Decomposing polynorbornene
to form millimeter to nanometer sized cavities

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Unity 4671E is a decomposable sacrificial polymer comprised of polynorbonene and manufactured by Promerous LLC (Brecksville, OH). Unity can be exposed by direct electron-beam exposure to create features as small as 60 nm and its low base dose of 10 uC/cm^2 allows for the simultaneous writing of both large features and small features without the long exposures that are typical of electron beam lithography. Unity is decomposable at temperatures higher than 400°C. These properties make Unity a good material for creating nanofluidic devices. In this project, the decomposition of Unity is analyzed for both large and small features to create fluidic devices. To this author's knowledge, the simultaneous decomposition of nanometer to millimeter-sized Unity features has not been previously been studied.

The standard procedure for decomposing Unity is encapsulating it in either an oxide or metal then decomposing in a nitrogen purged furnace at 430°C with a ramp rate of 25°C/min[1]. The Unity polymer decomposes and is vaporized through the encapsulating layer. This procedure works for features smaller than 6 microns. With features larger than 6 microns, the pressure build up from the vaporizing gases cracks the encapsulating layer, destroying the channel (Figure 1).

In this project, Unity 4671E was spun to a thickness of 400 nm onto silicon substrates. The samples were soft baked at 100°C for 5 minutes. The samples were exposed to an electron beam using a JEOL JBX-9300FS system at 100 kV acceleration voltage and 2 nA beam current. Unity is a negative tone resist. The samples were developed for 45 seconds in 2-heptanone and rinsed in isopropanol. After development, the samples were encapsulated in a titanium layer. It was found that a thicker layer of titanium (1.3 µm) prevented the channels from breaking with large features; however the channels were still deformed (Figure 2).

Using a step decomposition method as outlined by Wu et al.,[2] the decomposition rate was controlled by the percent mass lost, instead of temperature increase (Figure 3). The recipe used mimics the temperatures needed to lose mass at a rate of 1 wt% /min (calculated by Wu et al.[2]) with extra time to allow for the diffusion through the titanium layer. The Unity was decomposed in a nitrogen purged furnace with the following conditions: 350°C for 30 minutes, increase to 375°C at 1°C/min for 120 minutes, then increase to 400°C at 1°C/min for 120 minutes, and then increase to 450°C at 1°C/min for 60 minutes. With this procedure, a 2.5 mm basin and a 500 nm channel were written and decomposed through a 4.3 µm layer of titanium (Figure 4). Smaller features sizes (down to 60 nm) have been previously written with Unity, but have not yet been attempted with the larger patterns.

Simultaneous writing and decomposition of both millimeter and nanometer features have a wide variety of applications in both the microelectronics and biological fields. For practical applications of nanofluidic devices, such as lab-on-the chip devices, both micrometer-sized and nanometer-sized air cavities are needed.

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[1] N. Devin, D. Brown, P. Kohl, J. Vac. Sci. Techol. B, **27**, 6 (2009).
[2] Xiaoqun Wu, et al. J., Electrochem. Soc. **150** (9), H205 (2003).

Figure 1: A 20 µm channel that was cracked during decomposition

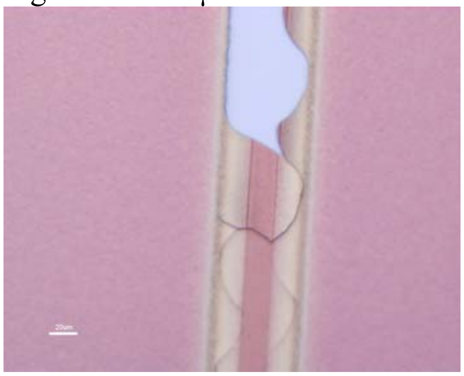

Figure 2: A deformed 20 µm channel coated with 1.3 um of titanium

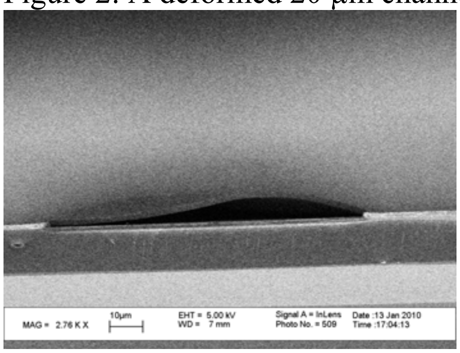

Figure 3: Thermal gravimetric analysis of polynorborene at 1 wt%/min by Wu et al. [2]

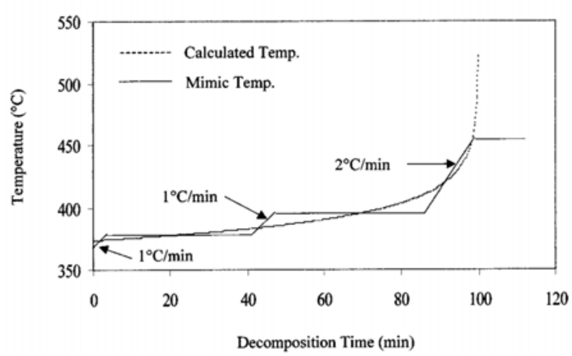

Figure 4: A 500 nm and 2.5 mm channel decomposed through 4.3 µm of titanium