# Patterning Unity 4698P with Electron Beam Lithography to Create Submicron Air Cavities

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Unity 4698P is a decomposable sacrificial polymer manufactured by Promerous LLC (Brecksville, OH). Previously, Unity products (Unity 4481P[1] and Unity 200[2]) have been patterned using photolithography to create micrometer-size air-cavities. In this project, direct electron-beam exposure was used to cross-link and pattern Unity rather than using ultraviolet (UV) exposure. To this author's knowledge, direct electron beam lithography has not previously been used to pattern Unity products.

Unity 4698P is a polynorborene based terpolymer. It was solvent cast from a solution which was 30-50% solids. When Unity 4698P is exposed to UV radiation, a photoacid generator (PAG) creates an acid that catalyzes epoxide ring-opening to achieve polymer cross-linking. After developing, the cross-linked polymer chains remain on the substrate forming the desired pattern. This paper investigates the cross-linking of polynorborene in Unity 4698P when exposed to an electron beam to create submicron patterns.

In this project, Unity 4698P was spun to a thickness of 400 nm onto silicon substrates. The samples were soft baked at varying temperatures. The soft bake temperature affects the dose needed during exposure (Fig 1). After soft baking at 100°C for 5 min, the samples were exposed to an electron beam using a JEOL JBX-9300FS system at 100 kV acceleration voltage and 50 pA beam current. Unity 4698P is a negative tone resist with a low base dose of 5 $uC/cm^2$. The samples were developed for 2 min and rinsed in a circulating water bath for 5 min to minimize residue. Four different developers were tried: toluene, 2-heptanone (MAK), cyclopentanone, and mesitylene. All developers had the same results (Fig 2). The minimum resolution of Unity 4698P achieved was 500 nm.

To test the decomposable property of Unity 4698P, 5 mm long lines with the widths of 2 µm, 500 nm, and 100 nm were exposed on two pieces of silicon coated with Unity 4698P. The pieces were developed in toluene and then coated with 200 nm of plasma enhanced chemical vapor deposition (PECVD) silicon oxide. One sample was decomposed at 430°C in a furnace. Both samples were cross-sectioned and imaged. The unbaked sample clearly had Unity 4698P encapsulated in the PECVD oxide (Fig 3) and the baked piece was hollow with no apparent residue (Fig 4). With the same procedure, air cavities were successfully created using a 200nm DC sputter coated titanium layer in place of the oxide layer. Therefore, Unity 4698P can decompose when coated with either titanium or PECVD oxide. Submicron air cavities can be very useful the microelectronics field. Some potential applications include microfluidics, waveguides surrounded by air, and a low-k option for electrical interconnects.

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[1] Wu, Xiaoqun, *et al*, J. Electrochem. Soc. 150, H205-H213 (2003).
[2] Dang, Bing, *et al*., J..Microelectromechan. Sys.15, 523-530 (2006).

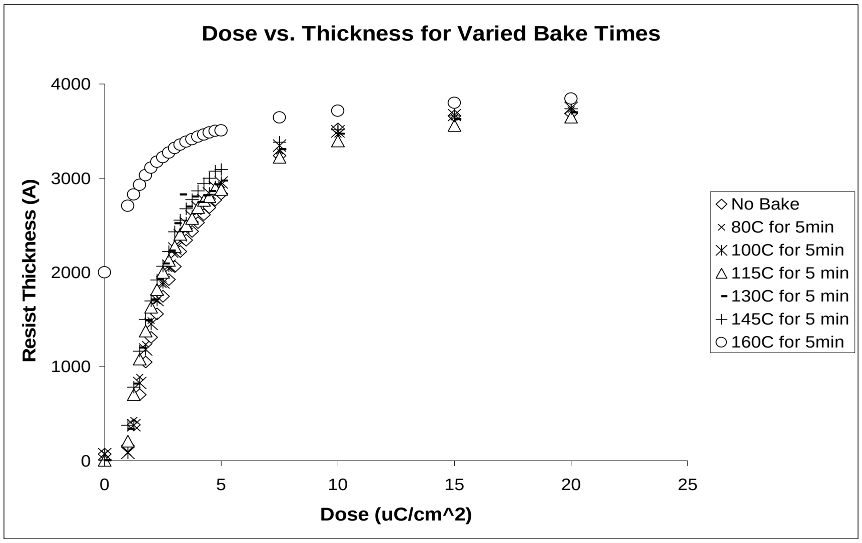


Figure 1: Unity 4698P thickness measured over a dose range for varied pre-bake temperatures

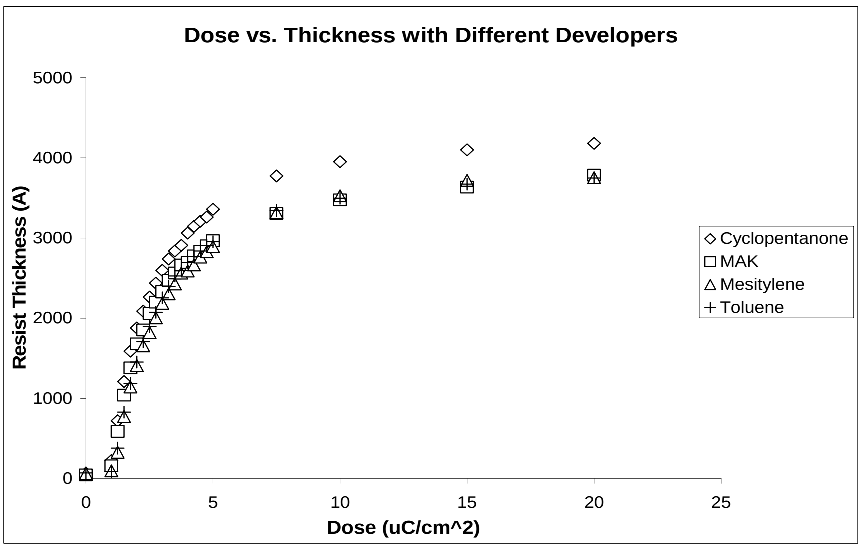


Figure 2: Unity 4698P thickness measured over a dose range with four different developers

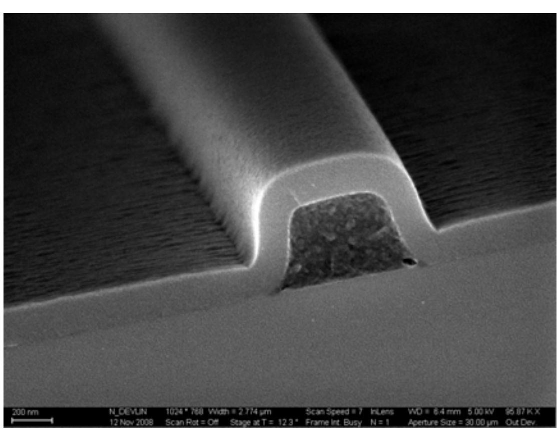

Figure 3: PECVD oxide coating of a 500nm line of patterned Unity with no decomposition

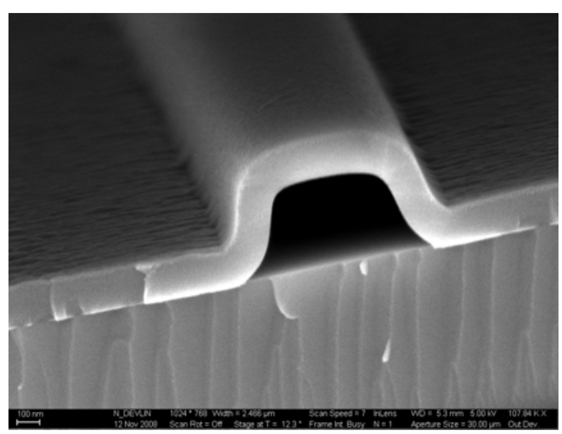

Figure 4: PECVD oxide coating after Unity decomposed by furnace creating 500nm channel