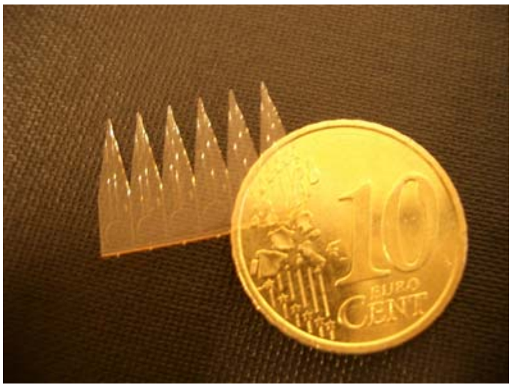
MICRONOVA
CENTRE FOR MICRO- AND NANOTECHNOLOGY
TKK – HELSINKI UNIVERSITY OF TECHNOLOGY

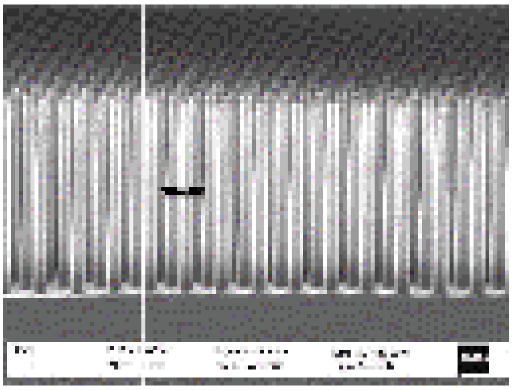
Microtechnology group

MICROELECTRONICS CENTRE

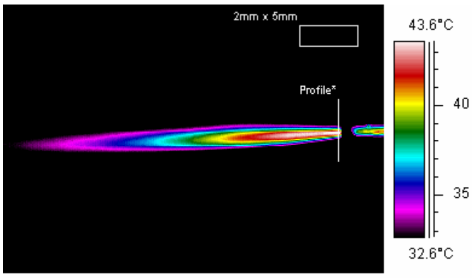
The Microtechnology group focuses on micro- and nanofabrication for fluidic, chemical and thermal systems. We study silicon, glass and polymer materials and fabrication techniques, especially patterning (thick resists, nanopatterning, etching, imprinting, casting), thin film deposition and wafer bonding. The devices we have fabricated include various mass spectrometry interface chips (ESI, APCI), separation systems for small molecules and proteins (CE, ITP, IEF, SDS-PAGE), gas sensors and biosensors and specialty thermometers for cryogenics. We are also involved in fluidic simulations, micro- and nanobeads in fluidic systems and fluidic interconnects to the macroworld.



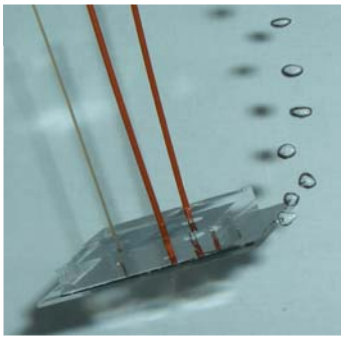
Electrospray tips made of SU-8



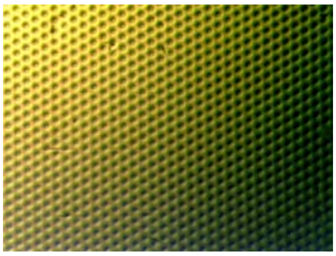
Cryo-DRIE etched silicon pillars



Gas jet from silicon/glass nebulizer



Fluidic connectors in PDMS



Micropatterned steel

29.11.2005

www.micronova.fi

RESEARCH AND EXPERTISE

Silicon microfabrication

Our fabrication line is geared for 100 mm wafer size. The same set of equipment is used for both research and for student labs (MOS-transistor course, and MEMS IR-emitter course).

- **Anisotropic wet etching**

Anisotropic wet etching in TMAH or KOH solution is one of the basic process in silicon microfabrication. The technique is based on the dependence of etch rate on the crystallographic orientation with (111) plane as the slow etching plane.

Anisotropic wet etching has been used to fabricate deep and smooth channels in silicon for Atmospheric Pressure Chemical Ionisation (APCI) chips. Optimisation of the mask with corner compensations and KOH etch and selectivities with IPA additions has enabled more complex mixer and nozzle shapes to be fabricated. Double-side alignment and etch from the both sides produces the inlet holes.

Thin silicon membranes were prepared by anisotropic wet etching in TMAH solution. Monitoring of the etch rate allows to make the membranes of few tens of micrometers without any additional etch stop technique. Those membranes are further processed for filters and separators by etching holes by subsequent electrochemical etching (porous silicon) or by plasma etching (RIE).

Highly boron doped layer can act as an etch stop, and this was exploited in fabrication of infrared emitters (or microglows). The shape of the emitter bridges was pre-determined by lithography step, and after initial pre-etch in plasma, the bridges were completely released by etching in KOH.

- **Electrochemical etching**

Electrochemical etching of silicon is attractive because the possibility to tune the pore size from a few nanometers to a few tens of micrometers, just by choosing wafer doping level and etching conditions. The porous layer thickness can reach hundreds of micrometers. Such a wide spectra of porous silicon layers and relatively simple formation technique lead to extremely wide area of possible applications.

In our group we are using electrochemical etching technique to fabricate thin porous membrane filter for biomedical samples. Depending on the purposes – filtration of microbeads, preconcentration of polymer samples or separation of nanometer-sized particles – macroporous (pore diameter about 1 µm) or microporous (pore size about 20-30 nm) silicon layer is prepared from the thin (10-40 µm) silicon membrane.

Porous silicon was successfully applied as a sample plate in DIOS (Desorption Ionization On Silicon) technique. Traditional MALDI (Matrix Assisted Laser Desorption Ionization) is based on special polymeric matrix material which itself produces additional peaks into mass spectrometry signal, increasing the noise level, especially in the low-mass region. Replacing the polymer matrix by porous silicon layer reduces noise and therefore increases sensitivity of the low-mass molecules. These chips have been successfully applied for drug molecule detection.

Electrochemical etching offers a way to produce the high-aspect-ratio-microstructures (HARMS). In the case of macroporous silicon, the ratio of pore depth to diameter can reach 100:1 or more.

Porous silicon layer is a good thermal insulator, what can be applied for making miniaturized IR-emitters or heaters. We are making the microglows, there the gap under the structure is replaced by thick microporous silicon layer, improving this way the mechanical strength of the fragile cantilevers and beams. Other option is to use porous silicon as a sacrificial layer replacing the deep anisotropic wet etching). In that case, the structure release can be done as a last operation, and less care must be taken to protect the metal contacts. Both those techniques are included into “Microglow” laboratory course, where students are getting the basic skills in silicon microtechnology.

- **DRIE**

DRIE etching of silicon provides good anisotropy, high etch rate and high selectivity. At the same time the profile control is precise and undercutting small. These qualities make possible to create high aspect-ratio structures. Both nanostructures and through-wafer etching can be accomplished.

Our ICP-DRIE system employs SF_6/O_2-based high-density plasmas at cryogenic temperatures. The etch rate of the silicon can be as high as 6 µm/min and selectivity of silicon with respect to silicon dioxide approximately 200. Standard photoresist masking (ca. 1 µm AZ-resist) is suitable for etch depths below 50 µm, and thick negative resists can be used for deep etching.

- **Bonding**

Anodic bonding is the mainstream bonding technique for silicon/glass bonding, and we have applied is also to glass/glass bonding with intermediate a-Si layers. Glass/glass fusion bonding is also being investigated. SU-8 photoepoxy adhesive bonding is described below.

Polymer microfabrication

- **SU-8**

SU-8 is thick epoxy based photoresist suitable for patterning of other layers or it can be applied as structural material for devices. SU-8 is patterned from micrometre up to millimetre thicknesses with standard UV-aligner. Width of structures is in micrometer scale. Very accurate wall profiles and thick layers make it suitable material for DRIE etch mask or for electroplating. We have used SU-8 to fabricate accurately defined mechanical parts and microfluidic components. Microchannels are enclosed with full wafer adhesive bonding technique developed in-house. The technique results in high quality microchannels with good yield. Microchannels have been used for analytical separations detections and researching of basic microfluidic properties. Size range of the enclosed microchannels of SU-8 is from 10 * 10 µm channels up to millimetres wide channels. SU-8 enables easy fabrication of complex channel geometries and also integration of more advanced features like electrodes or detection systems.

- **Micro Contact Printing**

Stamps of (Poly)dimethylsiloxane (PDMS) for microcontact printing (µCP) are fabricated by moulding the liquid prepolymer mixture on a master made of silicon. The polymer is then cured at elevated **temperatures and released from the master. The stamp is used for chemical patterning of surfaces. We are currently working on the fabrication of submicron structures.**

- **Embossing**

UV-embossing is used to form structures utilizing transparent PDMS stamp and UV light. Stamping of different polymer materials have been tested. Ormocers are hybrid inorganic/organic polymers, which are used in optical applications. We are developing methods to use ORMOCERs in microfluidic devices. Microfluidic channels with various widths have already been fabricated.

Fluidic chips

In most of our projects we concentrate on fabrication issues and our collaborators in chemistry, biotechnology and medicine are responsible for applications research. Design of the microfluific chips is the interface between fabrication and application. Layout design and mask fabrication are our responsibility.

Nebulizer chip for mass spectrometry involves design and integration issues like temparature range and uniformity, nozzle size and shape, dead volume minimization, interconnects with capillaries, surface adsorption, and others.

Electrospray Ionization (ESI) microchips for mass spectrometry are small polymer nozzles suitable for spraying fine spray of analytes. Lithographically defined nozzles are optimized to give stable spray with electric field only or with pressure assistance. Stable material selection without background contamination or other interference with materials has to be avoided.

Electrophoretic separations on microchip require fabrication with accurately defined microchannels. Enclosed channels should have all walls from the same material and uniform channel shape in centimetres long channels. Polymeric electrophoresis channel are made with lithography based wall definition and adhesive bonding.

SPE/CE chip design with a large volume bead filter reservoir involves flow field and electric field design, bead trapping efficiency, injection volume considerations and detection (LIF or conductivity).

Protein chip with 2-stage separation according to IEF (isoelectric point) and SDS-PAGE (molecular size) involves important scaling issues as there is very little experience in scaling these systems down in size. Surface-to-volume ratio considerations, materials interactions, fluid transfer and system partitioning issues have been studied.

We have also been carrying out research on magnetic microbeads in fluidic channels with integrated nickel micromagnets.

Chemical and Biosensors

We work in close collaboration with TKK Laboratory of Inorganic and Analytical Chemistry on electrochemiluminescnece sensors for biochemical analysis. These devices are based on cathodic voltage pulse which emits hot electrons through a thin (4 nm) tunneling oxide into aqueous solution, where they are involved in high energy electrochemistry. Extensive work has been done on the formation by thermal oxidation of ultimately thin oxides on highly doped silicon, for use as tunnelling electrodes for electrochemiluminescent (ECL) analysis by aqueous hot electrons.

Thermal microsystems

A testbed chip for gas sensor research is being developed in collaboration with Environics Oy, utilizing integrated heating, heat sensing and electrode structures. The microhotplate-type component will be a complete gas sensor after deposition of a gas-sensitive material over the electrode structures by e.g. atomic layer deposition (ALD). Major issues are temperature uniformity, power efficiency and long-term stability of the sensor, and compatibility with a range of ALD deposition processes.

For low-temperature measurements, a novel type of micro-scale Coulomb blockade thermometer (CBT) is being developed in collaboration with the TKK Low-temperature laboratory. A CBT consists of a metallic island with measurement electrodes connected via tunnel junctions, or more commonly, several such devices in series, and can be used to measure temperatures in the millikelvin range.

Other research topics

Fluidic simulations have been carried out in collaboration with CSC (The Centre for Scientific Computation) with Dr. Thomas Zwinger. ELMER FEM-program has been used to study pressure driven and electroosmotic flow in mixed material polymer fluidic channels. FEMLAB (Comsol Multiphysics) program has been employed to visualize gas jets from mass spectrometry chips.

In addition to traditional microfabrication materials we have also been involved in microprofiling steel, in collaboration with Dr. Yuriy Yagodzinskyy, TKK Laboratory of Engineering Materials.

STAFF

We are currently 3 PhDs, 4 PhD students and 3 undergraduates.

MAJOR FACILITIES AND EQUIPMENT

Microtechnology group utilizes Micronova cleanroom facilities for processing on 100 mm substrates. Post-processing with exotic and contaminating materials is carried out in MEMS and Thin Film labs outside the cleanroom.

CONTACT

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MORE INFORMATION: http:/micronova.tkk.fi/...

Recent Publications:

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