LiGA Fabricated Quadrupole Mass Filter and Scroll Pump for Meso-scale Mass Spectrometer

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The miniaturization of mass spectrometers is an important goal, not only in space-based missions where size and mass are critical specifications, but also in the new area of homeland defense where field detection of chemical and biochemical threats, as well as conventional explosives is needed.

JPL is currently engaged in developing a Gas Chromatograph/ Mass Spectrometer system comprised of miniaturized components, including quadrupole mass filter, scroll type roughing pumps, gas chromatograph, turbomolecular pumps, and power supply.

A quadrupole mass filter has been fabricated using LiGA technology with ultra thick PMMA, ranging from 3-6mm. Typical poles for this type of mass filter are made of rods with a circular cross section. The flexibility of a LiGA approach allows an elliptical cross section which will create a superior field configuration, and improve sensitivity by at least a factor or two.

The LiGA fabricated quadrupole mass filter will be mounted on a Low Temperature Co-fired Ceramic (LTCC) substrate. The LTCC substrate is multilayered and is used to vertically interconnect the poles to the rest of the system as well as to reduce overall feature size. The height of both the mass filter and the LTCC substrate is 3mm, although poles as high as 6mm have been successfully fabricated.

The successful fabrication of parts of this thickness required experimentation and modification of three phases of the LiGA process: exposure, development, and electroplating. The exposure times for ultra thick PMMA is significantly longer for two reasons. First, the simple fact that the PMMA is thicker means that it will take longer to expose. But secondly, and more importantly, heavy filtering of the softer end of the spectrum is needed to achieve a top-bottom dose ratio as close to one as possible. For these reasons, the exposure of 3mm thick PMMA will take over 3 days at the Advanced Light Source at Lawrence Berkeley Laboratory. For 6mm PMMA exposure times can be as long as a week.

These parts were exposed and developed "free standing" (i.e. not bonded to a plating base prior to exposure). If the substrate is bonded, then even using a megasonic system in the development process may not result in sufficient flow into the bottom of the pattern to achieve a fully developed substrate when the PMMA is sufficiently thick. If the developing solution can attack the substrate from both sides, then the cavity depth is cut in half.

While exposing and developing free-standing substrates is a good thing looked at in isolation, there has been great difficulty in electroplating substrates that were not bonded before processing. For thinner PMMA films, this has not been a problem, but once film thickness grew past 1mm, then it became useful to develop a method of electroplating free standing parts. This was accomplished by creating special electroplating fixtures that mechanically apply a uniform pressure over the substrate surface preventing leaking of plating solution under the mold. These techniques were used to create both the mass filter and the scroll pumps.