Spark Assisted Chemical Engraving (SACE)
An innovative technology with high potential for industry

L.A. Hof, R. Wüthrich
Electrochemical Green Engineering Group
Department of Mechanical and Industrial Engineering
Concordia University
Our Mission

*Develop green advanced manufacturing technologies meeting the demand of the fourth industrial revolution*
Our Expertise

Glass Machining
- Lab-on-Chip
- Multilayer chips
- Micro- to Macro-world interfaces

Post-Processing
- Multiscale electro-polishing
- Down to Ra of 50nm
- Broad range of materials including Titanium

Coating
- Complex parts
- Wide range of substrate materials
- Tuning surface wettability

Industry 4.0
- Batch Size 1 production
- Internet of Things (IoT)
- Ultra low-cost tooling
Electropolishing

Design it

Print it

Polish it

Use it

Counter electrode (CE)

3D printed CE holder

SLM part

Counter electrode (CE)

Roughness Profile SLM part Ti-alloy

Potentiostat

Workpiece

Reference electrode

Counter electrode

Electrolyte

Before EP

After EP

Ra 13.9 μm
Rz 50.42 μm

Ra 1.8 μm
Rz 0.26 μm
Room Temperature Nanocoating

400 µm through glass via Ni plated

Hydrophilic coating

Hydrophobic coating

Ra ~ 500 nm
Internet of Things

PC, Tablet, Smartphone, ...

IoT Device

Application Code

GeCo Library

Local Access over LAN

Back Office

Remote Data Acquisition
Glass Micromachining

- Med Tech
- Watch Industry
- Consumer Electronics
- Rapid Prototyping
Applications

MedTech
- Lab-On-Chip
- Multilayer chips
- Micro- to Macro-world interfaces
- Micro-cutting

Watch Industry
- Watchglass cutting
- Inner parts
- Anti-counterfeiting marks
- Localized glass strengthening

Consumer Electronics
- Drilling for Trough Glass Vias
- Micro-cutting of glass including thin (<300μm)
- Micro-cutting of hardened glass

Rapid Prototyping
- Industrial R&D
- Fundamental Research
- Surface engineering
- Batch Size 1 production
SACE Principle

- Chemical etching of glass by OH radicals
- Thermally catalysed
- Local flushing of electrolyte and heating of work-piece determines machining speed and quality
- Reaction:
  \[ \text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O} \]
Machinable materials

- Silicon oxide based materials
  - Pyrex
  - Mempax
  - BF33
  - D263T
  - AF32
  - B270
  - ...

- Glass
  - Corning Gorilla
  - AGC Dragontrail
  - Schott Xensation

- Quartz
  - Tempered Glass

- Vitreous enamel

- Silicon
Flexible Machining

Drilling

Milling

Cutting

500 µm
Ø 300 µm
1x1mm
6mm
Machining Specifications

<table>
<thead>
<tr>
<th>Machining Type</th>
<th>Specifications</th>
</tr>
</thead>
</table>
| Drilling             | • 150 μm < Ø < ∞  
                         | • 0 < depth < several mm  
                         | • 1-5 s down to 700 μm  
                         | • vertical to tapered holes (0 to 90°)  
                         | • aspect ratio 1:10 |
| Milling              | • 20 mm/min at 200 μm depth of cut  
                         | • several mm deep  
                         | • tolerances on channel width: 5 %  
                         | • aspect ratio 1:10 |
| Micro-cutting        | • 10 - 20 mm/min  
                         | • depth: 4 - 5 mm |
| Polishing            | • Very rough to very smooth surfaces are possible |
Micro-drilling of glass

Roundness error: < 2μm

∅ 380μm

1mm deep
1:5

50μm
Micro-milling of glass

Tool feed: 20 mm/min
Channel depth (one pass): 110 µm

300 µm

2.5D Machining

1x1 mm

Ra=1.2 µm

Clean cut
2.5D machining of glass

- 1 mm thick
- No burs
- No debris
- Straight side walls
- Accurate Z control
- Sharp edges
- 20 μm
SACE polishing (SACP)

Glass thickness: 500 μm

Rough cutting

Intermediate polishing

Polished

20μm

<1μm
SACE polishing (SACP)

100 µm
Idea-to-realization

- Design tooling
- Print tooling
- Design part
- Machine glass

- Low forces (~ 5 mN) exerted on workpiece during SACE machining → custom tooling can be 3D printed with ABS (= corrosive resistant)
- No need for extra fixtures
- No disturbing of local electrolyte flow → high machining quality

- Ultra-customized parts
- Low batch size fabrication
- Industry 4.0 compatible
Microfluidic for Medical Applications
Direct glass-to-glass bonding

SACE machined structure
No bulges /debris

Glass-to-glass fusion bonding

Glass - cover

Acoustic Microscope (Sonoscan®)
• Non-destructive testing
• Monitoring defects (e.g. voids, cracks)

No defects

Y-mixer
Microfluidic Connection

Glass

Tube connector

Glue

Glass

Tube connector

Glue

R = 250 µm

entrance

bottom

800 µm

1100 µm

200 µm
Industrial Production

- Mass and flexible production: prototyping small series, batch size-1, industry 4.0
- Modular concept with various number of heads
- Clean-room compatible
- Mask free process
- No tooling costs
- 2.5 D machining
- Burr and micro-crack free machining
Current industrial partners
What we offer

Continuing education

Laboratory analysis

R&D projects

Collaborative platforms
THANK YOU

Electrochemical Green Engineering Group

http://ege.encs.concordia.ca

Follow @ege_concordia