Nanofabrication of silicon carbon nitride cantilevers – Comparison of PMMA and HSQ based processes

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State-of-the-art chemical and biological sensing for medical diagnostics, pharmaceutical discoveries, spectrometric research, security applications etc., requires outstanding mass sensitivities – in some cases down to a few Daltons! The quest for ultra-low mass sensors capable of achieving such sensitivities has pushed NEMS device fabrication to the deep nanoscale. Demanding material requirements at this scale have promoted the development of various novel materials – amongst which silicon carbon nitride (SiCN) has enabled fabrication and interferometric measurement of sub-20 nm doubly clamped resonators [1, 2]. Previously, we presented fabrication (Fig. 1) of sub-20nm bridge structures using 3 keV e-beam lithography (EBL) and cold (-15°C) development [2]. Pushing the resonator beam widths to the sub-10 nm regime using PMMA is possible, but with short 1.0 µm beam lengths [2]. Moreover, accessing sub-10 nm with PMMA yields resonators with severe edge roughness problems. In this work, we discuss a new, simplified, and higher resolution approach using HSQ resist (Fig. 1) and 30 keV EBL. The development-stage optimization approaches for PMMA vs. HSQ resist are compared and differences in strategy are elucidated. Achieving ultra-high resolution patterns with HSQ requires specialized development recipes (Table 1) to push the pattern resolution and combat specific HSQ-related problems such as siloxane-like scum formation at high doses/voltages. We have combined hot development [3] with HF-trimming development [4] to create a multi-step development recipe (Table 1 recipe (C)) that clears the siloxane-like scum and provides pattern trimming (Fig. 2(b, c) vs. 2(a)). As a result, we have managed to fabricate sub-10 nm wide, 5 µm long, and 50 nm thick SiCN resonators (Fig. 2(c-f)). The beams are suspended 400 to 600 nm above the silicon surface and little or no scum is visible on the clamping point (Fig. 2(d)). The beams have uniform widths across the entire length of the resonator (Fig. 2(c, e)). This uniformity across the length of the device demonstrates that with co-optimization of exposure and development conditions, proximity effects can be avoided or compensated without the use of complicated correction algorithms.

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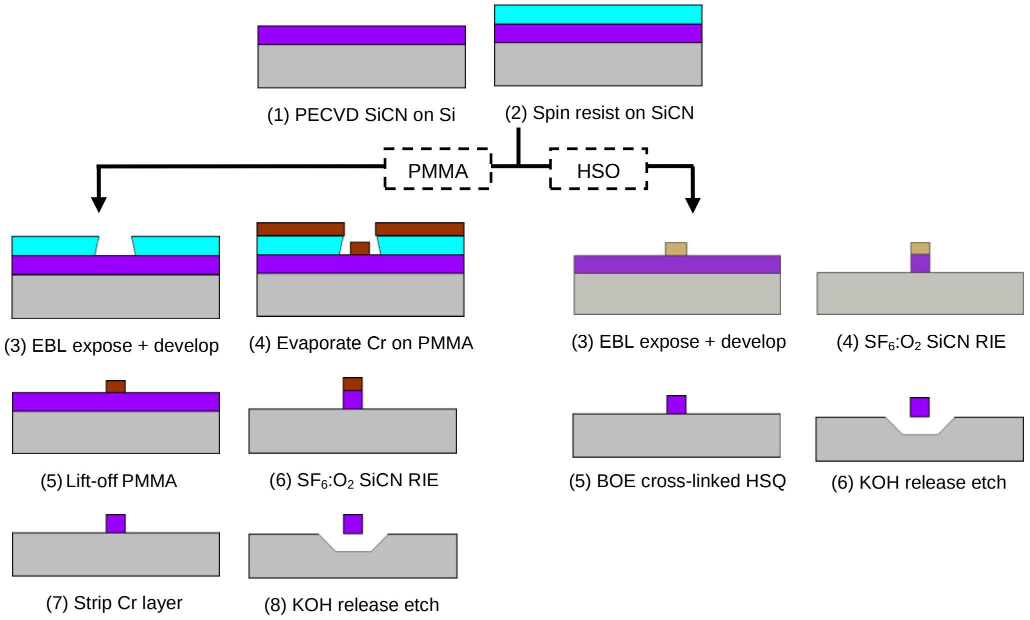

Figure 1. Two alternative processes for fabricating doubly clamped SiCN cantilevers based on positive (PMMA) and negative (HSQ) resists.

Table 1. Various schemes used for developing exposed HSQ structures

Recipe	*Developer Formulation*
(A)	75 sec dip in 25% TMAH
(B)	75 sec dip in 50°C 25% TMAH
(C)	75 sec dip in 50°C 25% TMAH + 30-60 sec dip in 2000:1 H_2O:BOE + 75 sec dip in 50°C 25% TMAH.

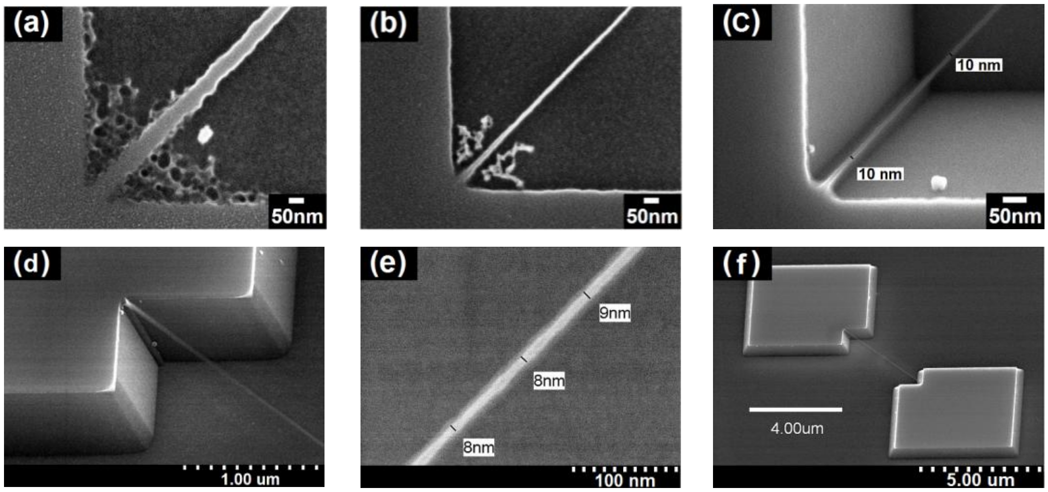

Figure 2. Micrographs of un-released SiCN pattern developed with (a & b) recipe (A) & (C), compared with released 5 μm long SiCN resonators showing (c & d) smooth uniform corner, (e) sub-10 nm width, and (f) device overview.