Nanometer scale anodic oxidation of SC1-treated Si(111) surfaces by AFM

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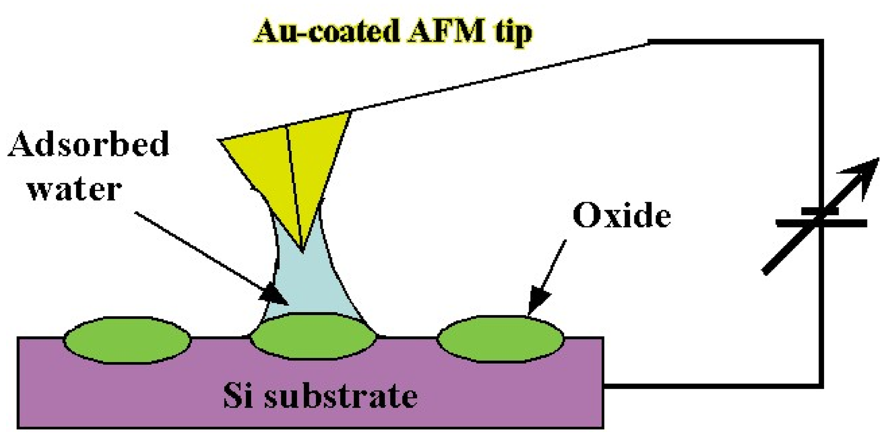
Introduction

The atomic force microscope (AFM) can be employed not only for imaging, but also for fabrication of structures on the surface. Using a conductive probe, oxide patterns can be fabricated on Si surfaces. This process is considered to be anodic oxidation mediated by the adsorbed water.



In our previous studies, we investigated the dependence of the dimensions of oxide structures on the applied voltage and the humidity of the ambient air. On bare Si surfaces, however, the thickness of the oxide was limited and the reproducibility was rather poor especially at lower humidity.

In this study, the oxidation process on the SC1- treated surface is investigated.

Experiment

Specimens were prepared from n-type Si (111) wafers (resistivity = 8 - 12 cm, thickness = 250 m).

A thin oxide layer was formed on the specimen by SC1 treatment in $NH_4OH : H_2O_2 : H_2O = 1 : 1 : 10$ solution at 80°C for 15 min.

For some of the specimens, the oxide layer was removed by HF treatment in $HF : H_2O = 1 : 100$ at room temperature for 1 min.

For some other specimens, the oxide surface was modified with chlorotrimethylsilane/hexane at 56°C for 1 hour. With this process, a hydrophobic surface was obtained.

Line patterns of oxide were fabricated with a gold-coated probe, which was moved on the surface at a rate of 1.15 - 2.3 m/s.

For the fabrication process and imaging, a contact-mode AFM, model SPI-3700/SFA-300 (SEIKO Instruments Inc.) was employed.

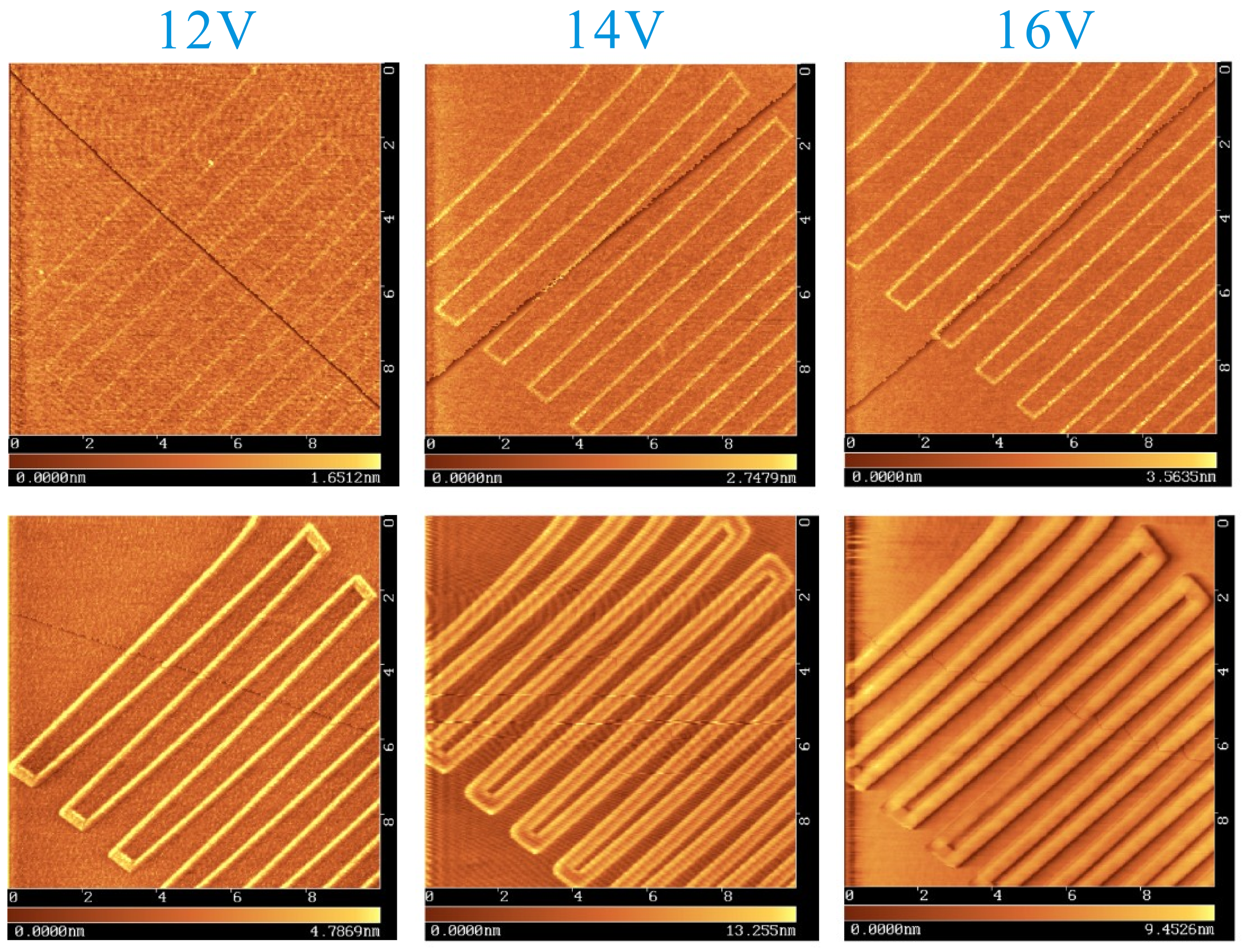
Results

AFM images of the line patterns fabricated with different bias voltages on HF- and SC1-treated Si(111) surfaces.

12V | 14V | 16V

HF-treated surface

SC1-treated surface



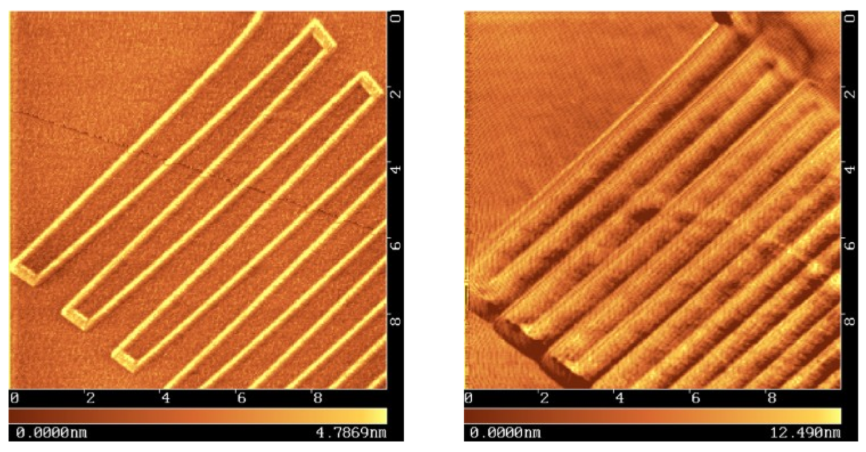
scan rate = 2.3 m/s

Dependence on the scan rate

2.3 m/s | 1.15 m/s

SC1-treated surface

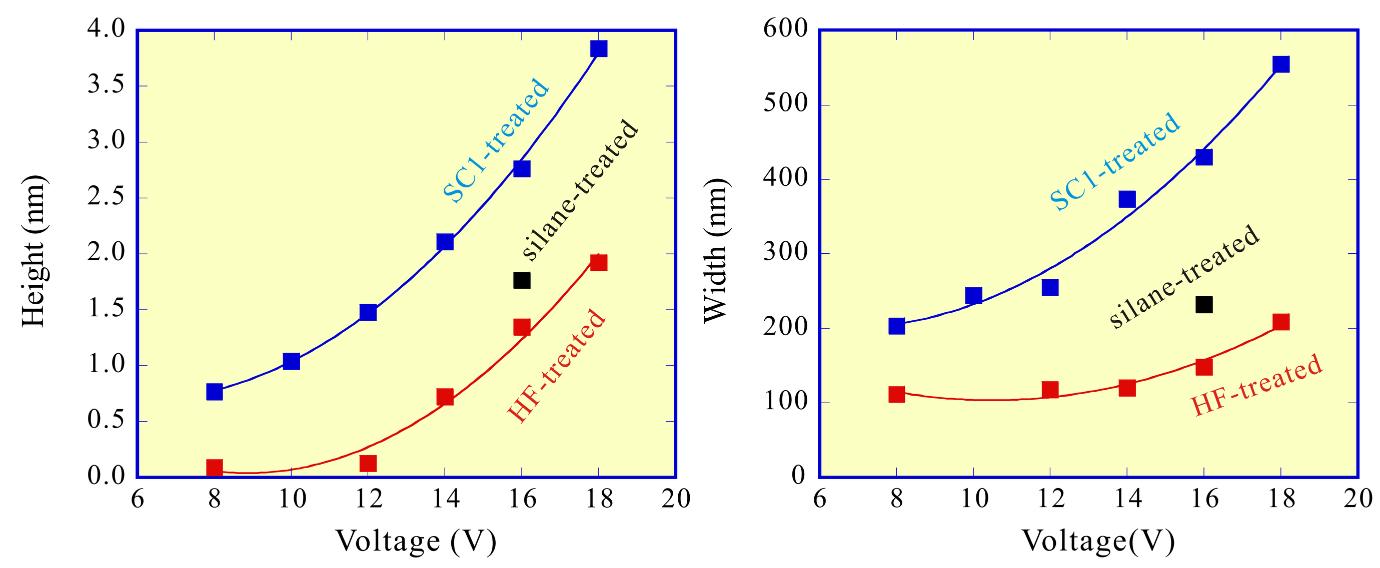
applied voltage = 12 V



H = 1.48 nm
W = 255 nm

H = 3.46 nm
W = 465 nm

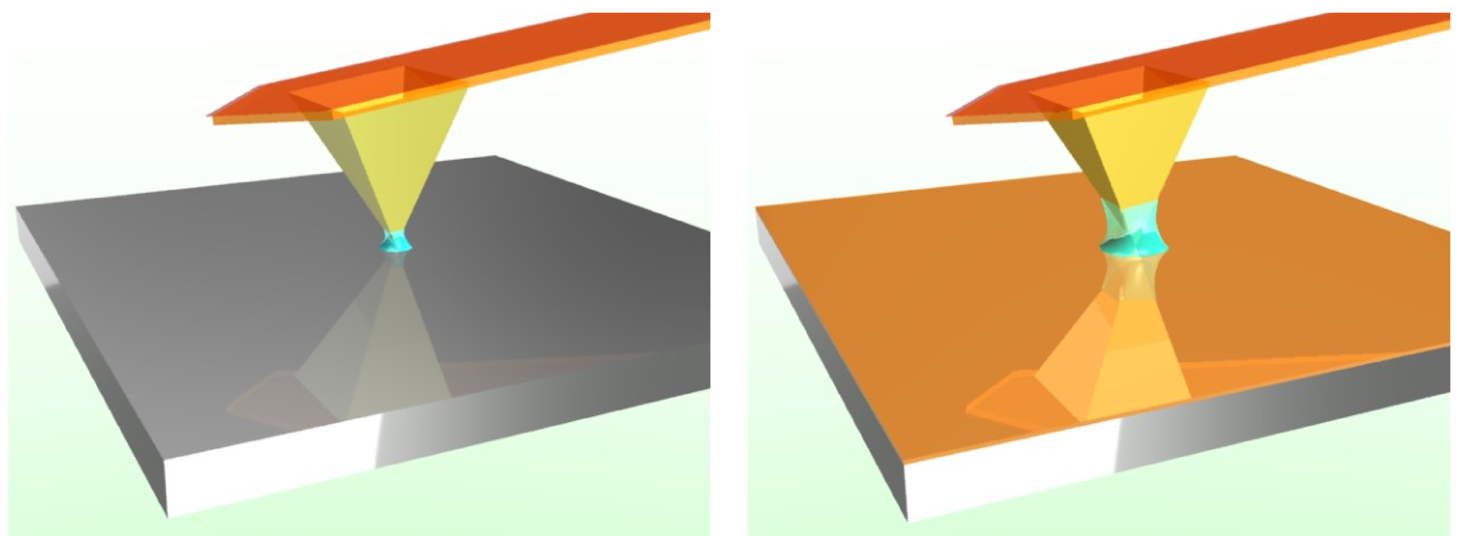
Dimensions of the line patterns fabricated on HF-, silane- and SC1-treated surfaces.



The largest and the smallest structures were obtained on SC1- and HF-treated surfaces, respectively.

Discussion

Considering the hydrophilicity and hydrophobicity of the surfaces, the present results should be attributed to the different amounts of adsorbed water, as schematically illustrated below.



HF-treated Si surface (hydrophobic) | SC1-treated SiO_2 surface (hydrophilic)

Conclusion

In the anodic oxidation process of Si by AFM, remarkably thicker and wider oxide patterns are reproducibly obtained on the SC1-treated surface than on the HF-treated surface. The control of hydrophilicity would enlarge the applicability of this technique to practical applications where fabrication and patterning of thicker oxide are required.

References

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