Advancements in the gas-phase MicroChemLab™

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Sandia's hand-held MicroChemLab™ system uses a micromachined preconcentrator (PC), a gas chromatography channel (GC) and a quartz surface acoustic wave array (SAW) detector for sensitive/selective detection of gas-phase chemical analytes [1-2]. Hybrid integration of these components has been used in the fielded system with great success. This approach has the benefit of allowing optimization of the individual components. Recent improvements in the hybrid integration scheme, such as using ceramic or silicon/glass manifolds, will be presented, as will be system performance against semivolatile compounds and toxic industrial chemicals. Recent improvements in microfabricated preconcentrators will also be presented. In particular, the design and performance of a new, three-dimensional micropreconcentrator will be discussed.

Excess dead volume, cold transfer lines and the relative difficulty of assembly of a hybrid system, have prompted an effort to monolithically integrate the silicon PC and GC with a suitable silicon-based detector, such as a magnetically-actuated flexural plate wave sensor (magFPW). As was previously reported [3], a PC, GC and magFPW have been monolithically integrated using Sandia's SwIFT processing architecture. In this scheme, front-side surface micromachining was combined with back end of line deep silicon Bosch etching to produce both high precision resistive heaters and transducers, and full-wafer-thickness fluidic flow channels. One important consequence of this methodology is the precise definition of thermal and acoustic boundaries for the PC and magFPW, respectively, using a sacrificial silicon dioxide layer trapped within a relatively impervious perimeter of lithographically-defined silicon-nitride. This procedure improved the acoustic performance of the magFPWs by suppressing undesired modes [3]. SwIFT process modules are roughly 2.8 mm x 6.3 mm in size and permitted an important demonstration of monolithic integration of the MicroChemLab™. While much was learned about the fabrication process, magFPW operation and the coating methods needed to functionalize the components, the length of GC allowable in this footprint was too short for effective separation of complicated sample mixtures.

To address these issues, a second generation of the monolithic MicroChemLab™ has been developed. The use of two adjacent modules has allowed the length of the spiral GC to increase from the 2.4 cm length fabricated in the first SwIFT design: one new design has an 8.1 cm long GC; another has an 11.8 cm long column. These are still inadequate for full separations in the field, but will provide useful testing for a limited analyte set. This will, in turn, permit evaluation of the functional features of the monolithic design prior to consuming the many modules needed to realize a full-length, field-deployable design. The 11.8 cm long, 50 micron wide GC mentioned above is integrated with a PC and dual magFPWs. The 8.1 cm, 50 micron wide GC, on the other hand, incorporates a novel magnetically-actuated, torsional resonator pair for sensing. This sensor is potentially more sensitive than the magFPW and, as with the magFPW, is actuated by Lorentz forces determined by an AC current through the device and a transverse, in-plane magnetic field. This chip design also incorporates a preliminary design of a surface-micromachined bypass valve to switch flow between the sampling and separation/detection portions of the overall system analysis routine. This is the first instance of a valve monolithically-integrated in the MicroChemLab™. This paper will describe design and fabrication, as well as packaging and GC coating methods.

References:

1. G. C. Frye-Mason, et. al., MicroTAS 2001.
2. G. C. Frye-Mason, et. al., MicroTAS 2000.
3. R.P. Manginell, et. al., MicroTAS 2003.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.