Catalyst Patterning for Carbon Nanotube Growth on Elevating Posts by Self-Aligned Double-Layer Electron Beam Lithography

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In order to achieve gas-flow alignment during chemical vapor deposition (CVD) growth of carbon nanotubes (CNTs), it is important to minimize interactions of the growing CNTs with the substrate. One way of reducing the interaction is to elevate the catalyst above the underlying substrate [1, 2]. Thus, a method to fabricate thin metallic CNT catalyst films on top of a protruding support material is needed. Since the elevating posts underneath the thin metallic catalyst films have to act as a diffusion barrier during CVD growth, the cross-linked high-resolution e-beam resist hydrogen silsesquioxane (HSQ), resembling SiO_x, is an ideal candidate material. In our process we perform a catalyst lift-off using PMMA e-beam lithography on top of an HSQ layer that is exposed simultaneously, resulting in catalyst layers on HSQ structures after HSQ development. The advantage of our process is that we can avoid a two-step lithography process [1] or the use of contact printing techniques [2] and precisely self-align the catalyst films homogeneously on protruding posts with diameters and heights in the tens of nanometers range.

In Fig. 1 the fabrication process is shown in detail. PMMA is spin-coated on top of a spin-coated and dried layer of HSQ (a). This step is critical, since the PMMA solvent will dissolve HSQ again, if it is not dried completely. On the other hand, drying of HSQ can significantly restrict resolution due to premature cross-linking [3]. By exposing both resists simultaneously, self-alignment is achieved (b). Since PMMA and HSQ are exposed with the same dose, development of the resists has to be optimized in order to make both resists equally sensitive [3]. After a standard lift-off process (c-e), HSQ is developed (f) and CNTs are grown on the protruding HSQ posts (g).

Feasibility of the process is shown in Fig. 2: metal catalyst film on top of HSQ before (left micrograph) and after CNT growth (right micrograph). In this case, no directed gas flow was applied but the intended effect of raising a significant fraction of the tubes above the substrate surface is evident.

The influence of the processing parameters on the resist performance of the double-layer will be presented together with resulting CNT structures and their characteristics. Gas-flow alignment will be investigated after process optimization.

[1] Z. Yu et al., Chem. Mater. 16 (2004) 3414
[2] A.M. Cassell et al., J. Am. Chem. Soc. 121 (1999) 7975
[3] M. Häffner et al., J. Vac. Sci. Technol. B 25 (2007) 2045

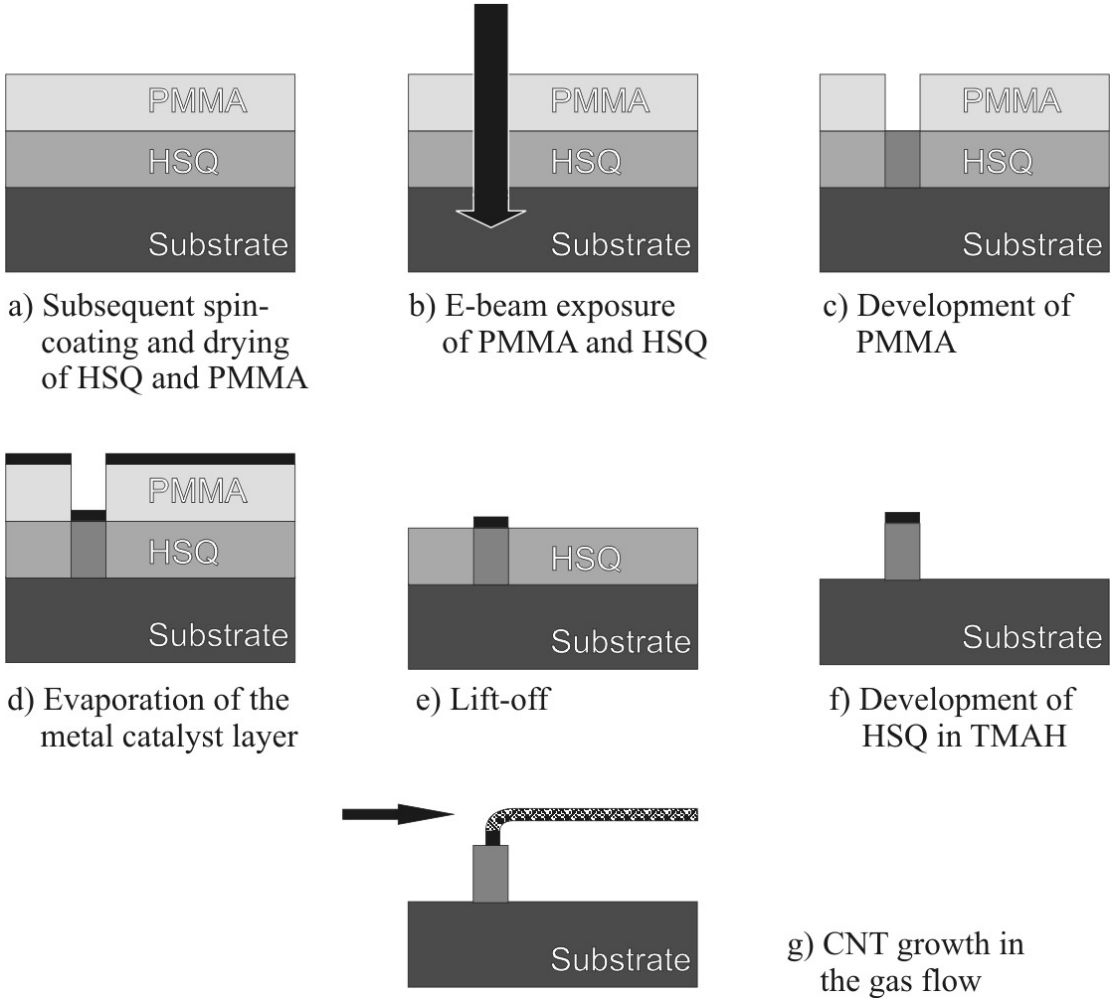

Fig.1: Self-aligned PMMA-HSQ fabrication process.

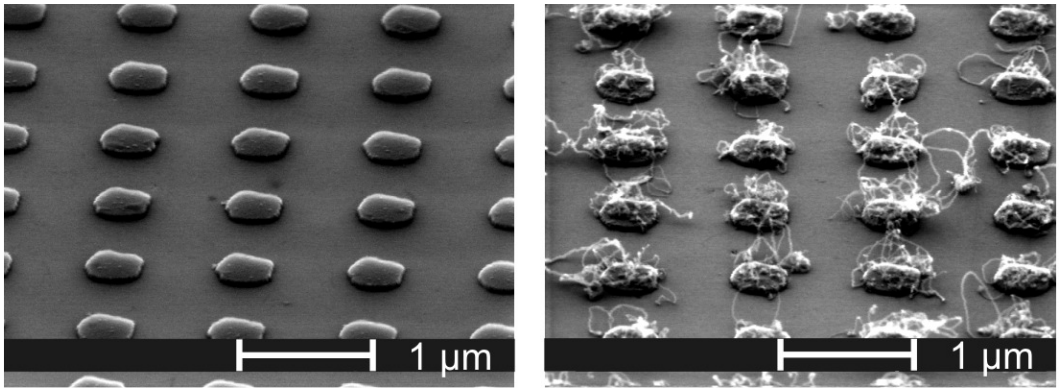

Fig. 2: Catalyst film on HSQ before (left) and after CNT growth (right).