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

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A MEMS vapor-jet pump for vacuum generation in miniaturized analytical systems, e.g. mass-spectrometers, is presented.

As pumps are an essential part of many systems for chemical and biomedical analysis, the development of micropumps is a fundamental challenge in the introduction of microsystems in these fields. Many approaches to realize miniaturized vacuum pumps have been pursued but the proposed pumps use either mechanically moving parts (membranes, valves), which may result in a short lifetime and decreased reliability, or do not meet the requirements for a high pump speed and low pressure generation. In this paper a new approach to micropumps is presented: Based on the theory and design of macroscopic vapor-jet and diffusion pumps, a miniaturized pump without moving parts is designed, fabricated and characterized which meets the needs for a high performance micropump. The microfabricated pump consists of two planar Laval nozzles (20 micron nozzle width) and water-cooled sidewalls. Presently an external supply of the working fluid is used (nitrogen gas, water vapor). As no mechanically moving parts are required, the pump system offers an advanced long-term stability. A detailed mathematical and physical description of the micro vapor-jet pump has been described in [1].
Based on simulation results, various systems with different geometries have been designed, fabricated and characterized. Starting from atmospheric pressure, a high pumping speed of more than 6.2 ml/min and an absolute pressure of 495 mbar were generated with this new type of micropump. The performance will be further improved by the use of different working fluids, multiple nozzle stages and the full integration of a heater and the working fluid recirculation which is already in progress. Different concepts for the working fluid evaporation and recirculation based on porous silicon and active or passive pump mechanisms which are currently investigated will be presented. The size of the complete pump system will not exceed 15 x 15 x 2 mm. The aim is a fully integrated and microfabricated vapor-jet which is capable of generating high pumping speed and low pressure in the range of several Pascal.

Microfabricated pressure sensors based on the Pirani principle have been integrated into the micropump to monitor and control its function. Due to its novel geometry and fabrication process the operating range of the sensors can easily be adapted to different pressure ranges without any change of the layout. An integrated full bride layout is used for temperature compensation. The characteristics of the sensors correspond well with theory and fully satisfy the specifications.

[1] M. Doms, J. Müller, A Micromachined Vapor-Jet Pump, Sens. Act. A, Vol. 119 No 2, Mai 2005, p. 462-467.