Micro Ion-Optical Systems Technology [MIST] for Atmospheric Pressure Sources

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Why are we interested in this?
The generation of ions and charged particles at atmospheric pressure is accomplished by a variety of macroscopic design and fabrication means. Recent developments in sources and optics design at atmospheric pressure show that maximum control of ion motion may be accomplishable by very precise control of geometric shapes and orientations of electrode elements and fluidic pathways. These sources feature topologies defined directly to 5-50 nm in complex fluidic fields, flow, heat transfer, and ultimately ion collection efficiency. Microsystems technologies are ideal for integration of MIST devices. Within the microfluidic mass spec instrumentation field there is ongoing interest in new atmospheric ion sources designs for more effective and variable ion generation. Similarly, we are interested in developing new atmospheric-source based fieldable mass spec devices beyond the membrane based undercooled mass spec we had developed in the past (1,2), while designing for maximum ion throughput sensitivity.

Initial work has demonstrated an increase in ion transport into the vacuum region by a factor of three to ten. Since greater ion collection efficiency can permit the reduction of the size of the aperture leading into the vacuum chamber, exponential reduction in vacuum throughput will occur. Our interest then is, how to achieve controlled, efficient ion transport from atmospheric pressure to vacuum pressure to enable continued miniaturization of compact mass spectrometers?

What is the solution? MIST.
The objective of the present studies is to apply alternative (non-silicon-based) microfabrication technologies to generation of atmospheric pressure ion optical devices. We have devised novel materials, processes, and designs for non-optical systems for control of ion field shaping. Ion field shaping of atmospheric pressure ion sources is accomplished using photoresist and metal layers. These materials are being developed with photodefinable bonding materials and various electroformed metals. The choice of MIST means we are driven by the requirement of a low investment process, a material capable of high levels of assembly system integration, while providing a vacuum compatibility competitive to glass.

What worked well: PCBMEMS

We have been exploring ion optical elements for atmospheric ion sources (Fries et al. 2004, Sheehan et al. 2004) in fabricating and control the transport of ions through the interface region between atmospheric sources and the vacuum region of a mass analyzer. This is the new vacuum miniaturization strategy. Ion optical elements are used to increase the focusing of ions from the atmospheric ion generators into the very small differential pump apertures at the interface of the vacuum system reducing the gas load and decreasing the need for power hungry high throughput vacuum pumping solutions.

What material to use?
In making Micro Ion-Optical Systems Technology [MIST] it is possible to employ standard silicon MEMS technology but silicon has limits in area extending the ease of creating 3D systems and in a less reflective material for high voltage applications. We chose to use polymeric dielectrics and metal thin films, a process combination for high field strength applications in our PCBMEMS process flow. Our particular choice for dielectric is Liquid Crystal Polymer.

The laminates we have designed and fabricated are based on liquid crystal polymers (LCP) with photodefinable bonding materials and various electroformed metals. The choice of PCBMEMS was driven by the requirement of a low investment process, a material capable of high levels of assembly systems integration, while providing a vacuum compatibility competitive to glass.

Microfabrication of the polymer dielectric for fluid flow control and the metallization for electrical field control has been devised. We consider these first steps in a process that will ultimately lead us to better understanding of the combined physics (flow characteristics along streamlines, particle size, electric forces, mass and density of atmospheric ion optics resulting in more accurate simulation results, more complex ion optical systems and real control of the ion stream).

LCP Physical Properties

► High refractive index (1.6-1.7)
► Excellent barrier properties (similar to glass)
► High LCP melt temperatures processing
► Low loss tangent (~0.002 at 20 GHz) suitable for high frequency electrical applications
► Controlled low coefficient of thermal expansion
► Good adhesion to metals
► High LCP melt temperatures processing
► Low dielectric constant (~2.9 at 20 GHz) Low dielectric)
► Excellent thermal stability

Metals plating

Deposition (~50 um)

Process flow for PCB technology

Left image: Laser micromachining of Kapton dielectric with metal layer
Right image: Laser micromachining of Kapton dielectric with 50 um laser showing redeposition of material

Structures fabricated on top of structures using the PCBMEMS process

Ions Through the Aperture Array!

Conclusion: First Steps!

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