Hamburg University of Technology
Department of Micro Systems Technology

A High-Performance Vapor-Jet Micropump For Miniaturized Mass-Spectrometers

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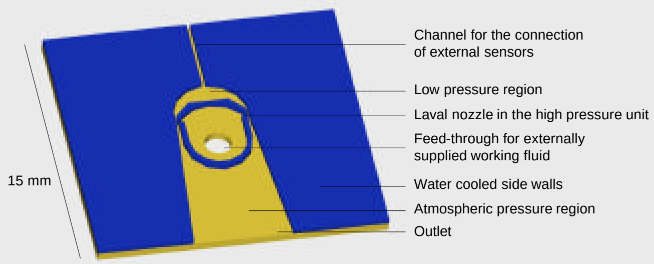
Objective

- Development of a micromachined vacuum pump for miniaturized analytical instruments (e.g. a micro mass spectrometer)
- No moving parts to increase the long-term functionality
- High performance: Generation of low pressure and a high pumping speed starting from atmospheric pressure
- Full integration for small size and low power consumption

Design and Fabrication

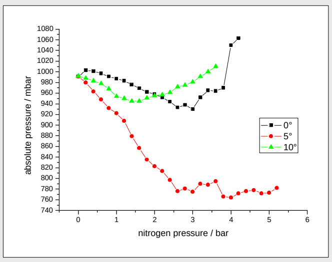
- Design based on macroscopic diffusion pumps
- A high pressure gas or vapor expands through nozzles
- Pumping is achieved via momentum transfer of the gas- or vapor-jet to the gas molecules in the low-pressure region
- The vapor condenses on the cooled side walls
- The first design uses externally supplied N_2-gas or water vapor to verify the pump principle in a microsystem



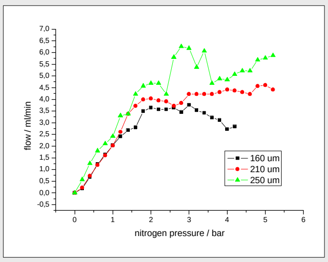
- The pump is fabricated on a silicon substrate (100µm) between two anodically bonded borosilicate substrates
- DRIE (ASE®) is used for the silicon through wafer etching

Characterization

- Externally supplied nitrogen gas or water vapor
- Measurement of pressure and flow by external sensors



Absolute pressure in the vacuum region as a function of nitrogen pressure inside the high pressure unit for different side wall angles.

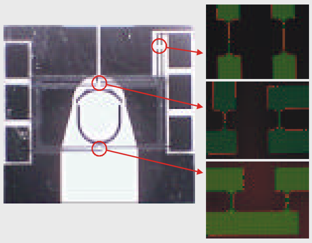


Pumping speed as a function of nitrogen pressure inside the high pressure unit for different distances between the nozzle and the side wall.

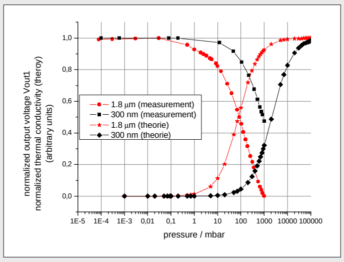
- Pump principle is proven to be working in a microsystem
- Optimum nozzle and side wall geometry are determined
- Minimum pressure obtained using water vapor: 495 mbar abs.
- Maximum pumping speed obtained: 6.2 ml/min

Integrated Pirani pressure sensor

- Measurement of the pressure dependent effective thermal conductivity (?) of a gas
- ? is pressure dependent when the mean free path of the gas molecules is limited
- Setup: Free-standing platinum bridge at a defined distance to the substrate which acts as a heat sink
- Measurement of the resistance of the free-standing bridge
- The distance between the heated bridge and the heat sink determines the measurement range



Micro vapor-jet vacuum pump with integrated Pirani pressure sensors in a full bridge circuit



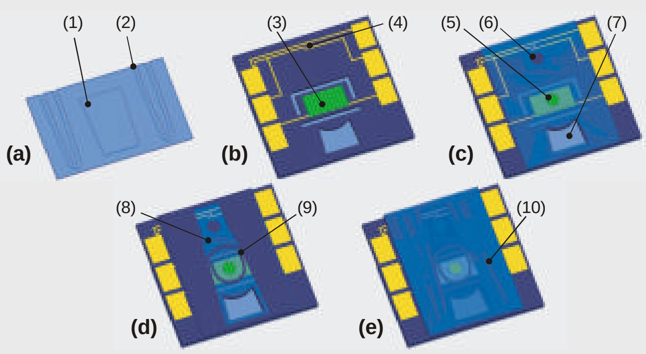
Normalized output voltage of the sensor and normalized theoretical thermal conductivity as a function of pressure

- Measurements correspond well with theory
- Simple fabrication process with only two mask steps using ZnO as a sacrificial layer for the free-standing bridge

Outlook

Integration of the working fluid circulation

- Evaporation of a liquid working fluid by a platinum heater coil through a porous silicon membrane
- Hydrophobic coatings (plasmapolymerized PTFE, MVD) are used to guide the condensed working fluid to the heater
- The system consists of five anodically bonded substrates



3D-drawing of the currently investigated pump design. **(a)** Borosilicate substrate with a cavity for the working fluid circulation from the high-pressure region to the heater (1) and channels for water cooling (2), **(b)** silicon substrate with a heater coil on a porous silicon membrane (3) and an integrated Pirani pressure sensor, **(c)** borosilicate substrate with a feed through for evaporated (5) and condensed (7) working fluid and an opening between the low-pressure region and the pressure sensor (6), **(d)** silicon substrate with the DRIE fabricated pump body: low-pressure region (8) and nozzle assembly [high pressure unit] (9), **(e)** channels for water cooling of the pump side walls (10) in a borosilicate substrate.

- Choice of working fluids
- Integration of multiple nozzle stages
- Decreasing the generated pressure down to several Pascal