44 (0)1248 383662

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