Nanotrench Formation along Step Edges of Vicinal Si(111) Surfaces by Wet-chemical Treatments

K. Arima,[1] Z. Ma, [1] T. Takeuchi, [1] R. Hashimoto, [1] R. Sun, [1] K. Yamamura [1,2]

[1] Department of Precision Engineering, Osaka University, 2-1, Yamada-oka, Suita, Osaka 565-0871, Japan

[2] Research Center for Precision Engineering, Osaka University, 2-1, Yamada-oka, Suita, Osaka 565-0871, Japan

We aim at forming atomic-thick Si ribbons from a silicon-on-insulator (SOI) layer possessing a vicinal (111) surface by combining multiple wet-chemical treatments. Among the treatments, the most important one is to cut neighboring Si terraces along atomic step edges by metal-assisted chemical etching (MacEtch). To test this MacEtch performance, we have started experiments using a Si(111) bulk wafer. The Si surface has the miscut angle of 0.2° in the $\langle 11\bar{2} \rangle$ direction.

After a cut sample was wet cleaned, it was immersed in water in which the concentration of dissolved O_2 molecules was very low, or a ppb level [1]. This process is referred to as the first LOW (Low dissolved-O_2 Water) treatment. We find that a Si(111) surface composed of flat terraces and biatomic steps was formed by this first LOW treatment, as shown in Fig. 1(a). Then it was immersed in LOW containing Ag^+ ions at a concentration of 5 ppm, which is referred to as the second LOW treatment. Figure 1(b) indicates that Ag atoms were selectively reduced at the edges of atomic steps on Si(111) to form Ag nanowires, as reported by another group [2]. Finally, the Si sample with Ag nanowires was immersed into a mixture of HF and H_2O_2. Figure 1(c) indicates that the self-assembled Ag nanowires after the second LOW treatment were replaced by almost continuous nanotrenches, as some examples are shown by arrows in Fig. 1(c). This is probably because the Ag nanowires acted as a catalyst to enhance chemical etching of the Si surface underneath [3]. By applying this sequence for a thin SOI layer, we expect to form Si ribbons of which both a width and a thickness are controlled in a self-assembled manner.

References:

[1] H. Fukidome and M. Matsumura, *Jpn. J. Appl. Phys*., **38**, L1085 (1999).

[2] N. Tokuda, N. Sasaki, H. Watanabe, K. Miki, S. Yamasaki, R. Hasunuma, and K. Yamabe, *J. Phys. Chem. B*, **109**, 12655 (2005).

[3] Z. Ma, S Masumoto, K. Kawai, K. Yamamura, and K. Arima, *Langmuir*, **38**, 3748 (2022).

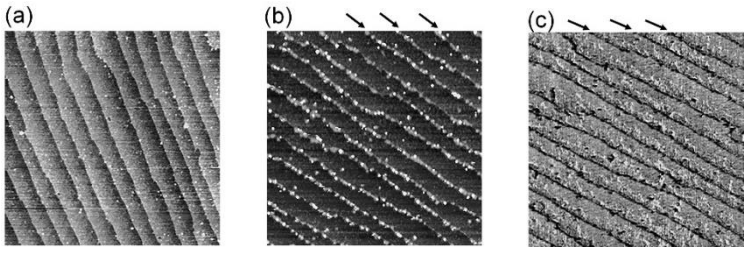

Figure 1. AFM images (1×1 μm^2). After (a) first, and (b) second LOW treatment, respectively. (c) After subsequent etching of a sample in (b) in HF and H_2O_2.

+ Author for correspondence: arima@prec.eng.osaka-u.ac.jp