

## Deep plasma etching of Parylene C patterns for biomedical applications

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**Parylene C** (PaC) is a transparent, conformably-deposited polymer that has gained attention over the years in the biomedical field. Indeed, it presents with outstanding **biocompatibility** (USP Class VI), excellent **chemical inertness** and **low Young's modulus**. The CVD deposition process at room temperature allows for optimal, pinhole-free coverage over a substrate surface. Initially used as an encapsulation material, Parylene C is now investigated in thicker layers (~20-25µm) as a flexible substrate for a wide range of biomedical devices (1,2). However, the structuration of highly defined patterns in thick Parylene C films is a critical step in Parylene microfabrication technology. Techniques based on laser, scalpel and wet etching have shown to be unsuitable for properly cut structures, *i.e.* with dimension control and limited residues. Plasma etching remains nowadays the most widespread option, but fast etching rate, lack of residues and high aspect ratios are still challenging (1,3). To overcome these issues, the selection of both **mask material** and **plasma conditions** is crucial.

The first step is to find a suitable **mask** that withstands powerful oxygen plasma. A thin metallic mask (Nickel, ~1µm) provides a well-defined solution but is subject to sputtering and important residues. Thick positive photoresist such as AZ40XT is also tried out, but quickly overheats in the plasma chamber. On the other hand, a thick negative photoresist (~50 µm), the **Intervia BPN**, was appraised ideal for such masking. It is patterned in less than 30 minutes and provides conformal coverage over the plasma length, with minimal residues.

**Plasma conditions** (gas type, gas flow, pressure, ICP power, bias power and temperature) are also studied as to their influence on the resulting Parylene etching rate and selectivity over BPN photoresist. Specifically, the addition of a short fluorinated step in the midst of an oxygen-based plasma recipe is here shown to etch oxidized residues inside the openings, resulting in a clean cut profile.

As an example, the cutting of flexible 25µm-thick Parylene C-based neural electrodes is carried out (4). **Culture cell tests** are performed on these devices to show that the etching process (photoresist, plasma, stripping) does not advocate cytotoxicity. Both qualitative fluorescent imaging and quantitative MTT assays proves no significant difference in cell viability between neuron-derived cells proliferating over the devices or in control wells.

Overall, for the first time, **negative resist (BPN)** coating followed by **RIE-ICP** are used in order to pattern Parylene C-based structures, with a **clean cut, vertical profile, fast etching rate** (~0.8 µm/min) and conservation of **device biocompatibility**.

1. Meng E et al. Plasma removal of Parylene C. J Micromech Microeng. 2008; 18(4):045004.
2. Castagnola V, Bergaud C et al. Parylene-based flexible neural probes with PEDOT coated surface for brain stimulation and recording. Biosensors and Bioelectronics; 2014, p. 450–7.
3. Selvarasah et al. A reusable high aspect ratio parylene-C shadow mask technology for diverse micropatterning applications. Sensors Actuators A Phys. 2008 Jul; 145-146:306–15.
4. Lecomte A, Bergaud C et al. Silk and PEG as means to stiffen a parylene probe for insertion in the brain: toward a double time-scale tool for local drug delivery. J Micromech Microeng. 2015;25(12):125003.

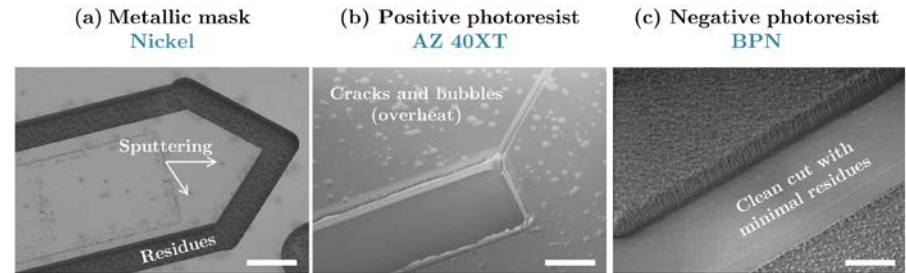


Figure 1. SEM images of plasma-etched 23 µm-thick Parylene structures using different mask types (scale bar is 50 µm).

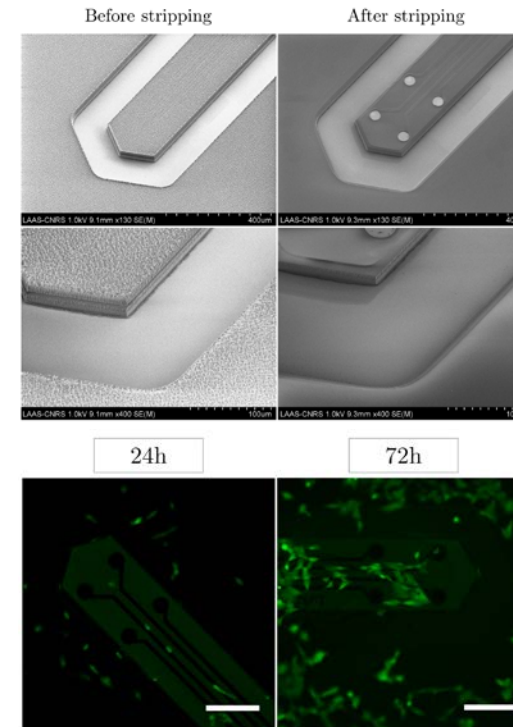


Figure 2. SEM images of a Parylene C neural probe cut out of the wafer using RIE-ICP, before and after the stripping of the BPN photoresist. The cut is clean, the profile is vertical and with no residues in the openings.

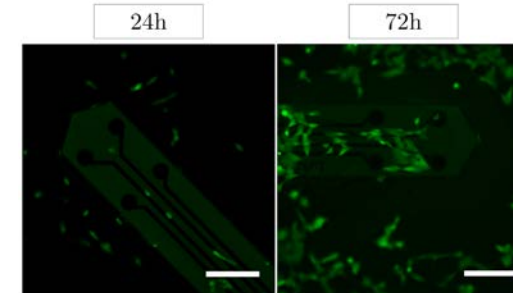


Figure 3. Fluorescent viability assay of a SH-SY5Y cell culture over Parylene C implants. Images were taken at 24 and 72 hours. Live cells appear in green and dead cells appear in red. No dead cell was present around the probe. Scale bar is 200µm.