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Enhanced Alkaline Etching of Silicon Dioxide and Silicon through Ion Implantation

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1. Abstract

This project investigated the feasibility of enhanced surface etching through the implantation of Helium and Neon ions, with the use of a safer alternative to hydrofluoric acid. Using 2M NaOH, an initial etching rate increase of **(5 ± 0.5) nm/min** and **(5.8 ± 0.5) nm/min** for Helium and Neon respectively was found. This effect was not seen on a silicon wafer with a native oxide, due to significant reaction rate differences.

2. Motivation

This project wished to address the issue of sustainable chemistry and the use of hydrofluoric acid (HF) in silicon assembly. Removing the native silicon oxide layer before silicon wafer processing is very important to maintain surface smoothness. HF solutions are very selective towards silicon oxides over crystalline silicon. This makes it very useful despite its acute toxicity and extreme danger to life. Creating other methods for preparing and/or etching silicon that are sustainable and suitable for undergraduate use is of utmost importance.

3. Simulation and Experiment

Recent studies have shown that the injection of ions into the surface of materials can increase the etching rates of these materials when under a liquid etchant [1][2]. It is believed that the major cause of this is the creation of defects in the material as the ion passes through. This leaves dangling bonds, which the etchant can easily attack by the following reaction:

$$SiO_2 + 4\,NaOH \leftrightarrow Na_4SiO_4 + 2\,H_2O$$

Using an ion bombardment simulation software (SRIM), the effects of two different ions (Helium and Neon) were investigated. The energies of the ions and the number of ions used were changed to get an average damage density, shown in *fig.* 1. Here 30keV was selected and simulated.

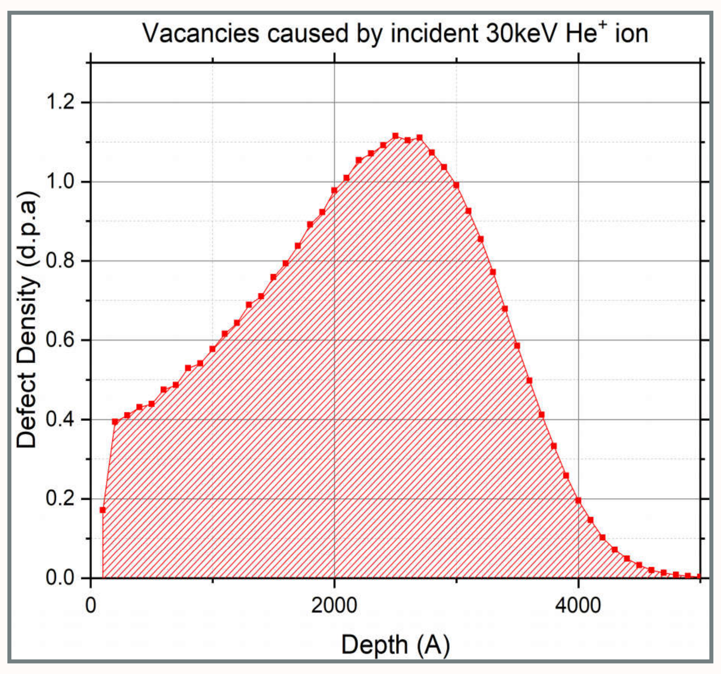


Fig. 1: A simulation of the number of defects per atom caused by incident He+ ions as a function of depth. Note how there is a steep

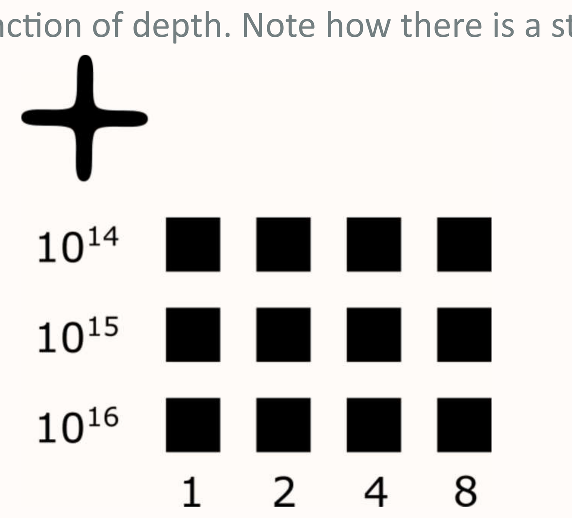


Fig 2: Image of the array showing the doses implanted, in units of ions/cm^2.

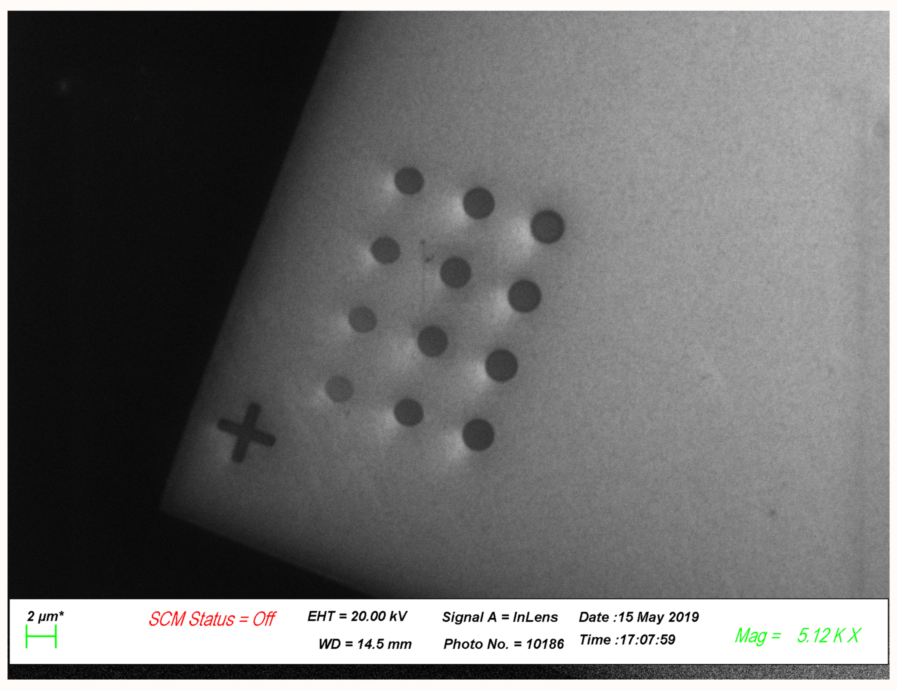


Fig. 3: Scanning Electron Microscope image of the irradiated regions post-etching. The darker colours indicate a deeper well and coordinate well with increasing dose.

It was expected that the etch rate would depend solely on the defect density in the material, which is highly dose dependent. To test the dependence of the dose on the material, a grid as shown in *fig.* 3 was used. This allowed us easily identify which circle corresponded to which dose.

4. Silicon Dioxide Etching

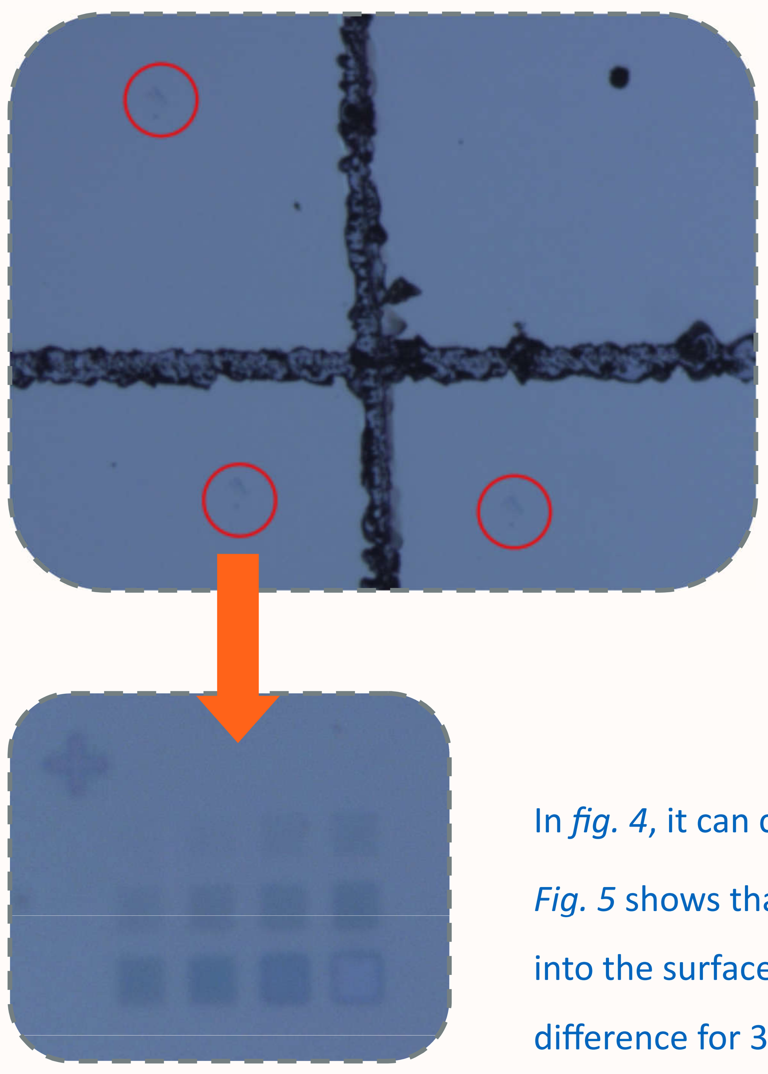


Fig 4: Shown above is an optical image of the areas. Below is a zoomed in image.

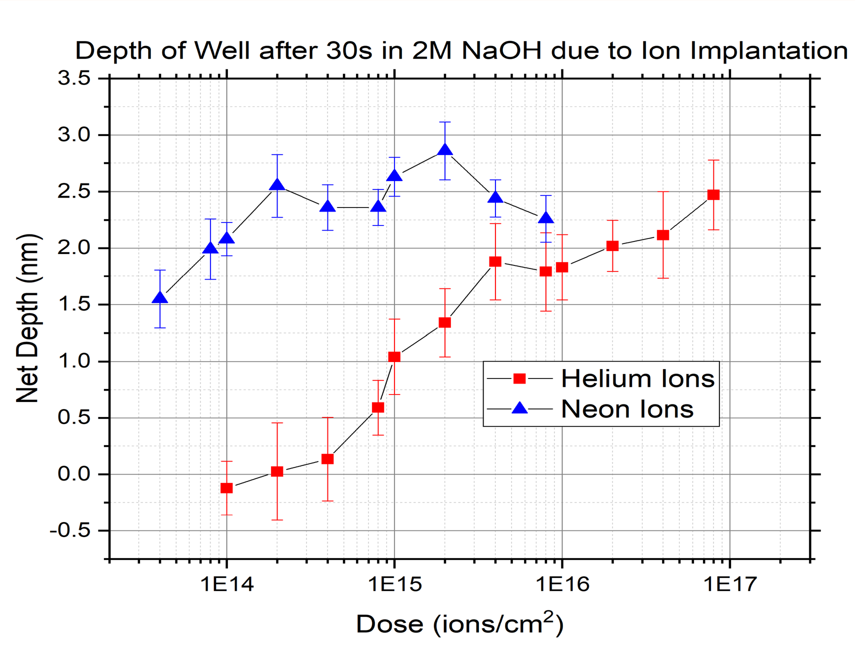


Fig. 5: Depth of wells depending on the ion dose for both helium and neon.

In *fig. 4*, it can clearly be seen the need for markers to locate the areas. *Fig. 5* shows that the etch rate does increase when ions are implanted into the surface and sub-surface for Silicon Dioxide. It is a substantial difference for 30s of etching.

Any swelling of the surface or removal of material in the wells due to ion implantation were controlled

Because the absolute etch rate could not be measured due to issues with protective resists, this comparative measurement allowed us to deduce a etch rate increase of (5 ± 0.5) nm/min for Helium and (5.8 ± 0.5) nm/min.

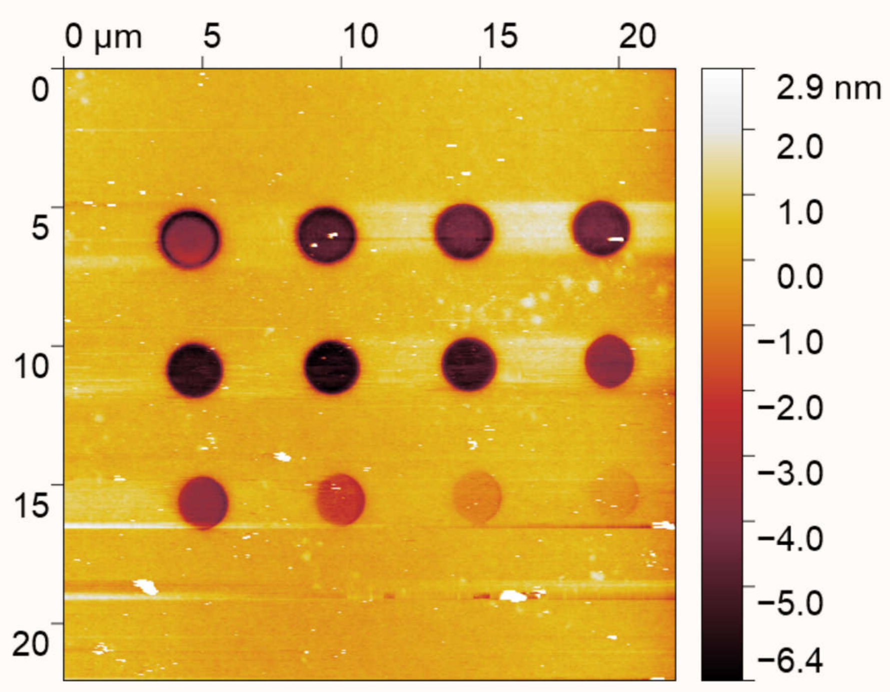


Fig 6: Atomic Force Microscopy image of the wells post-etching.

5. The Effects of the Native Oxide

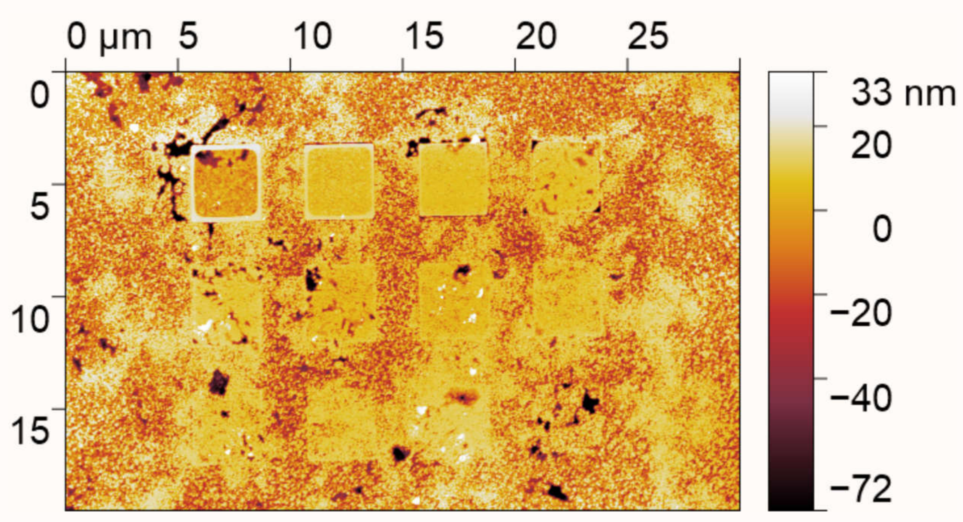
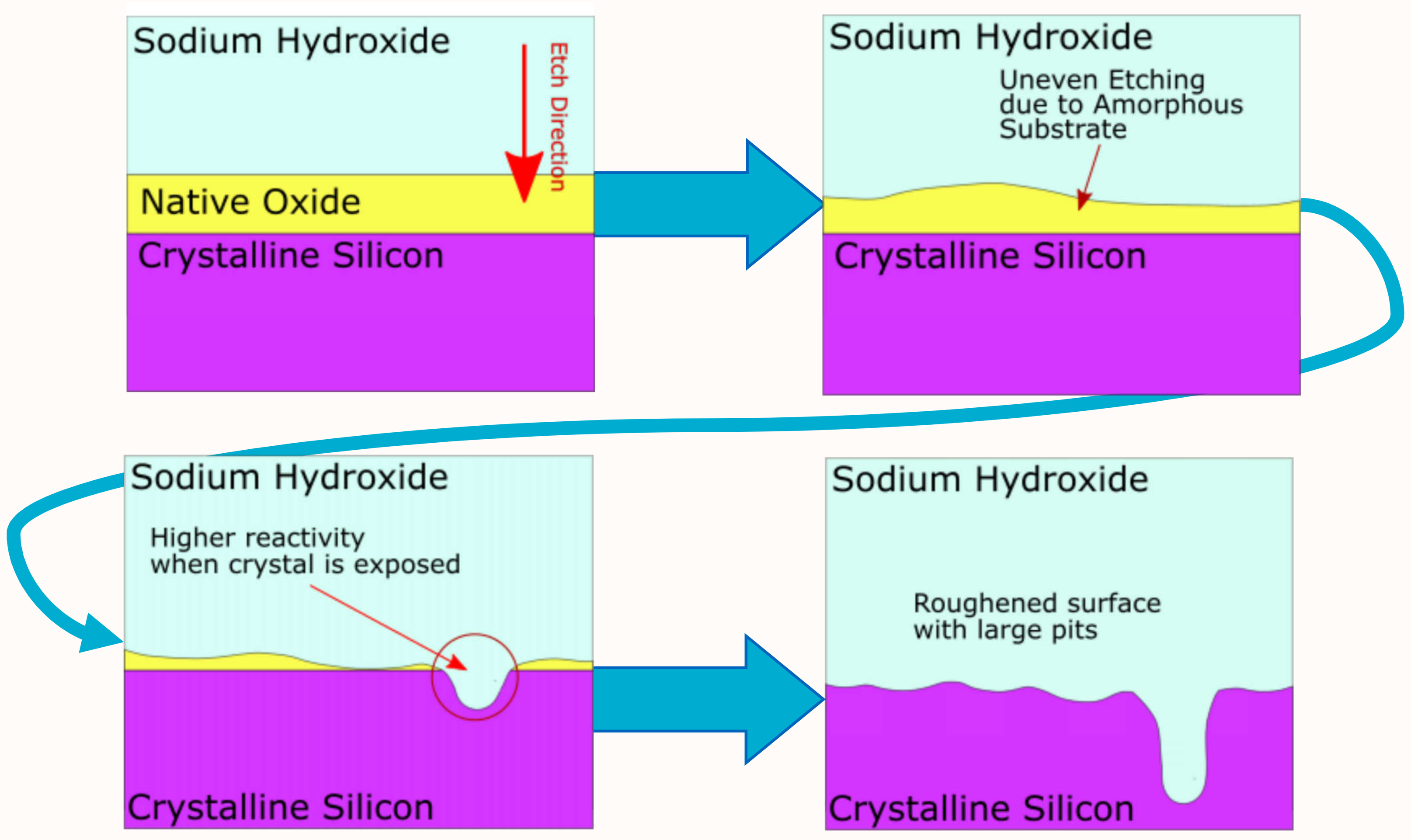


Fig 7: Atomic Force Microscopy image of a silicon wafer after ion implantation and etching in 2M Sodium Hydroxide.

Investigating how this process operates on a silicon wafer with a native oxide of <10nm thick led to development of large pits. This is illustrated below [3].

There is evidence to suggest that ion implantation caused an increase in etch resistance in the silicon, shown by the lighter squares in *fig. 7*.



6. References and Acknowledgements

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[3] I. Zubel, “Silicon anisotropic etching in alkaline solutions II on the influence of anisotropy on the smoothness of etched surfaces,” Sensors Actuators A Phys., vol. 70, no. 3, pp. 260–268, 1998

I would like to acknowledge the Laidlaw Undergraduate Research and Leadership Programme for support and funding during this project. I would also like to thank Pierce Maguire, Daragh Keane and Jakub Jadwiszczak for their time and contributions to this project.