A Single Chip Mass Spectrometer in MEMS Technology

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The concept and its experimental proof of a planar integrated micro mass spectrometer (PIMMS) fabricated as single chip is presented. All essential components like the ion source, the ion optics, the mass separator, the energy filter, and the detector are integrated on a chip with a small size (5x10mm²). This size allows an operation of the PIMMS at a pressure of 1Pa (7.5mTorr), which can be generated by a one stage pumping system or a micro pump [1]. The concept and layout of this PIMMS is optimized for cost efficient mass fabrication using only standard MEMS processes.

The function principle is based on electron impact ionization and a synchronous ion shield (SIS) separator. The PIMMS generates ions by electron impact ionization: A microwave plasma electron source [2] provides the necessary electron beam (1 A/cm²) for ionizing the sample gas. This electron beam impinges the sample gas in the ionization chamber. The generated ions are extracted from the ionization chamber, focused by the ion optics, and accelerated to a defined kinetic energy, i.e. their velocity is mass dependent. The SIS mass separator consists of several electrodes forming an ion channel. Within this channel a traveling electrical field is generated by two 180° phase shifted square wave (SW) signals applied to every second electrode. Only ions traveling synchronous with the electrical field pass the separator, the others are filtered out. By varying the frequency of the SW signals a mass interval can be scanned, where a frequency interval of 10 to 35 MHz corresponds to a mass range of 100 to 10 amu, respectively. Between mass separator and detector an energy filter, arranged as 90° electrostatic sector, reduces the negative impact of the distributed start energy of the ions.

The MEMS based fabrication offers the possibility of mass production, e.g. on a 4-inch wafer about 100 PIMMS are processed at the same time. All critical structures are fabricated by a single anisotropic deep silicon etching [3] step, eliminating the need for adjustment between the units of the PIMMS. Each side of these 300 µm thick silicon structures is bonded to a glass substrate with metal structures for contacting the silicon electrodes.

Several gas compositions of carbon dioxide, nitrogen, argon, neon, and air have been identified using the PIMMS. With initial measurements of mass spectra the function principle of the PIMMS was proven, and it is already possible to separate argon (40amu) from carbon dioxide (44amu).

The entire system is very cost-efficient due to its small size and its mass producibility based on one simple photo mask for all critical structures. The vacuum and power requirements for the PIMMS are relaxed compared to those of state of the art mass spectrometers. The PIMMS is predestinated for mobile measurements, portable applications as well as specialized applications in harsh environments.

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[2] J.-P. Hauschild, E. Wapelhorst, J. Müller "A Fully Integrated Plasma Electron Source for Micro Mass Spectrometers",µTAS, Boston, Massachusetts, USA, 2005
[3] Ayon, R. Braff, C.C. Lin, H.H. Sawin, M.A. Schmidt, "Characterization of a Time Multiplexed Inductively Coupled Plasma Etcher," *J Electrochemical Soc*, **1999**, 146, 339.