PHS8310E: Microfabrication

Team 6

LAB 1 - CLEANING

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INTRODUCTION

Microfabrication requires rigorous control of the environment and of substrate quality to ensure the reliable fabrication of microsystems. Contaminants on silicon wafers can severely affect electrical and mechanical properties, making cleaning a crucial first step.

The objective of this first laboratory was to introduce cleanroom safety rules and proper conduct, as well as to prepare two substrates—a silicon wafer and a Silicon-On-Insulator (SOI) wafer—that will be used in subsequent fabrication steps. Cleaning was performed using a piranha solution, to remove organic contaminants and grow a thin oxide, followed by hydrofluoric acid (HF), to strip the oxide and leave a clean silicon surface. This preparation ensures that the wafers meet the quality standards required for later processes such as photolithography and etching.

EXPERIMENTAL SECTION

Two samples were used in this laboratory: a crystalline silicon wafer and a Silicon-On-Insulator (SOI) wafer. Both were placed in a plastic support for handling during the cleaning steps.

The cleaning began with the preparation of a piranha solution (H_2SO_4:H_2O_2 in a 3:1 ratio, ~200 mL). Each sample was immersed for ten minutes to remove organic contaminants and promote the growth of a thin oxide layer. The wafers were then rinsed sequentially in two deionized (DI) water baths for two minutes each.

Next, the wafers were immersed for two minutes in a 1% hydrofluoric acid (HF) solution, pre-prepared at the correct concentration, to strip the thin oxide layer. They were then rinsed in the DI water baths for five minutes each.

Finally, the cleaned wafers were dried with a nitrogen gun and stored in their labeled sample box for use in subsequent laboratories.

DISCUSSION

POST-LAB QUESTIONS

The 2 samples are now cleaned and ready for the next steps. We have been able to observe that the cleaning with the piranha solution removed the contaminants and left an oxide that made the surface of the sample hydrophilic, and that the HF solution removed that oxide and made it hydrophobic. In the absence of other worthy results, the answers to the post-lab questions will complete this section.

“Acid” chemical hoods are specially designed for cleanroom work. Name at least three differences between these acid hoods and conventional hoods. What are the advantages and disadvantages of such a system?

1. Conventional fume hoods protect the user by exhausting fumes away, whereas laminar flow hoods in cleanrooms protect the sample by providing HEPA-filtered vertical airflow. The drawback is that vapors may descend toward the operator.

2. Acid hoods are made from acid-resistant materials (e.g., polypropylene, PVDF) rather than stainless steel, but this makes them less resistant to high temperatures.

3. They include specialized drainage and neutralization systems for handling corrosive solutions, which improves safety for wafer cleaning but increases cost and complexity of installation and maintenance.

Name five different types of contaminants that can be found on wafers, as well as their impact on the components to be manufactured (MEMS, MOS) in terms of properties, quality, etc. [2 points]

1. Organics – Anything unwanted that contains carbon. It can be skin oils, lubricants, photoresist or others. It can play a role in adhesion of deposition. It can also create uneven surfaces.

2. Metals – Logically, for semiconductors technologies, unwanted metals can be very bad for electrical properties. It could create leakage currents or change threshold voltages for example.

3. Oxides - Any exposed silicon grows a thin layer of SiO_2 over time. When it is not wanted, it is a contaminant. Oxides are insulators, and when electrical properties are important as in MOS or MEMS, high resistance is bad. Also, a thin layer of oxide can prevent the growth of silicon layers or other films.

4. Dopants – Dopants have a huge impact on electrical properties. If dopants are introduced or the distribution is uneven, MOS could be grandly affected.

5. Particles (Dusts) – These are defined as contaminants at a macro level. Particles block light during photolithography. If the particles are bigger than the feature being made, we can have problems. Also, in MEMS, it could block moving components.

List the advantages and disadvantages of using an SOI wafer (volume process) for laboratories compared to a multilayer process (surface, i.e., layer growth). [2 points]

Using an SOI wafer in a volume process offers several advantages compared to a multilayer surface growth process. Because the top device layer of an SOI wafer is monocrystalline silicon, it provides better mechanical strength and lower electrical resistivity than deposited polycrystalline films. This leads to improved reproducibility and performance for MEMS devices such as interdigitated combs or microtweezers, since stress and grain boundary effects are minimized. Another benefit is that the thickness of the device layer is well controlled by the wafer manufacturer, ensuring uniformity across all samples. In addition, the monocrystalline structure of SOI means that the crystal lattice is continuous and uniformly oriented across the wafer, unlike polycrystalline layers where misaligned grains and grain boundaries degrade both electrical and mechanical properties.

However, SOI wafers also have important disadvantages. They are significantly more expensive than standard silicon wafers with deposited films, which makes them less practical in some contexts. In addition, the thicknesses of the silicon and buried oxide layers are fixed when the wafers are purchased, while a multilayer deposition process allows more flexibility in adjusting thicknesses as needed. Finally, once an SOI wafer is chosen, the design is constrained by its specifications, whereas surface growth techniques can be tailored for different requirements.

Before and after HF cleaning, do water drops spread on the surface or bead? Why? [1 point]

Before the HF cleaning, when the samples were taken out of the rinsing bath right after being cleaned with the piranha solution, water spread on the surface and stuck to it. It showed a clear hydrophilic behaviour, water sticking so much to the surface that it evaporated before sliding down the sample. This phenomenon is explained by the hydrogen bond forming between the oxide at the surface of the silicon and the polar water molecules. After the HF cleaning, however, we observe the opposite phenomenon. Because the layer of silicon oxide is removed by the acid, the H-bond cannot form and the surface becomes hydrophobic. The surface was not even wet when removed from the rinsing bassi and when splashed with water, the drops made beads at the surface.

Why do we have dedicated glassware for each microfabrication step, especially piranha and HF solutions? [1 point]

Because each chemical used in microfabrication leaves residues that can dangerously react with others, it is essential to dedicate glassware to a single solution. For instance, if glassware previously exposed to organic solvents were reused for piranha solution, the violent reactivity of piranha with organics could cause an uncontrolled reaction. Similarly, hydrofluoric acid etches glass and leaves fluorine residues, which could contaminate other solutions or wafers if the same beaker were reused. By keeping separate, dedicated glassware for piranha, HF, and other steps, cross-contamination is avoided, chemical reactions remain controlled, and the quality and safety of wafer processing are maintained.

Could the entire process flow (all four labs) be completed using a different silico crystalline orientation? Explain. [1 point]

For this particular process flow, monocrystalline SiO_2 with (1,0,0) orientation really is the best material we can use. First, the system we are building requires a material that has good electrical and mechanical properties, so a polycrystalline layer of SiO_2 would not have been effective because it presents a high electrical resistance as well as mechanical constraints. (PHS8310E - Laboratory 1: Cleaning - Fall 2025). In theory, this laboratory could have been realised using a monocrystalline layer with another orientation than (1,0,0), like the (1,1,1) crystal we saw in the introduction of the lab, but it would have been difficult if not impossible, to cut all the 90° angles we need for this laboratory since the (1,1,1) orientation crystals tend to break at 60° angles.

CONCLUSION

During this laboratory, the samples have been cleaned using a Piranha solution and an HF solution, in that order, to remove the organic contaminants and the oxide layer. The surfaces are now ready for the next step of the process: photolithography. The next lab will consist of patterning electrical contacts for the micro-tweezers by a photolithography-metallization-lift off process, that could not have been done on a dirty wafer.