Lift-off of Sub-15-nm Hydrogen Silsesquioxane (HSQ) Structures

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Hydrogen Silsesquioxane (HSQ) is a well-established negative-tone scanning-electron-beam lithography (SEBL) resist and is used to pattern structures smaller than 10 nm half-pitch[1]. Techniques for pattern transfer of HSQ are desirable for realizing various nanotechnology applications requiring such resolutions. While this material has been used extensively for etching, little work has investigated the capabilities of HSQ for lift-off [2]. Here, we demonstrate lift-off as an image-reversing pattern-transfer technique on SEBL-patterned HSQ structures.

Using the process proposed in our work, reliable and reproducible lift-off of complex and arbitrarily shaped HSQ structures with resolutions down to 15 nm half-pitch can be achieved as is illustrated in Fig. 1.The resolution and the reliability provided by the proposed process are substantially enabled by three particular procedures: warm buffered-HF liftoff; ultrasonic agitation; and manual scrubbing.

Before applying these procedures, the buffered HF used for the lift-off step was ineffective at removing the HSQ features and the metal deposited on top of them. In our attempts to overcome this problem, we found that using 35°C buffered HF instead of room temperature and applying ultrasonic agitation during lift-off made feature removal substantially more effective. Feature removal was further enhanced by subsequent manual scrubbing of the sample surface with a Q-tip of pure cotton drenched with isopropanol (IPA) after the exposure of the sample to the buffered HF. The impact of these measures is illustrated in Fig. 2.

By performing multiple experiments, we analyzed the influence of these three procedures and verified that the combination of all three of them, i.e. use of warm buffer HF together with ultrasonic agitation and subsequent Q-tip scrubbing allows for the reliable and reproducible lift-off of SEBL-patterned HSQ features down to resolutions of 15 nm half-pitch as shown in Fig. 1.

For sub-15-nm-half-pitch structures, even after these procedures, lift-off resulted in incomplete feature removal or in a tearing of the metal deposited in the resist features trenches. The latter problem was analyzed and showed to be correlated with the existence of resist residue in the HSQ feature trenches.

With continued optimization, further improvements to the resolution of the process should be possible.

[1] J. K. W. Yang and K. K. Berggren, J. Vac. Sci. Technol. B **25**(6), 2025-1019 (2007).
[2] R. V. Seidel, A. P. Graham, J. Kretz, B. Rajasekharan et al., Nano Letters, **5**(1), 147-150, (2005)

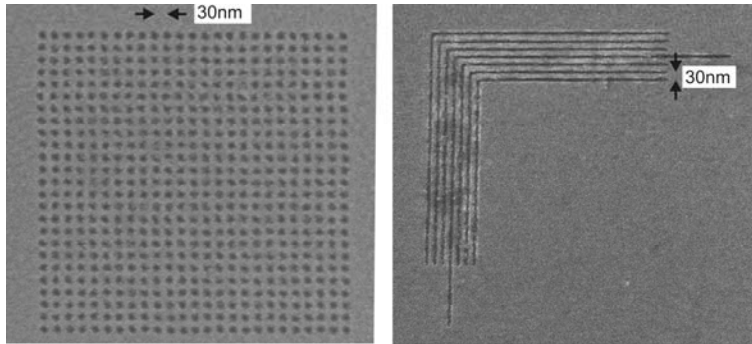

Fig. 1: SEM of a 30nm-pitch dot array (left) and a 30nm-pitch nested-"L" array (right) transferred into a 5nm thick Chromium film. Lift-off has been performed using buffer HF at 35°C, ultrasonic agitation and subsequent Q-tip scrubbing.