Nanostamp with high density and high aspect ratio over 1 tera bit/inch^2

Min-Hyun Lee, Kipil Lim*, Hyun-Mi Kim and Ki-Bum Kim

Dept. of Materials Sci. and Eng., Seoul National Univ., Seoul 151-742 Korea

** Korea Institute of Science and Technology, Seoul 136-791 Korea*

In the high density nanopattern formation by nanoimprint process, the resulted resolution strongly depends on the resolution of imprint stamp. Therefore, the formation of imprint stamp with high density and high aspect ratio is a key factor. We reported the fabrication of nanoimprint mold with Si nano pillar array of 25 nm pitch by e-beam lithography and Cl_2 reactive ion etching (RIE) using HSQ resist which has one of the best resolution below 10 nm and the nanoimprint results using Si nano-pillar array.[1][2] However, Si nano-pillar array below 20nm pitch disappeared after Cl_2 RIE.

Figures 1 (a)~(c) show the Si nano-pillar morphology after Cl_2 RIE process as an e-beam exposure dose. Nano-pillars with 25nm pitch are merged during the etching by Cl_2 RIE, which may be due to the resist scum and the isotropic etching by Cl_2 plasma. For the isolated nano-dot array pattern, we introduce the vacuum treatment of HSQ resist instead of pre-bake step before the e-beam exposure and SF_6+O_2 reactive ion etching process. The vacuum treatment reduce the residual resist scum after the development and the SF_6+O_2 RIE process is resulted the vertical side wall slop of each nano-pillar [Figure 1 (d), (e), and (f)].

While etching selectivity of Cl_2 RIE is about 3, the etching selectivity of SF_6 is about 5. (See Figure 2) After SF_6 RIE, Si nano-pillars fall down by undercut because SF_6 gases chemically etch the Si substrate. In order to prohibit the undercut, O_2 gas is introduced in etching species. Figure 2 shows the etching rate and etching selectivity between Si and HSQ as a function of O_2 ratio. Etching rate of Si by SF_6+O_2 RIE has decreased with increasing the O_2 ratio, while etching rate of HSQ keeps a similar value about 25 nm/min. Therefore, the etching selectivity is decreased from 5 to 1 with increasing O_2 ratio from 1 % to 60 %. We set to the etching condition of 66% SF_6 + 34% O_2 gas mixture with high selectivity about 3 and perpendicular side wall profile of nano-pillar.

In this presentation, we will show the Si nano-pillar array with below 20 nm pitch and over 1:2 aspect ratio using the vacuum treatment before the e-beam exposure and SF_6 + O_2 RIE. In e-beam lithography of nano-dot array with high density, the increase of electron dose per dot is normally observed by e-beam proximity effect. We will show the simulation about the proximity effect in high density nano-dot array formation by e-beam lithography with high energy over 100kV.

[1] J.S. Wi, H.S. Lee, K. Lim, S.W. Nam, H.M. Kim, S.Y. Park, J.J. Lee, C.D. Hong, S.H. Jin, and K.B. Kim, Small, 4, (2008) 2118-2122.

[2] H. S. Lee, J. S. Wi, S. W. Nam, H. M. Kim, and K. B. Kim, J. Vac. Sci. Technol. B 27, (2009) 188-192

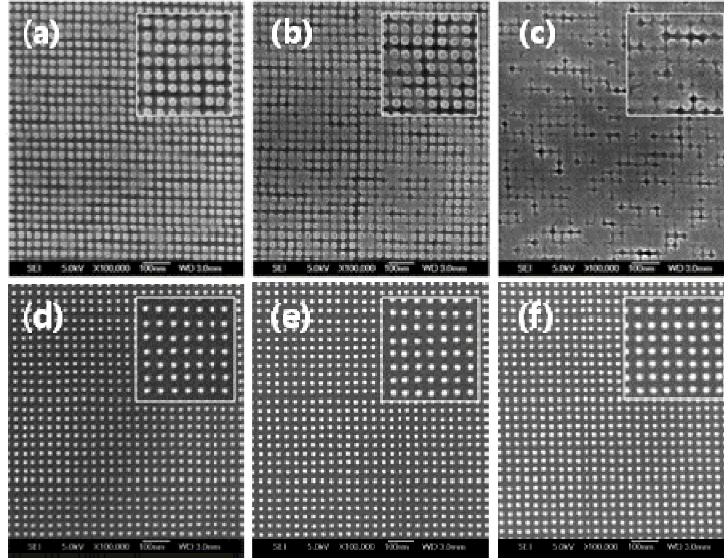

Fig. 1. Nano-dot arrays ; (a), (b) and (c) pre-bake process and Cl_2 RIE [(a) 24.3, (b)27, and (c) 29.7 μC/dot] and (d), (e) and (f) vacuum treatment and SF_6+O_2 RIE [(d) 23.4, (e)27, and (f) 30.6 μC/dot].

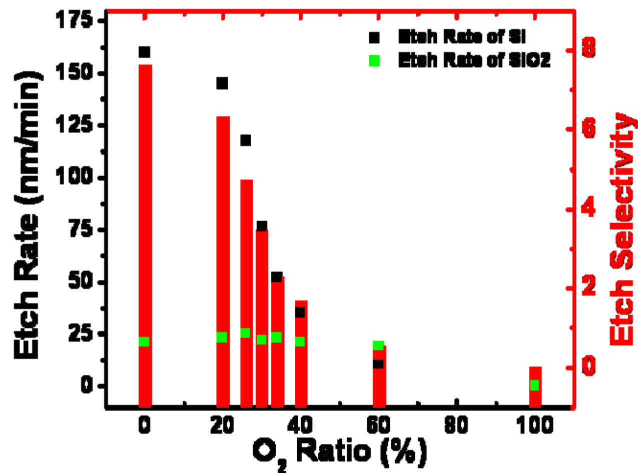

Fig. 2. Etch rate of Si and HSQ and their etch selectivity (= etch rate of Si/etch rate of HSQ) as a function of O_2 ration in SF_6 gas