Fundamentals of Micro and Nanofabrication
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Lecture - 60
Lab demo: Silicon Nitride cantilever fabrication-2

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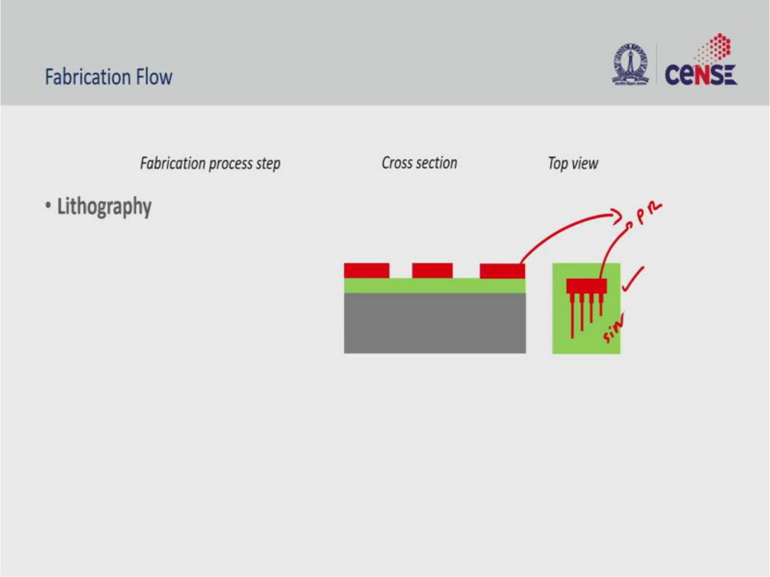

Fabrication Flow

Fabrication process step | *Cross section* | *Top view*

- Lithography

The lithography involves coating substrate with photoresist, and then the pattern transfer from the mask onto the soft photoresist.

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The above slide shows the lithography bay inside a cleanroom. The lithography bay will have yellow light instead of white light to avoid the photosensitive photoresist to get exposed to broadband source or the source of the exposure itself before illuminating using lithography tool.

The bay has all the required tools for lithography like baking tools, coating tools and inspection tools.

The first step in lithography is dehydration bake, to remove any water sitting on the wafer using a hot plate.

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Dehydration bake is done at around 110 degree C, slightly above the boiling point of water, so that all the water present in the wafer is evaporated. After dehydration, the wafer is taken for coating photoresist using spin coating technique.

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The wafer is placed on the spinner and an appropriate program for rotation is selected. A sufficient amount of photoresist drop casted on the wafer.

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When we run the programme, wafer will rotate at various RPMS. Initially, at lower rpm for spreading the resist followed by higher RPM to thin it down to get uniform coating.

Once the coating is done, the wafer is taken out of the chuck and soft baked. During the soft bake solvents will evaporate from the coated viscous photoresist and solidify. The soft bake temperature depends on the photoresist used.

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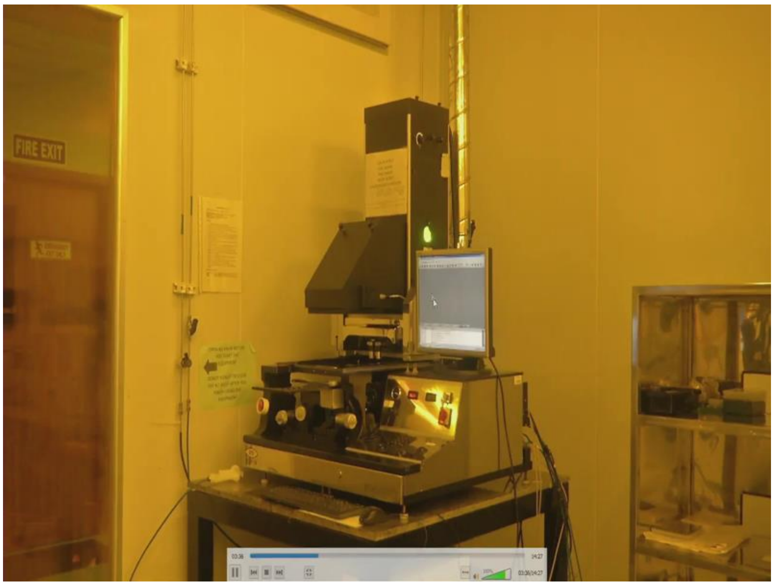

After the soft bake, the sample is taken for exposure. We use a contact or proximity liner tool for exposure. The tool has various components; a tower with an optical source, gas control lines, exhaust.

The tool is logged in and activated by selecting an appropriate program. Then we place the chuck, and the mask holder is held in place by screwing in. the mask plate is taken out of the mask box, and using a nitrogen gun, loose particles sitting on the mask is dusted off. The mask is then placed on the transfer chuck and transferred inside. The mask holder will take the mask and hold it in place. Various adjustments are made using the vernier and the microscope is brought in to visualize the positioning of the mask. The microscope is moved to bring the alignment marker in the view and adjustments are made for the mask to held in place without any alignment errors. After the alignment, the wafer is placed on the chuck and then it is inserted inside to align on top of the mask. The objective will focus on the mask with the wafer in the background so visualize the alignment marker both on the wafer and on the mask.

The structures in the mask is then aligned with the structure present on the wafer using alignment structure. The wafer is moved in both translational and rotational to get minimal misalignment between the two layers; the layer that is already present on the wafer and the layer that we will project. So, fine alignment is done now. So, the operator is checking if the alignment is good on different sides. Alignment is checked at various corners and regions with some critical structures to avoid misalignments. After the alignment, the microscopes are retrieved, and the wafer is exposed. During exposure, a blue light appears, and once the exposure is done, the exposure head is retrieved. The mask lifted up, which was in contact with the wafer, and then the wafer was taken out.

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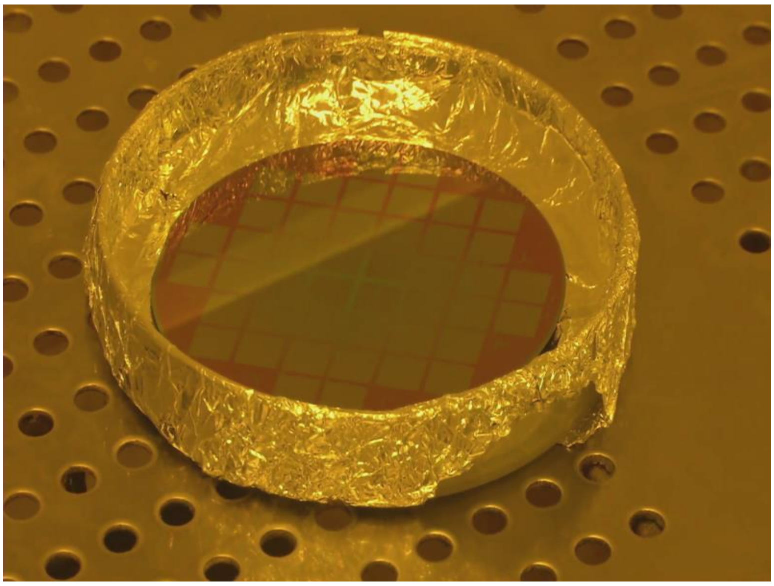

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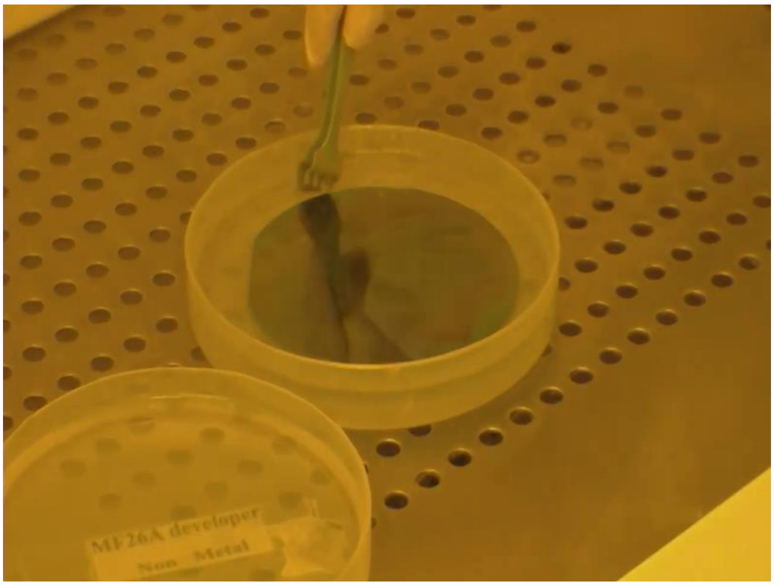

The exposed wafer is developed using a developer. During development, the features slowly starts appearing. After developing for the required amount of time, the wafer is rinsed with DI water to arrest further development. After rinsing, the wafer is blow-dried using nitrogen gun to remove all the water that is present on the wafer surface. Then the wafer is inspected to check if the developed structures are similar to that we have designed. We had designed a cantilever and we expect to reproduce those cantilevers on the wafer surface. The wafer consists of two regions; the blue region where the photoresist is removed during development to expose the silicon nitride, and the lighter structure is the photoresist. The photoresist patterns are the designed cantilevers. Then we inspect further to check any defects present on the wafer. After inspection, the wafer is hard-baked. During hard bake, all the hydrants or water that was present on the wafer is removed.

The next step is to transfer the structures on the photoresist into silicon nitride.

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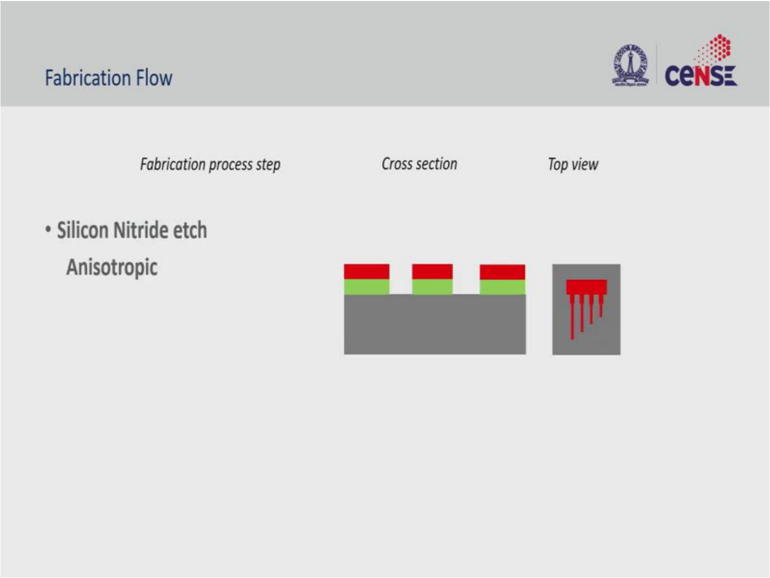

Fabrication Flow

- Silicon Nitride etch
  Anisotropic

To transfer the pattern from photo resist to the film, silicon nitride is anisotropcally etched using ICP RIE tool.

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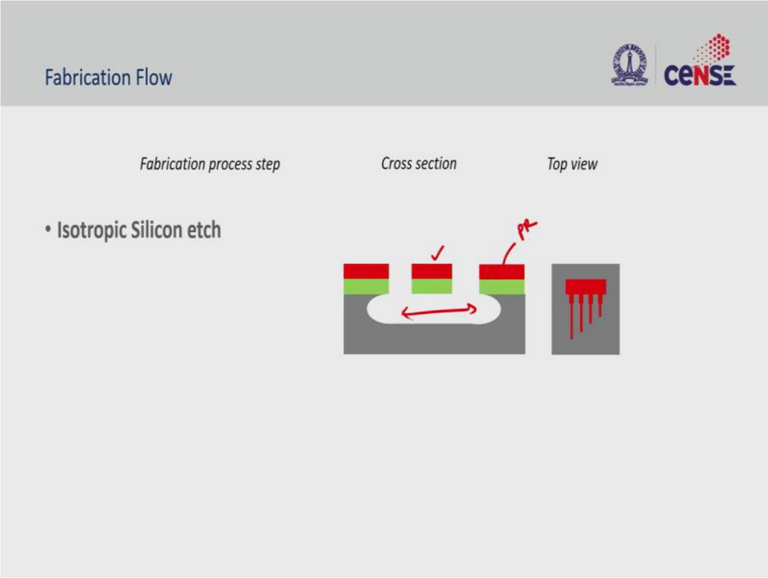

Fabrication Flow

Fabrication process step *Cross section* *Top view*

- Isotropic Silicon etch

To release silicon nitride cantilever, the underlying silicon is etched isotropically using ICP RIE tool. Here SF6 gas is used for isotropic etch silicon.

Once the cantilevers are free-standing, photoresist present on top of the cantilever need to be removed.

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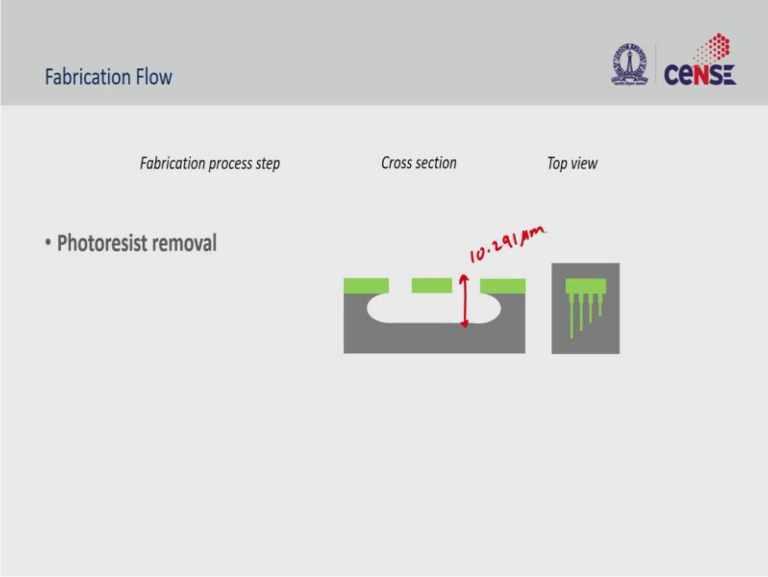

Fabrication Flow

Fabrication process step *Cross section* *Top view*

- Photoresist removal

To remove this photoresist, we use oxygen plasma treatment. All the three etching processes can be done using a single tool.

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We use the ICP RIE reactor for anisotropic silicon nitride etch and isotropic etch of silicon and then remove the photoresist. The tool consists of an inductively coupled plasma (ICP) reactor that generates high-density plasma, and the wafer is going to sit at the bottom.

The tool is operated using software.

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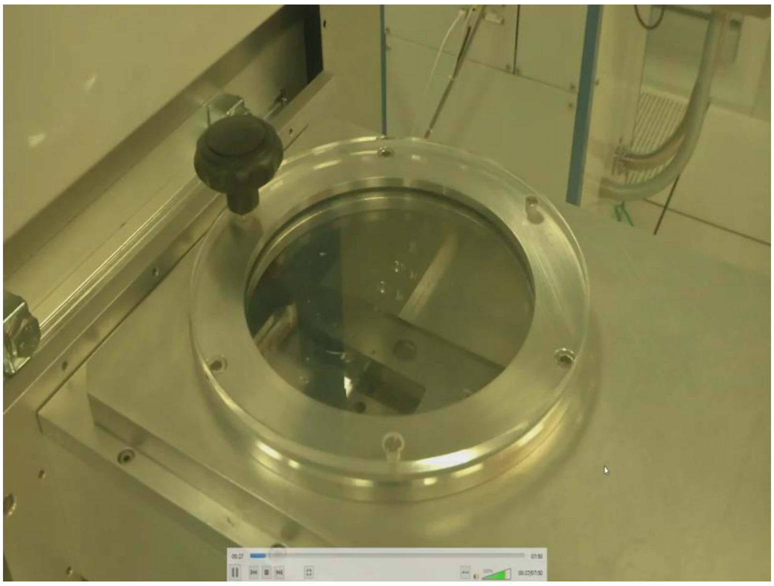

The wafer that needs to be etched is loaded in the load lock, and it is pumped. Once the required pressure is reached, the robot arm will transfer the wafer into the chamber.

After loading, an appropriate recipe is selected to etch the nitride. Once the recipe is run, various gases flow into the chamber, also time and pressure required to etch silicon nitride is also maintained.

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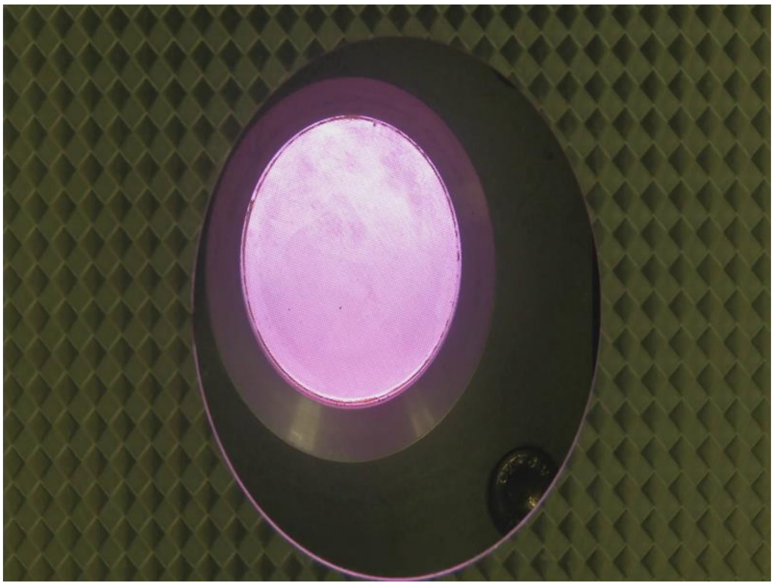

When the required pressure and gas combination for silicon nitride is achieved, the plasma will strike, as shown in the above image. Plasma is generated when the excited gas molecules come to the ground state, emitting a photon. Plasma goes off when the etching is done.

The next step is to etch underlying silicon isotropically using fluorine chemistry. After silicon photoresist is etching using oxygen plasma, which also cleans up all the residues on top of the wafer. After the completion of the process the wafer is retrieved from the chamber using a robot arm, and then the wafer is taken out.

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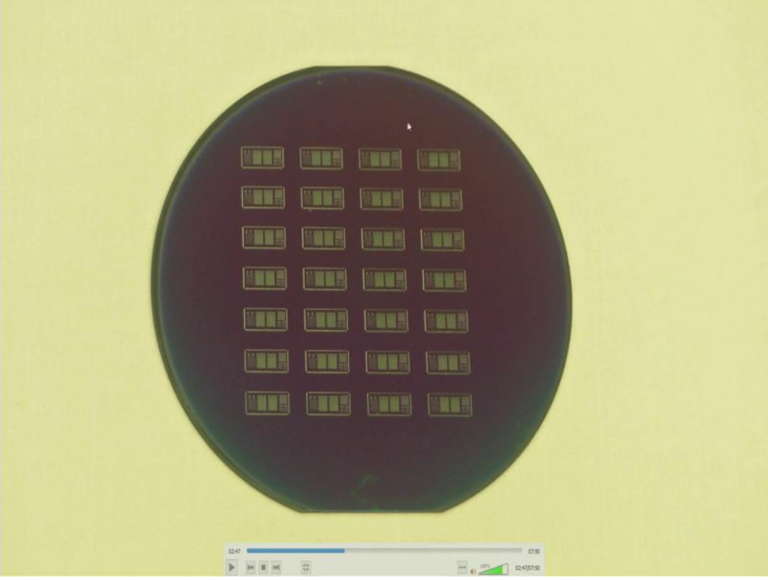

The above image shows an etched wafer. The dark region is the silicon nitride, and the light region is the underneath silicon. The free-standing silicon nitride cantilevers are released by etching silicon to create an undercut. The wafer is then inspected using a microscope.

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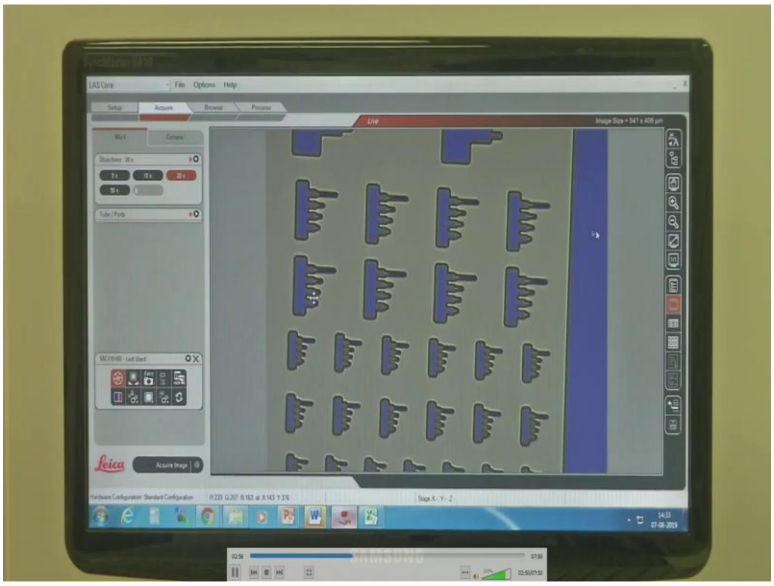

Microscope image shows silicon nitride of various shapes and sizes cantilevers on a silicon substrate. The cantilever view is then zoomed in to check the quality of the cantilever fabricated.

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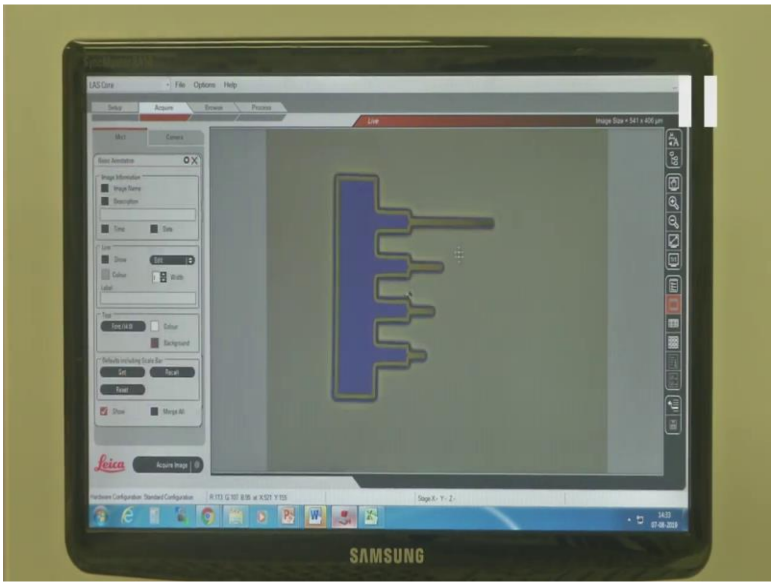

So, what you see here is one of the cantilever groups. The cantilever shows 2 regions: blue in color, silicon nitride with silicon underneath is the fixed region, while the blue region's boundary line is the released silicon nitride cantilever without silicon underneath. During the inspection, it is important to measure the width and length of the features.

The end of the long cantilever will go out of focus by focusing on a fixed part with silicon underneath the region. This is because beams will not be flat; there will be a curling effect due to the stress of silicon nitride film. In the shorter cantilever, the whole cantilever is in focus; the reason for this is the curling is not aggressive because of its short length.

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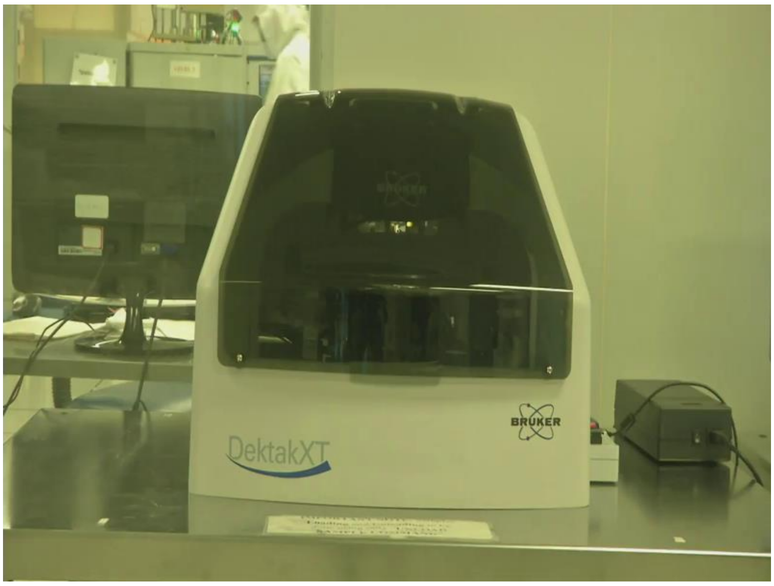

After microscopic inspection, the step height of the structure is measured using a profiler. The tool consists of a stylus that will move over the structure. It is contact mode measurement; we expect a large height difference between the etched and unetched region since the sample is over etched to create an undercut. The profile obtained is baseline corrected, and then the height difference is measured. Measurement shows a step height of about 10.291 μm, with approximately 200nm of nitride and 10μm of silicon.

This was a complete demonstration of cantilever fabrication.

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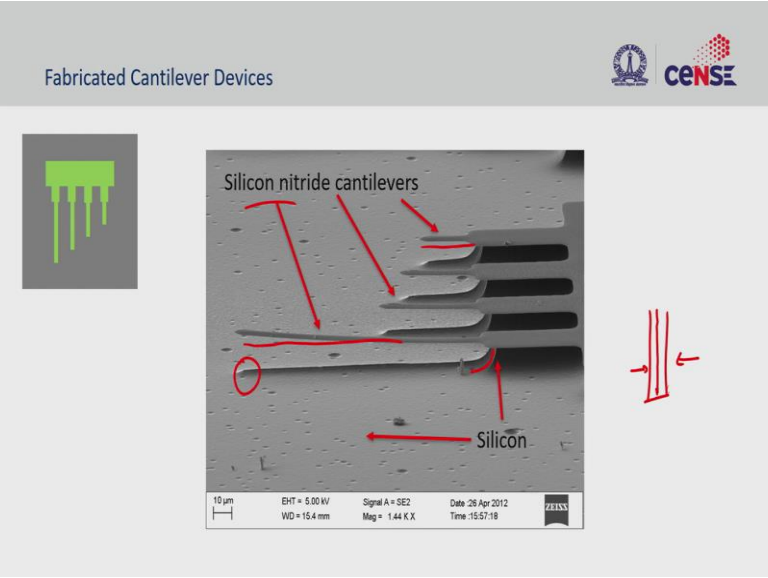
Fabricated Cantilever Devices

The fabricated cantilever is imaged using a scanning electron microscope image, SEM. The above SEM image nitride cantilevers of different lengths. As mentioned, the long cantilever is curled up while the shorter ones are flat. Underneath the cantilever, we observe a shadow due etch rate difference edges and center in isotropic the silicon etch.

We have demonstrated the fabrication of a silicon nitride cantilever using various unit processes studied in the course. This is all done using cleanroom tools at the Centre for Nano Science and Engineering, NNFC. The process requires planning and following all the procedures within each unit process to achieve the desired device.

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