Development of Metal Etch Mask by Single Layer Lift-Off for Silicon Nitride Photonic Crystals

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Recently Silicon nitride (SiN) has attracted many interests as an ideal material for photonics device applications such as photonic crystal (PC) due its large transparency bandwidth that spans the entire visible and part of the UV spectrum. The fabrication of these devices in a SiN material system has relied on direct patterning of a polymer etch mask from ebeam resist, followed by dry etching using fluorine chemistry. However, SiN generally exhibits poor etch selectivity relative to ebeam resist under dry etching, which results in significant degradation of the mask pattern. This degradation typically results in sloped sidewalls that greatly reduce the quality (Q) factor of the device[1]. One method to improve the sidewall profile of the structures is to use a hard etch mask that does not degrade under dry etching.

We present a method for fabrication of nanoscale patterns in SiN using a hard chrome (Cr) mask formed by metal liftoff with a negative ebeam resist (maN-2401). This approach enables to make a robust etch mask without the need for exposing large areas of the sample by electron beam lithography. Fig 1(a) shows a SEM image of cross section of patterned SiN membrane using an reactive ion etching (RIE) with a Cr mask. In Fig 1(b) we demonstrate the ability to fabricate feature sizes as small as 50 nm, which are then transferred to a 200 nm thick SiN membrane. The fabricated structures exhibit straight sidewalls, excellent etch uniformity, and enable patterning of nano structures with very high aspect ratios. We use this technique to fabricate two-dimensional PCs in a SiN membrane shown in Fig 1(c). The PCs are characterized and shown to have quality factors as high as 1460 in Fig 1(d).

Fig 2 illustrates our fabrication procedure for patterning of the metal Cr mask and subsequent transfer to SiN. The negative tone ebeam resist, ma-N 2401 (Micro Resist Technology), is applied on a 200 nm thick SiN substrate. The resist layer is patterned by ebeam lithography and development process to form the negative mask pattern. A metal mask is obtained by a 20 nm Cr deposition onto the sample by using an ebeam evaporator and liftoff the resist layer. Once the Cr etch mask is formed, the pattern is transferred to the SiN layer using RIE. For suspended structures, the sacrificial Si layer is etched in KOH solution. Once the structure is finalized, the Cr mask can be removed by chemical etchant.

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[1] M. Barth, J. Kouba, J. Stingl, B. Löchel, and O. Benson, “Modification of visible spontaneous emission with silicon nitride photonic crystal nanocavities,” Opt. Express 15, 17231 (2007).

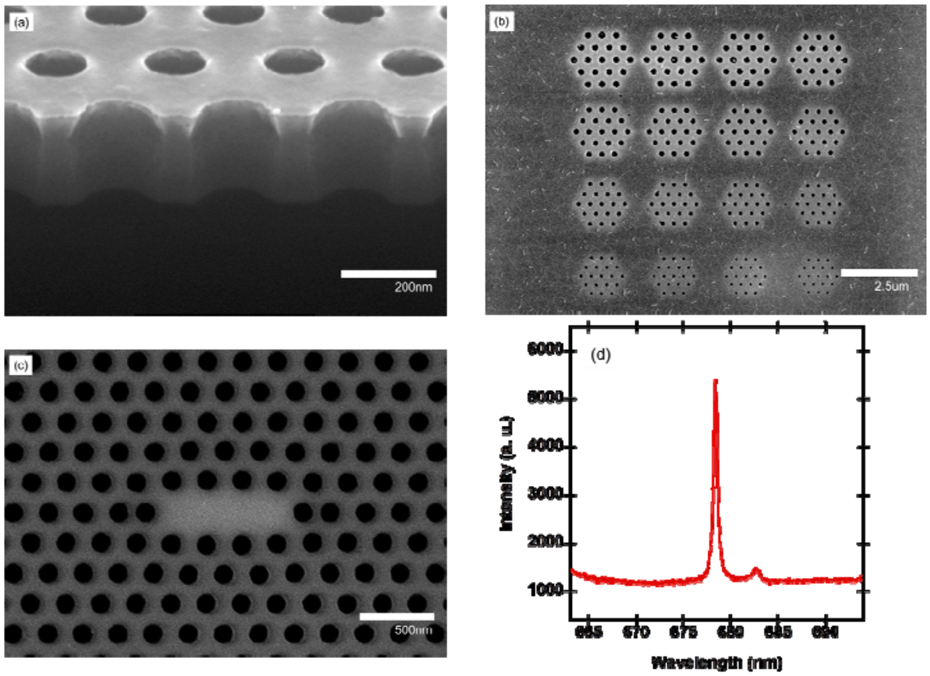

Figure 1: (a) Cross sectional image of etched holes after RIE, (b) SEM image showing an array of fabricated air holes with diameter size ranging from 250 nm down to 50 nm, (c) SEM top view of fabricated PC nanocavity. (d) PL spectra measured from sample displayed in panel (c).

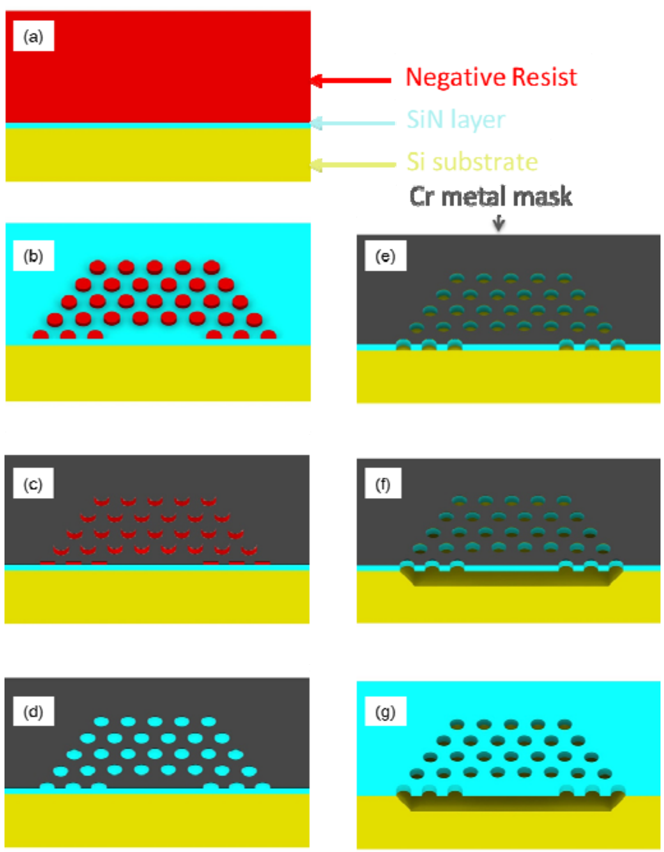

Figure 2: Sketch of the fabrication process, (a) negative ebeam resist spun on SiN layer, (b) ebeam exposure and development to define patterns in the resist, (c) 20 nm Cr deposition with ebeam evaporator, (d) hard metal mask formed via Lift-off technique, (e) RIE to transfer patterns into the SiN, (f) KOH wet etching to remove the Si underneath the PCs, (g) removal of the Cr mask.