Cl_2-based ICP etching of photonic crystals for the visible spectrum in GaN and SiC

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An increasing number of photonic integrated circuits (PICs) is based on the control of light by Photonic Crystal (PC) building blocks. With the right design of the periodic structure, light propagation in a PC element can be blocked for a certain range of frequencies, thus forming a photonic bandgap (PBG). In the near-infrared spectral range, the photonic bandgap was demonstrated for high aspect ratio structures in InP [1] and GaN [2], and also several PC based devices [3, 4, 5] have been realized.

For optical devices in the visible light spectral range, i.e 380-760 nm wavelength, wide bandgap materials like GaN and SiC are of great interest. Our current work is aimed at the top-down fabrication of PC structures for visible wavelengths in these materials by Cl_2-based ICP etching. A reproducible control of high aspect ratio dry etching of GaN and SiC for the visible light PC element is not only a challenge because of the scaling down to sub-100 nm dimensions. Also, the high bonding energy in these materials requires a strong ion-induced etching process, which puts a heavy load on the etch mask (fig. 1). Ions scattered from the mask bounce to other areas in the cavity and induce unintentional sidewall erosion inside a PC structure.

To reach the required etch depth and anisotropy in PC structures the combined result of the surface temperature, the plasma chemistry and the radical-ion synergy in the nanocavity are of crucial importance. We will present the results of on-chip temperature measurements, which show the effect of He-backside streaming and the importance of the use of heat sink paste (fig. 2). Furthermore we will compare Ar and N_2 additions to Cl_2-based ICP etching of GaN, SiC and the used (hard)masks, in terms of passivation and etch enhancement. Preliminary results on GaN are shown in figure 3. With the Cl_2/N_2 mixture the difference in etch rate of samples *with* or *without* heat sink paste is small. It points to a dominance of ion impact in the rate limiting step. On the contrary, with the Cl_2/Ar mixture there is strong increase in etch rate at a lower sample temperature. In this case the temperature driven adsorption may be more important. A more ample process study on GaN and SiC PC formation will be presented.

[1] R. van der Heijden, C.F. Carlström, J.A.P. Snijders, R.W. van der Heijden, F. Karouta, R. Nötzel, H.W.M. Salemink, Appl. Phys. Lett. **88**, 161112 (2006)

[2] J. Caro, E.M. Roeling, B. Rong, M.H. Nguyen, E.W.J.M. van der Drift, S. Rogge, F. Karouta, R.W. van der Heijden, H.W.M. Salemink, Appl. Phys. Lett. **93**, 051117 (2008)

[3] H.H.J.E. Kicken, I. Barbu, R.W. van der Heijden, F. Karouta, R. Nötzel, E. Van der Drift, H.W.M. Salemink, Optics Letters **34**, 2207-2209 (2009)

[4] P. Strasser, R. Flückiger, R. Wüest, F. Robin, H. Jäckel, Opt. Express **15**, 8472-8478 (2007)

[5] H. Benisty, C. Cambournac, O. Khayam, M. Ayre, F. van Laere, D. van Thourhout, R. Baets, T. Stomeo, T.F. Krauss, M. Kamp, H. Hofmann, A. Forchel, D.F.G. Gallagher, Proceedings ECOC 2008, Belgium, 97-98 (2008)

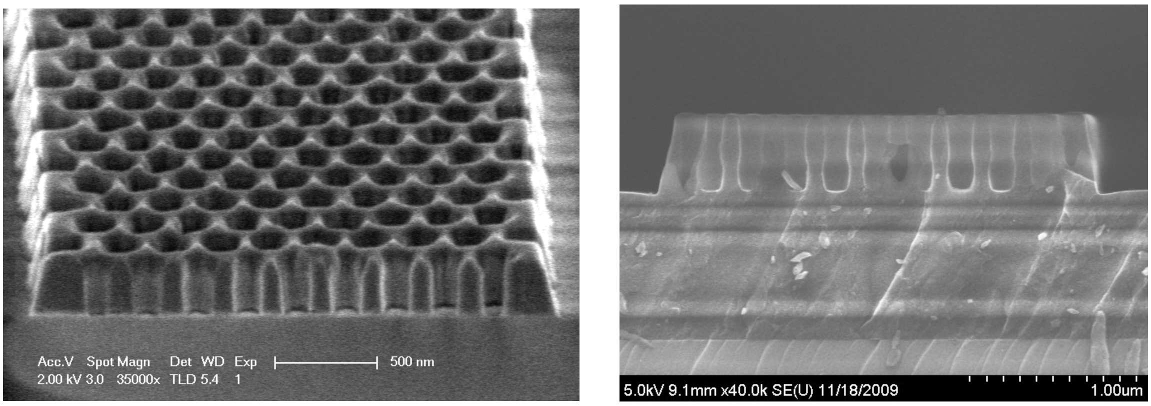

Fig. 1: ICP etched PC structures in GaN (left) and SiC (right) using a Cl_2/N_2 mixture. The effects of unintentional mask erosion are visible on the topside of the GaN and in the SiC also at the sidewalls.

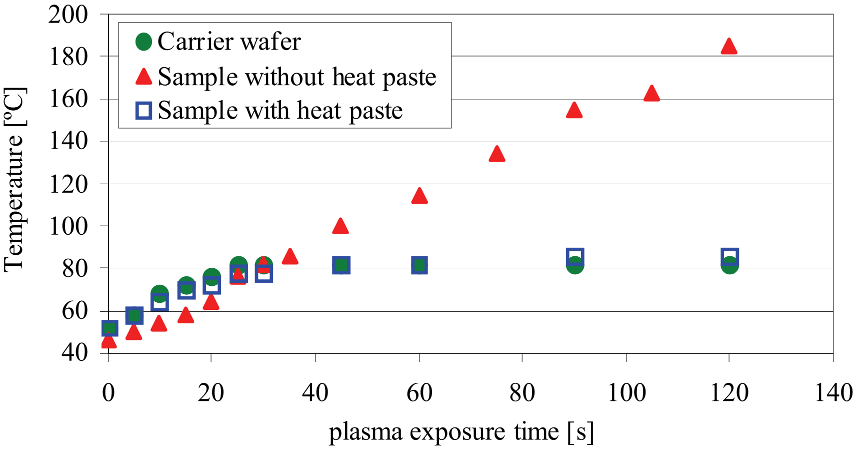

Fig. 2: Temperature development during plasma exposure (P_{coil}=1000 W, P_{platen}=100 W) of a silicon chip on top of a carrier wafer with and without heat paste.

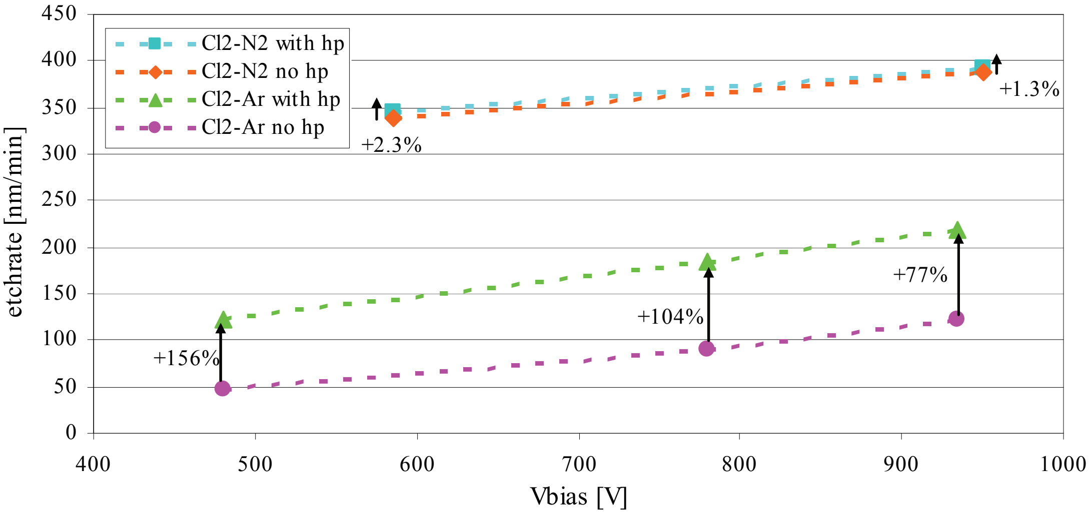

Fig. 3: GaN etch rates versus V_{bias} during Cl_2/N_2 and Cl_2/Ar ICP etching. Note the widely different result for N_2 and Ar admixture.