Integration of Microfluidics to Electrospray Ionization Mass Spectrometry Using a Chip-Embedded SU-8 Electrospray Tip

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Abstract:
We present two methods for creating polymeric microfluidic devices integrated with electrospray tips for use with mass spectrometry. SU-8 was used to create microfluidic channels and electrospray tips. The planar electrospray tips were located at the end of microfluidic channels and were formed using standard photolithography. The encapsulation of the microfluidic channels was accomplished by using thermal and press bonding between two SU-8 layers, or by employing a sacrificial layer removal technique. We successfully coupled these microfluidic chips to a mass spectrometer. In particular, the microfluidic device fabricated with the sacrificial layer removal method shows satisfactory electrospray stability.

Summary:
Progress towards the combination of microfluidics and mass spectrometry has been promising. In particular, polymeric microfluidic devices have been studied because of their compatibility with mass spectrometry. Recently, polymers including cyclic olefin copolymer and parylene were employed to create microfluidic devices for pre-concentration [1], analyte separation [2] and electrospray ionization [3]. In this work, we present two methods to create an SU-8 microfluidic device with an electrospray tip.

The integration of a polymer-based planar electrospray tip with a polymeric microfluidic device has been achieved without a transfer capillary or liquid junction. By using SU-8, both the channels and the electrospray tip can be patterned accurately. Due to its solvent-resistant property, SU-8 is an excellent material for microfluidic devices. Figure 1 shows optical micrographs and SEM images of the devices. In the first process, pressure and thermal bonding of two SU-8 layers has been used for channel encapsulation. Three SU-8 layers with 14 µm thickness were formed by photolithography. After the deposition of the first tip layer, a gold electrode was patterned using e-beam deposition and photolithography. The microfluidic channels (60 µm x 14 µm cross-section) were deposited on the tip (bottom) layer and encapsulated by a lid layer using thermal and press bonding. Secondly, a sacrificial template of AZP 4620 was employed for channel formation. After the SU-8 channel formation on the tip layer, these channels were filled with AZP 4620 and the sacrificial template pattern was defined by standard photolithography. After deposition and exposure of another top SU-8 layer, the entire device was developed in SU-8 developer. High-pressure use of the device is possible due to the tight sealing between the two SU-8 layers. It is possible to demonstrate the capability of an integrated on-chip polymer electrospray tip. We have monitored the total ion current (TIC) of a calibration sample solution containing caffeine (m/z = 195), L-methionyl-arginyl-phenylalanyl-alanineacetate.H2O (MRFA) (m/z = 524) and ultramark 1621 using both devices. We also present the mass spectra of the calibration sample and the stability of the electrospray through an integrated tip (Figure 2). The TIC from the device using the sacrificial template method yields better electrospray stability (Relative standard deviation (RSD) = 9%) than that from the device using the bonding method (RSD = 23%).

References:
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- Polymeric microfluidic device coupled to mass spectrometry.
- Polymer electrospray ionization tip.
- Encapsulation: Direct bonding, sacrificial layer removal.

Figure 1: (A) SEM image of the electrospray tip. (B) SEM image of the channel cross-section. (C) Optical images of the channel filled with liquid and the electrospray tip. (D) Device picture.

Figure 2: (A) TIC (RSD = 23%) from the device fabricated with a direct bonding method. (B) TIC (RSD = 9%) from the device fabricated with a sacrificial method. (C) Mass spectrum of the calibration sample.