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Fabrication of Wide Area Two-Dimensional Photonic Crystal Using Holographic Lithography

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1. Introduction

Two-dimensional photonic crystals(PC) patterned on the planar waveguides are of great interest in optoelectronic applications such as band pass filters and micro-waveguide and photonic circuits[1]. Most of the photonic crystals made today are patterned by either electron beam lithography or carefully aligned phase-masks[2]. This method is useful for precise patterning of photonic crystals but is not appropriate for wide area patterning. For photonic crystals that are used as a waveguide or photonic crystal integrated circuits, large portion of the device must be patterned with photonic crystal structure. This is difficult and time consuming for electron beam lithography, since the photonic crystal patterns are in the sub micrometer range and the patterned circuit or devices tends to be in the couple of hundred micrometers to few millimeters. Therefore, we used holographic lithography to pattern PC's uniform over one quarter of a 2 inch InP wafer instead of electron beam lithography. Also the patterned PC's were dry etched on to InP using RIE with CH4/H2 mixtures. Dry etched InP PC's are then observed using scanning electron microscope.

2. Photonic Crystal Fabrication

Two dimensional PCs consist of both triangular and rectangular lattice of circular inverted holes etched uniformly over one quarter of a 2 inch InP wafer. First 50nm thick SiNx were deposited with plasma enhanced chemical vapor deposition (PECVD) on the surface of the InP layer as an image transfer layer. The PECVD was performed at 300 °C with radio frequency power of 20W, maintaining the base pressure at 0.6Torr. For the deposition of SiNx films, the SiH4 and N2 flow rates were fixed at 4.2sccm and 750sccm, respectively. After the deposition, Hexamethyldisilazane(HMDS) was spin coated on to the SiNx layer for adhesive purpose. Then 250nm thick diluted photo-resist was spin coated on the SiNx layer.

In the lithography step of the process, holographic lithography system was used to provide wide (one quarter of a 2 inch wafer) area with PC patterns over the InP wafer[3]. The Schematic diagram of the lithography step is shown on figure 1. Interference pattern of 1st holographic

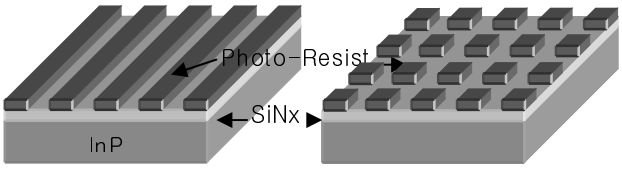

Fig 1. Schematic illustration of the 1st exposure(left) and 2nd exposure during the lithography step.

lithography was taken parallel to the cleaved edge of the InP substrate. In the 2nd lithography the sample was rotated 90 (rectangular) and 30degrees (triangular) from the previous lithography. It is speculated that during this 2nd lithography the corners of the rectangular pattern tends to erode and makes the square pattern into circular photonic crystal pattern. Also the etching depth, period and duty rate (pattern: non-pattern) which is very crucial in designing photonic crystals, were decided during this part of the process. Holographic lithography system was used to realize 600nm period PC photo-resist patterns as shown on figure 2. The pattern was then transferred from the photo-resist into underlying SiNx layer using CF4/O2 based reactive ion etching(RIE) with gas flow rate and base pressure of 40sccm and 30mTorr respectively.

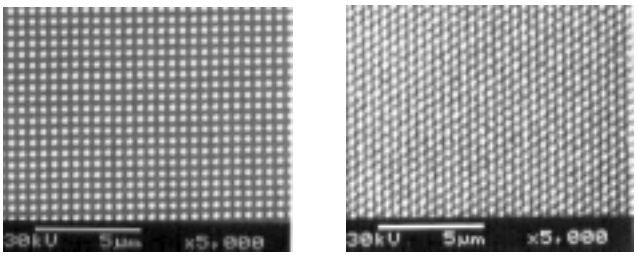

Fig 2. Scanning electron microscopic(SEM) view of 600nm period photo-resist rectangular (left) and triangular (right) lattice PC patterns formed by holographic lithography.

As shown from our previous work[4] where InP is dry etched with high aspect ratio and nearly vertical walls, the pattern was then transferred from the SiNx into underlying InP layer using CH4/H2 based reactive ion etching with etched depth of 400nm. Dry etching of InP was uniform all over quarter of 2 inch wafer. Etched PCs showed inverted circular shape as expected. Figure 3 illustrates the SEM image of InP dry etched photonic crystal fabricated by double exposure of holographic lithography.

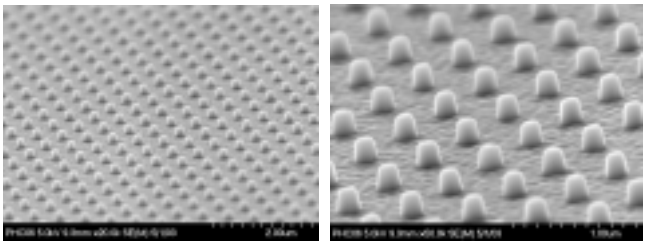

Fig 3. Scanning electron microscopic(SEM) view of 600nm period 400nm deep InP rectangular lattice Photonic Crystal formed by holographic lithography

3. Conclusions

We demonstrated a method to realize wide area (one quarter of 2 inch InP wafer) two dimensional photonic crystal with high uniformity and precise rectangular and triangular lattice photonic crystal pattern using double exposure of holographic lithography. This fabrication method is much more effective and time saving for wide area photonic crystal fabrication compared to electron lithography and phase-mask lithography. Also with the use of image reversal technique, circular PC holes were realized with the use of double exposure holographic lithography method. Further application of this PC will be discussed during the conference.

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