Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

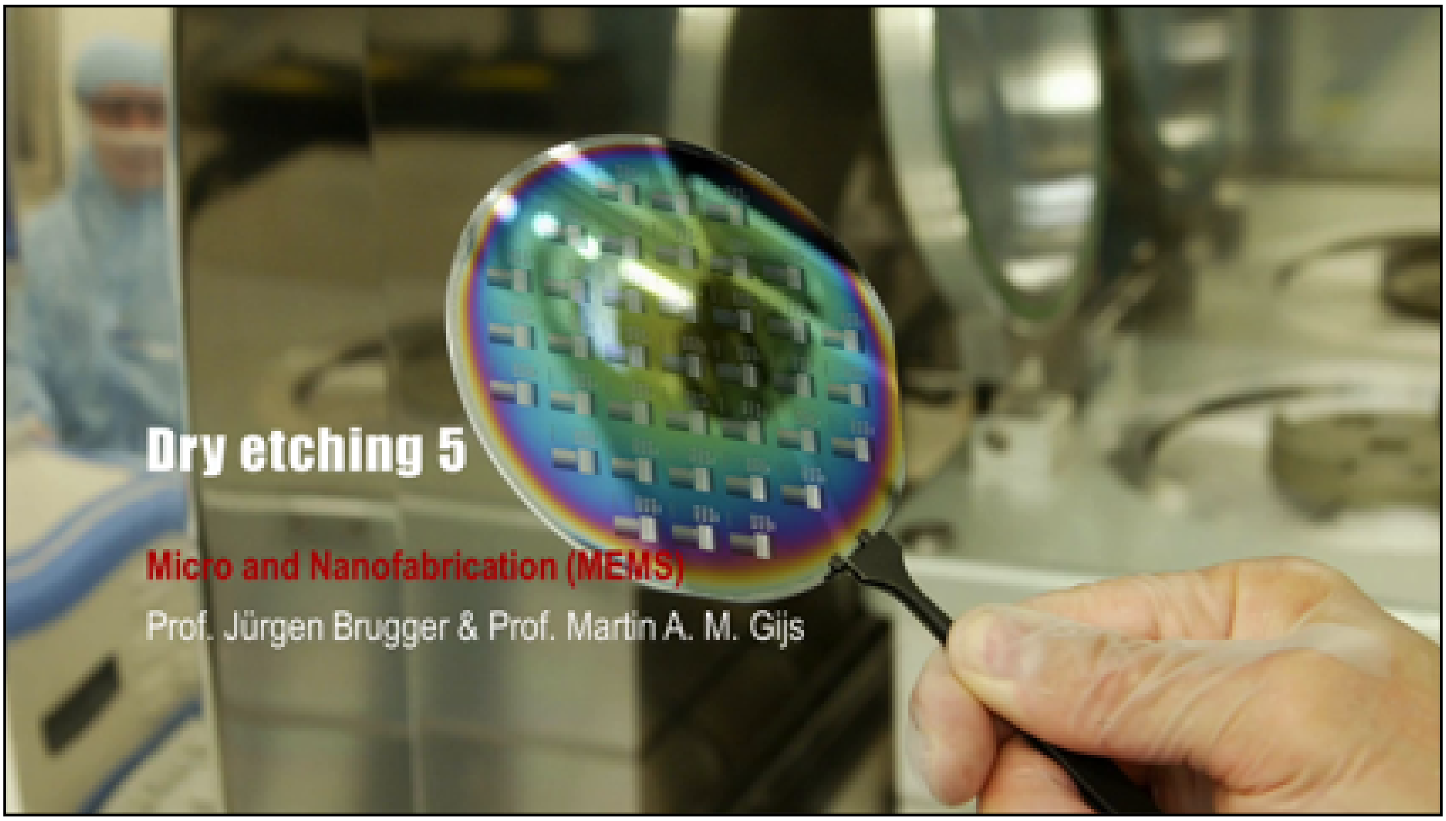
5.5 Dry etching 5

Concepts (extracted from automatically generated subtitles):

Ion beam etchers. Beam of ions. Main etching mechanism of an ion beam. Ion beams. Ion beam etching system. Reactive gas. Second option. Use of a single reactive gas. Possible chemical reactions. Clear limitation. Low-thrust space applications. High kinetic energy of the ions. Grid structure. Inert gas. Chemical activity of the second gas.

to video sequence search
(within Micro and Nanofabrication (MEMS).)

to video



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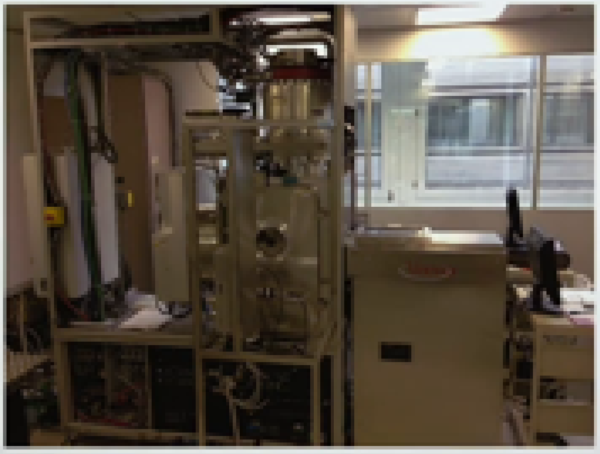
notes

summary

0m 0s

Ion beam etching (IBE)



- Low energy ion beam sources originally were developed for use in low-thrust space applications
- If no volatile products are formed during etching process, physical sputtering is the dominant etching mechanism (e.g. Ar beam)
- Low operation pressure (10^{-4} - 0.1 mbar), collision-less transport, no re-deposition of sputtered material
- Easy to vary the angle of incidence of the ion beam onto the sample, which is impossible in a plasma-based process

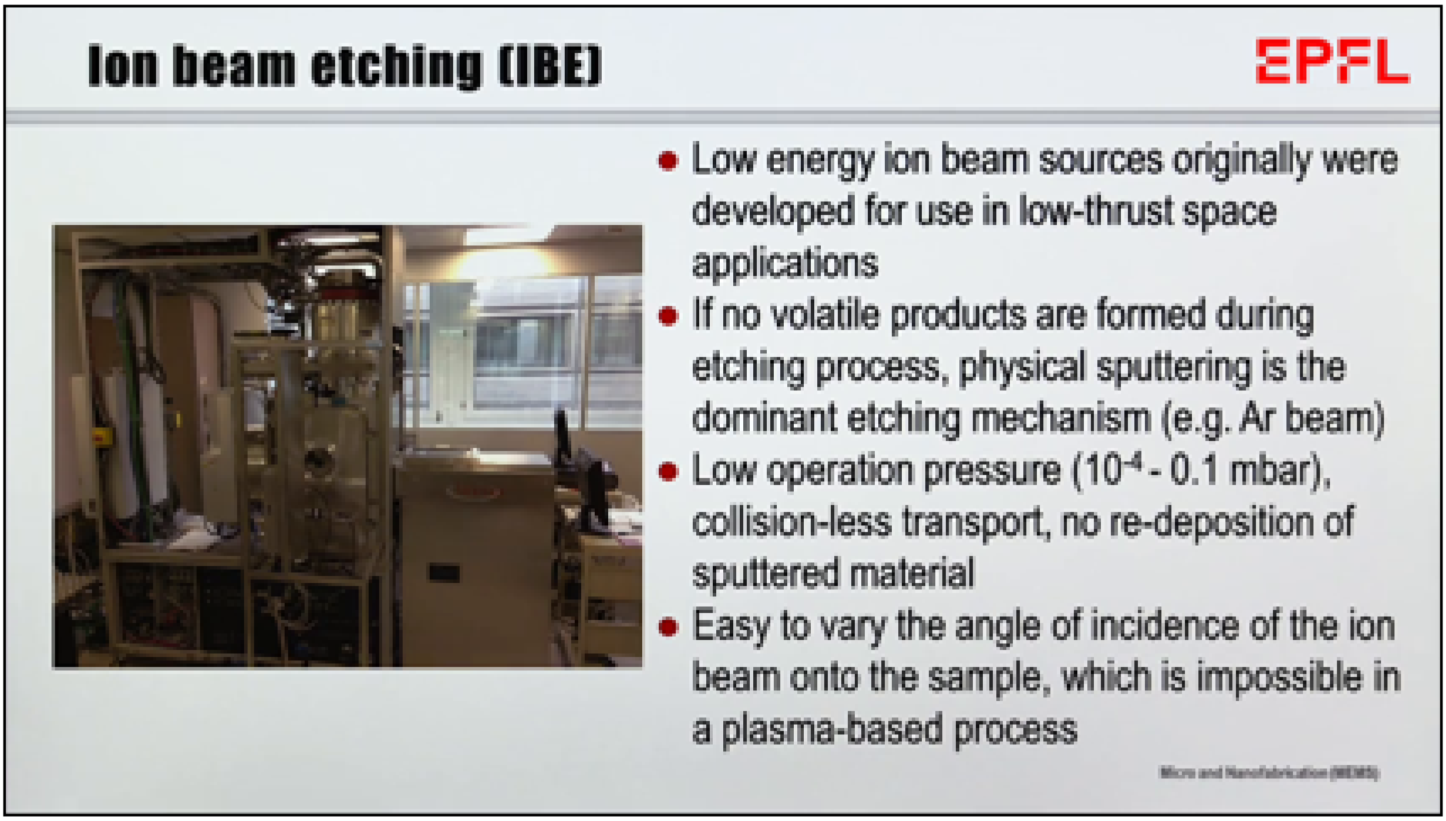
Micro and Nanofabrication (MEMS)

In this lesson we will introduce ion beam etchers, in which the substrate to be etched is not located within the plasma, but subjected to a beam of ions.

notes

summary

0m 1s

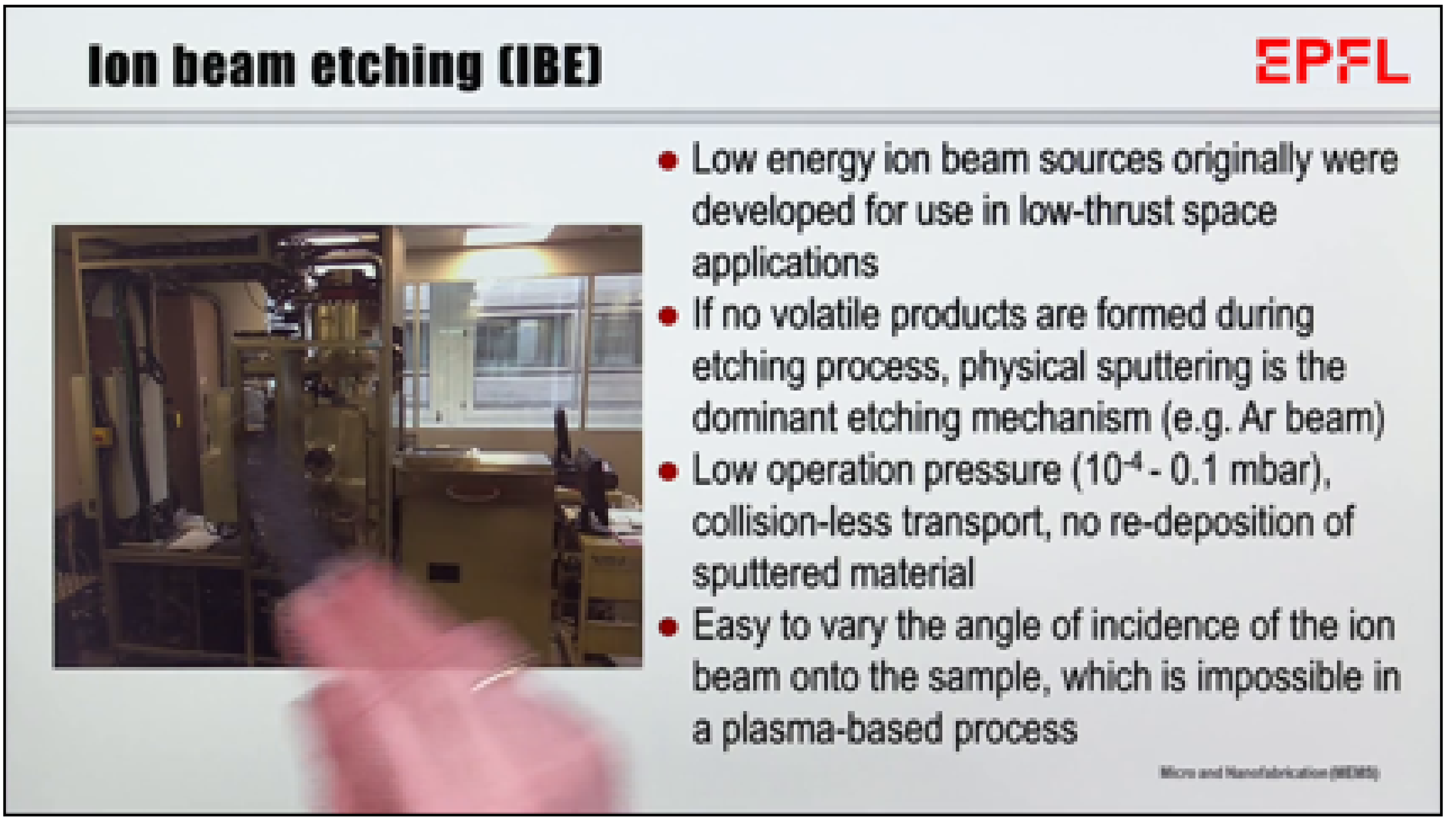


One can also use ion beams to etch wafers. Ion beams originally were used for low-thrust space applications. The main etching mechanism of an ion beam is physical sputtering due to the high kinetic energy of the ions. The technique uses a low operation pressure leading to large mean free paths and little or no re-deposition of material that is etched away from the substrate.

notes

summary

0m 17s



Here we see an ion beam etching system.

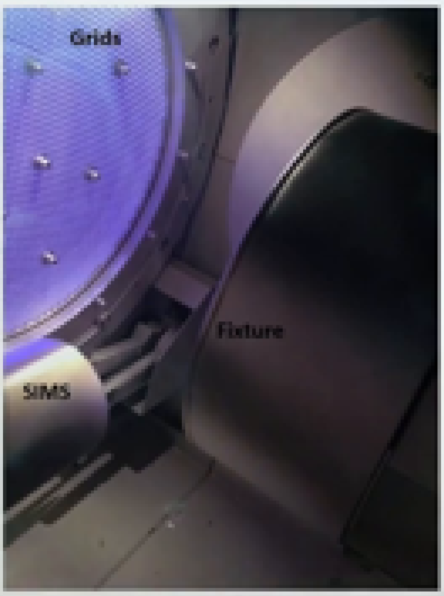
notes

summary

0m 49s

IBE : two main techniques for chemical etching

EPFL



- Injection of a reactive gas directly into the ion source: Reactive Ion Beam Etching (RIBE)
  - Reactive ions (e.g. Cl^+, Cl^{2+}) are extracted through grids and directed onto the sample with appropriate energy (few hundreds of volts)
  - No control of neutral radicals flux
- Inert gas is used in the ion beam and a flux of reactive gas may be added and is directed onto the sample: Chemically-assisted Ion Beam Etching (CAIBE)
  - Independent control of ion flux and neutral flux
  - Rapid diffusion of reactive gas (0.1 mbar) and ion source contamination possible

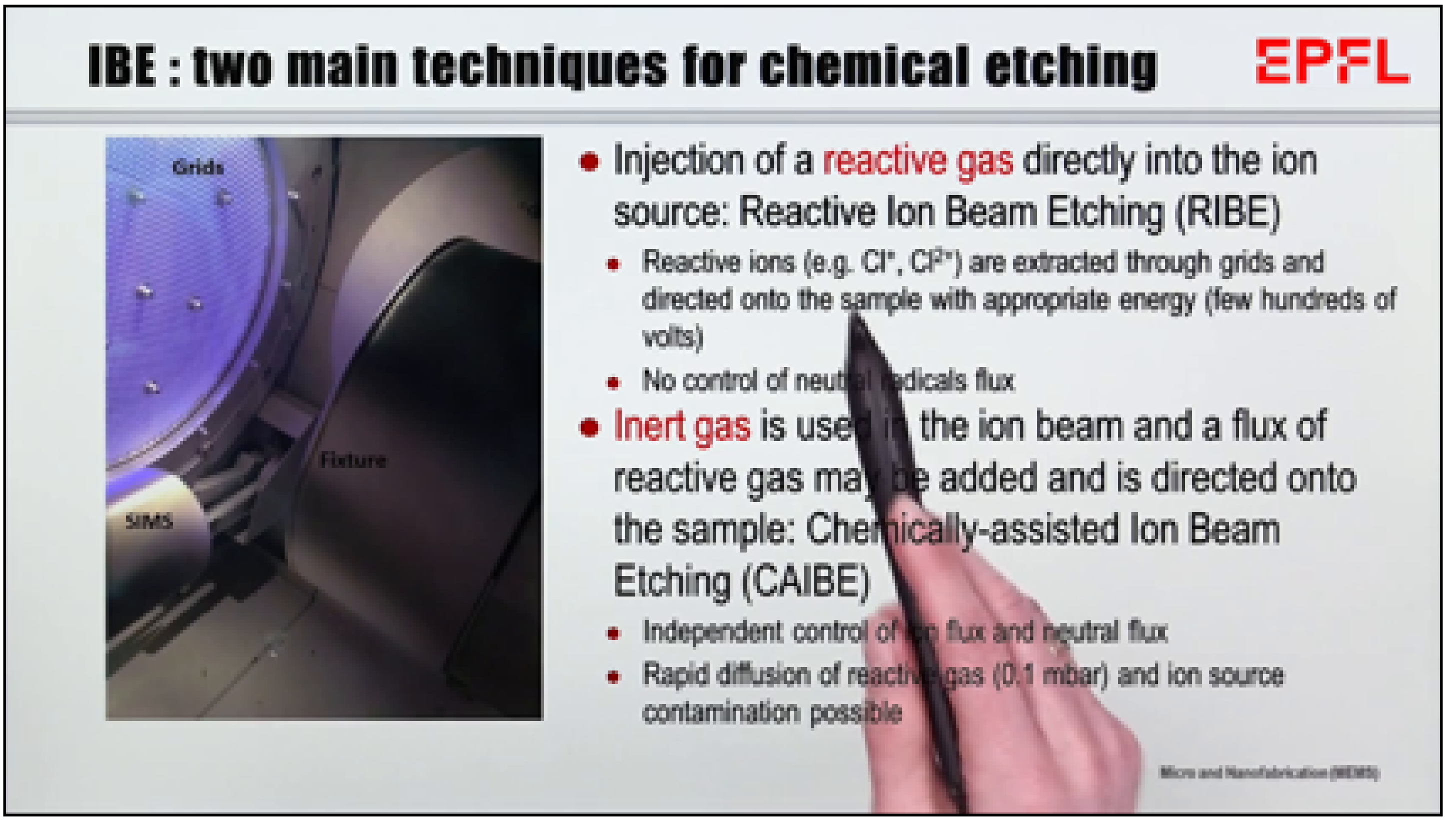
Micro and Nanofabrication (MEMS)

Inside such a system, it is possible to vary the angle of incidence of the ion beam onto the wafer, which is not possible in a plasma-based process.

notes

summary

0m 51s

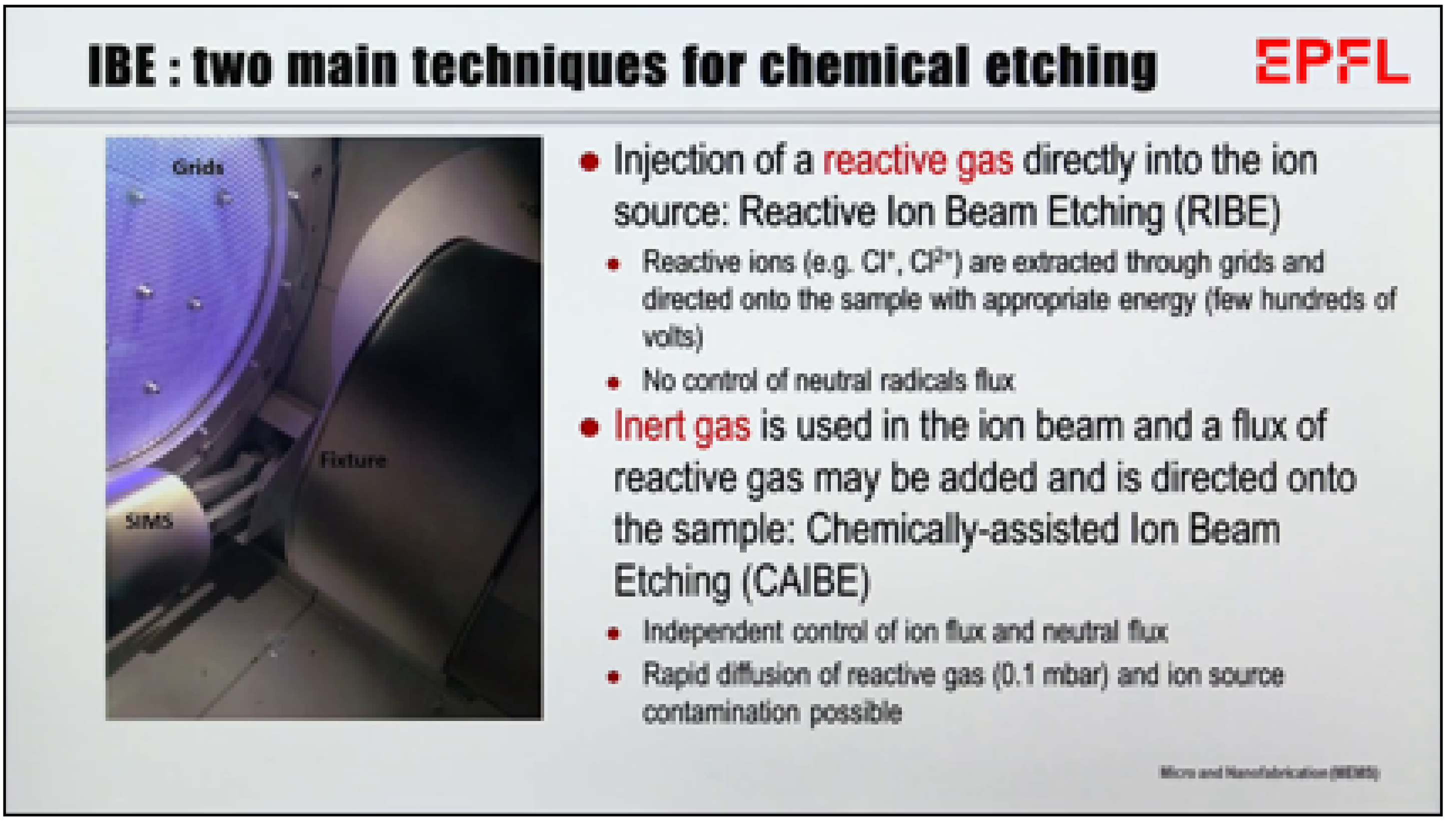


This picture shows the inside of the ion beam etcher. Ions pass through this grid structure and will bombard the wafer, which is here placed on this fixture. An analytical, secondary ion mass spectroscopy equipment is incorporated to probe the evolution of the etching. Two main techniques are used in ion beam etching. One can inject a reactive gas into the ion source and then the technique is called *reactive ion beam etching.* Examples of such reactive ions

notes

summary

1m 6s



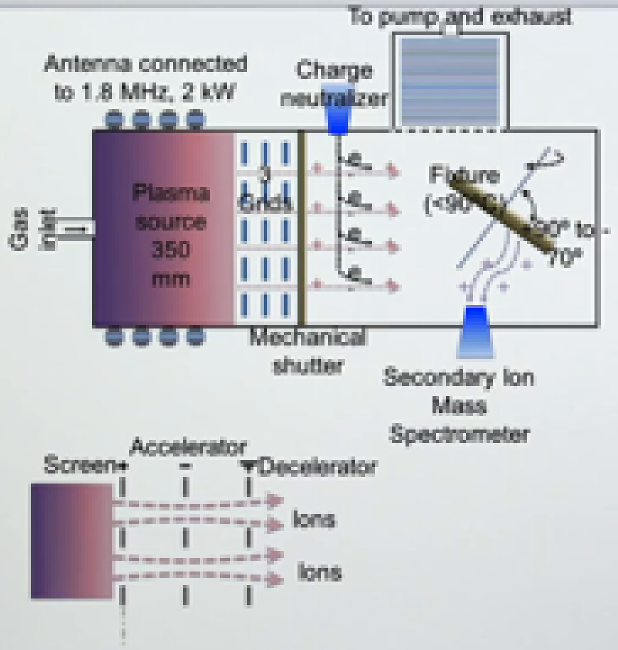
are chlorine or fluorine ions. Use of a single reactive gas allows no independent control of ions, and neutral radicals flux in the system because there is only a single gas. The second option is to use an inert gas, like argon, for the ion beam. Then it is possible to add a flux of neutral reactive gas via another entrance close to the substrate. So here is the reactive gas, and then the argon ions come to bombard the wafer. This combination of physical etching with chemical activity of the second gas makes that one calls this *chemically-assisted ion beam etching.* (CAIBE)

notes

summary

1m 49s

Example of ion beam etcher



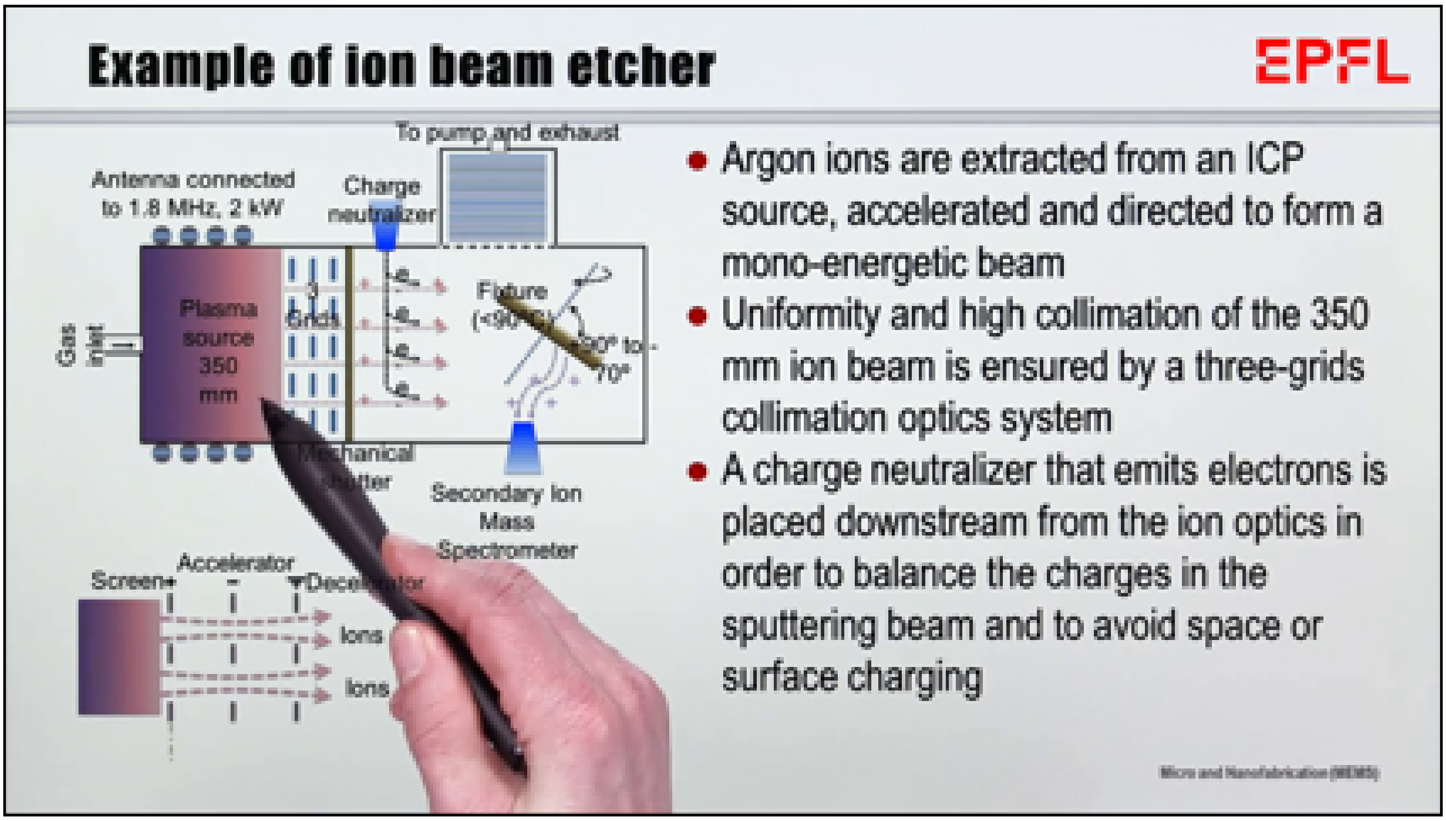
- Argon ions are extracted from an ICP source, accelerated and directed to form a mono-energetic beam
- Uniformity and high collimation of the 350 mm ion beam is ensured by a three-grids collimation optics system
- A charge neutralizer that emits electrons is placed downstream from the ion optics in order to balance the charges in the sputtering beam and to avoid space or surface charging

Here one can independently control ion flux and a neutral flux. However, an inconvenience (disadvantage) of this latter technique is that the reactive gas may diffuse through the system back through the grids and contaminate the ion source.

notes

summary

2m 49s

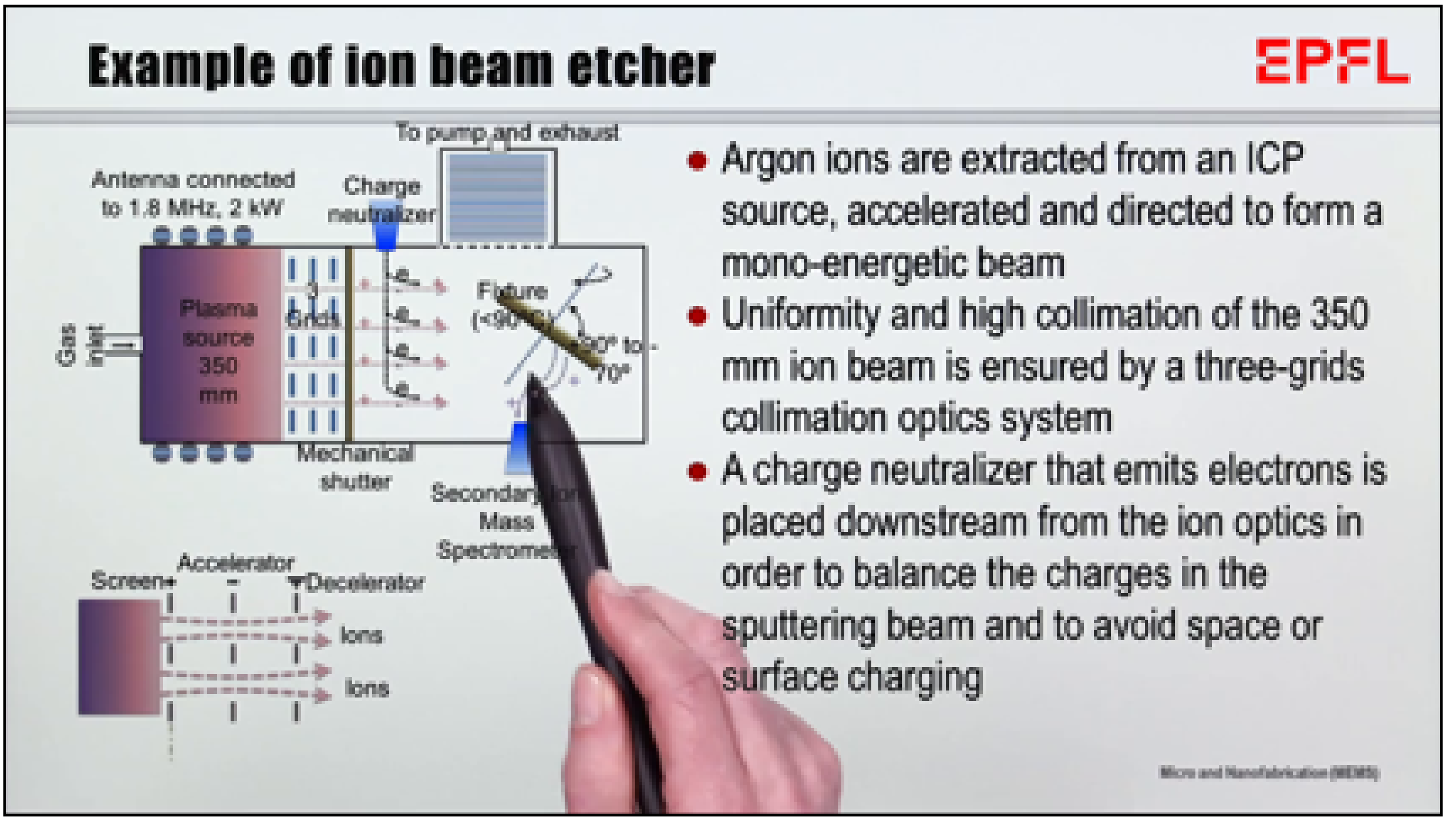


Here we show schematic diagrams of the inside of the ion beam etchers. Argon ions are created in an ICP source

notes

summary

3m 10s

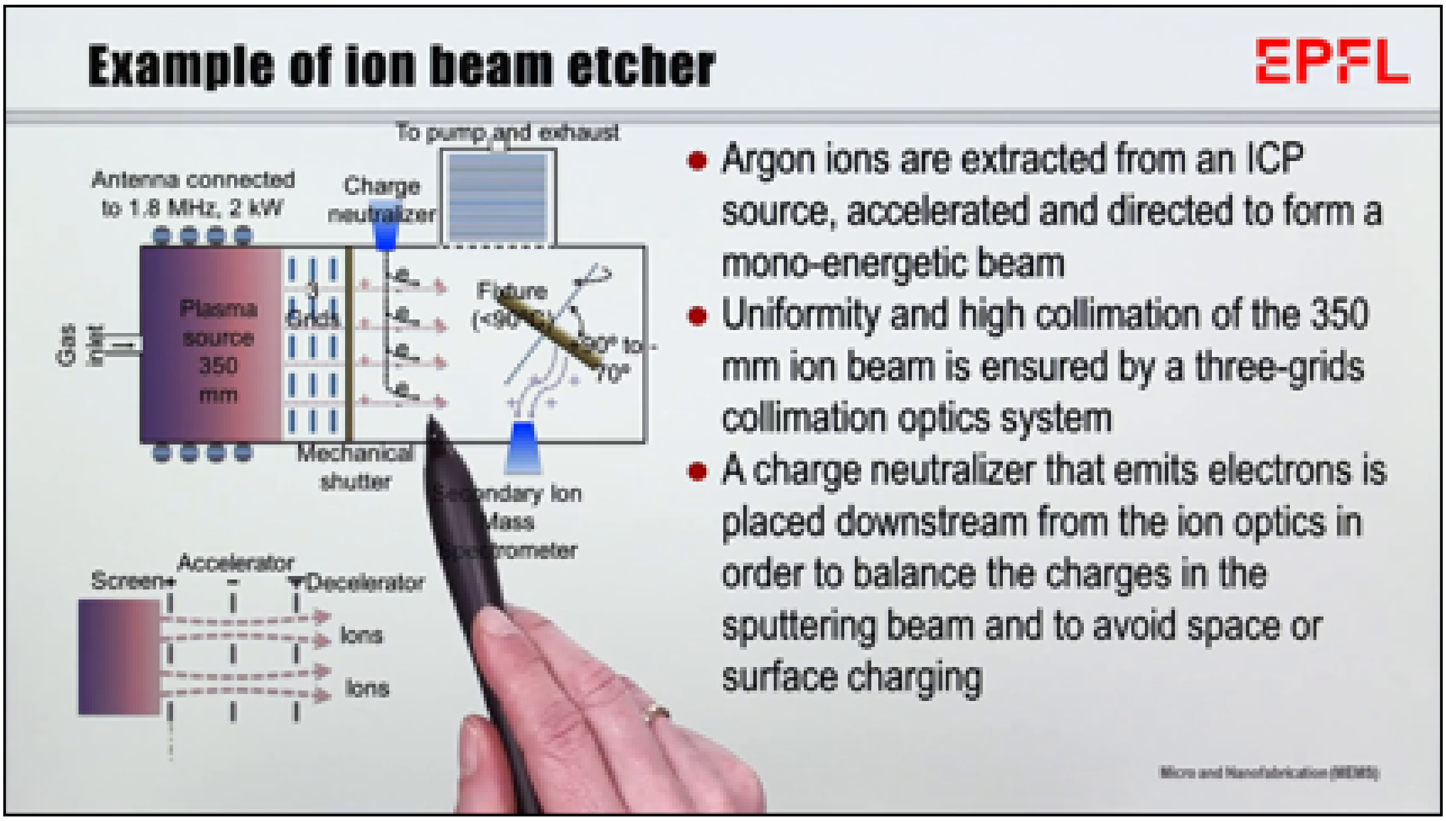


and then are accelerated via three grids towards the substrate.

notes

summary

3m 23s

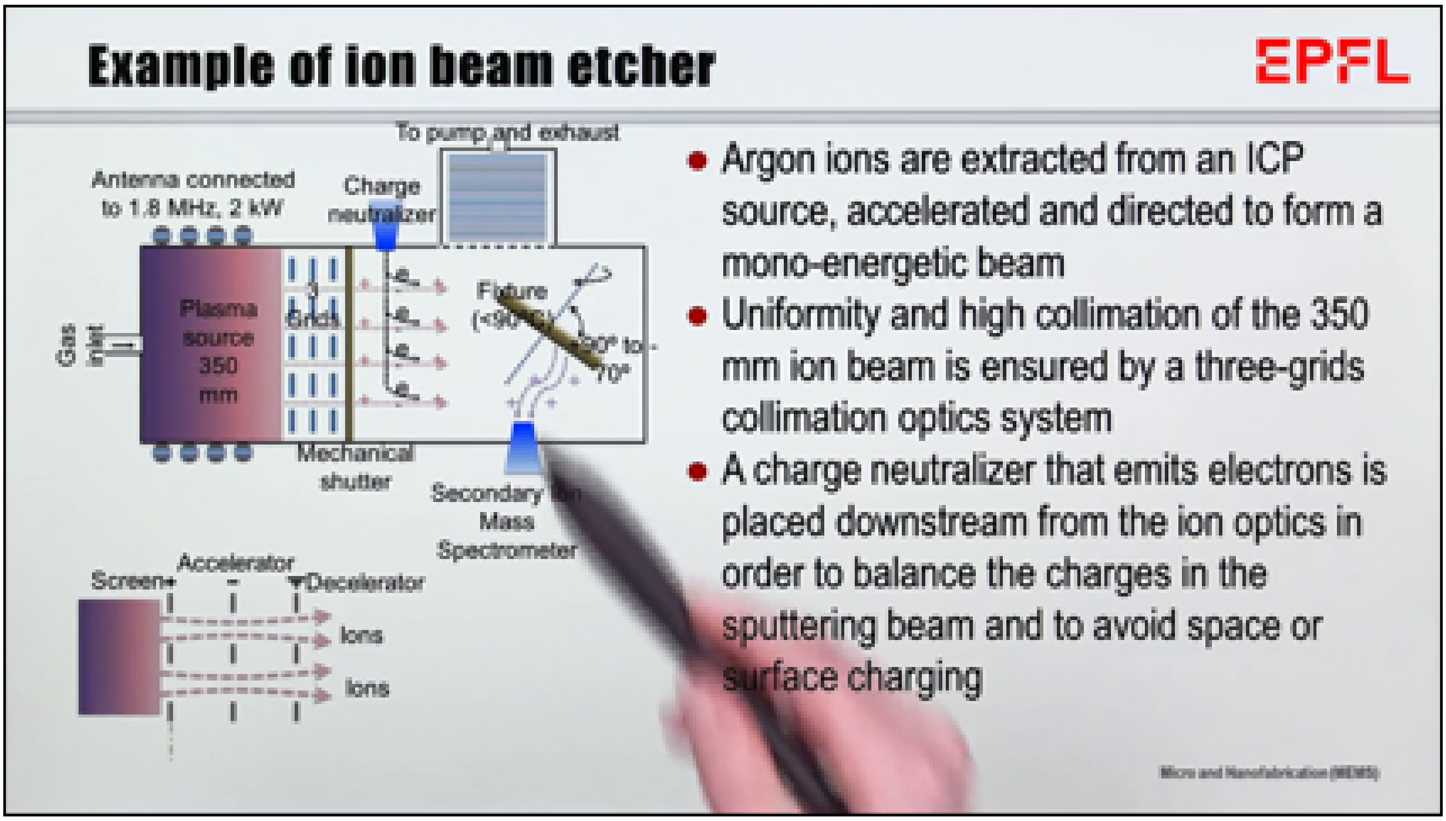


The three grids on which different voltages are applied are schematically drawn here. After having passed through this grid structure, a charge neutralizer emits electrons

notes

summary

3m 29s



to balance the charges in the ion beam to avoid excessive electrostatic charging in the reactor.

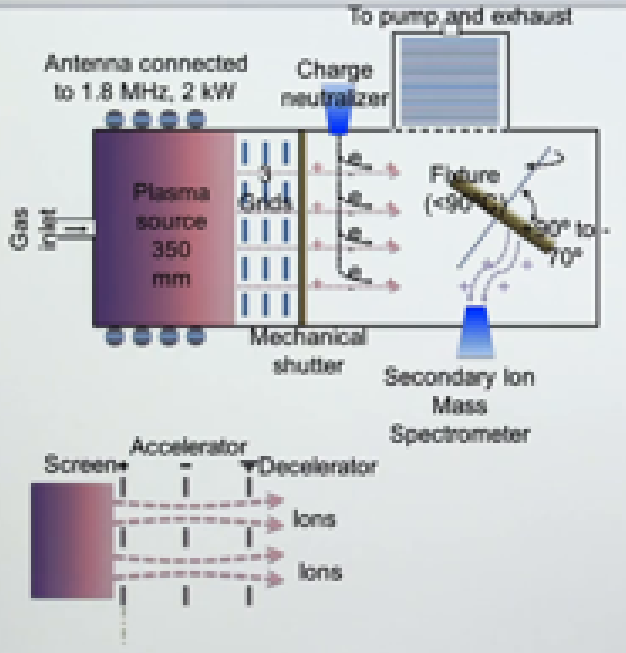
notes

summary

3m 49s

Example of ion beam etcher

EPFL



- Argon ions are extracted from an ICP source, accelerated and directed to form a mono-energetic beam
- Uniformity and high collimation of the 350 mm ion beam is ensured by a three-grids collimation optics system
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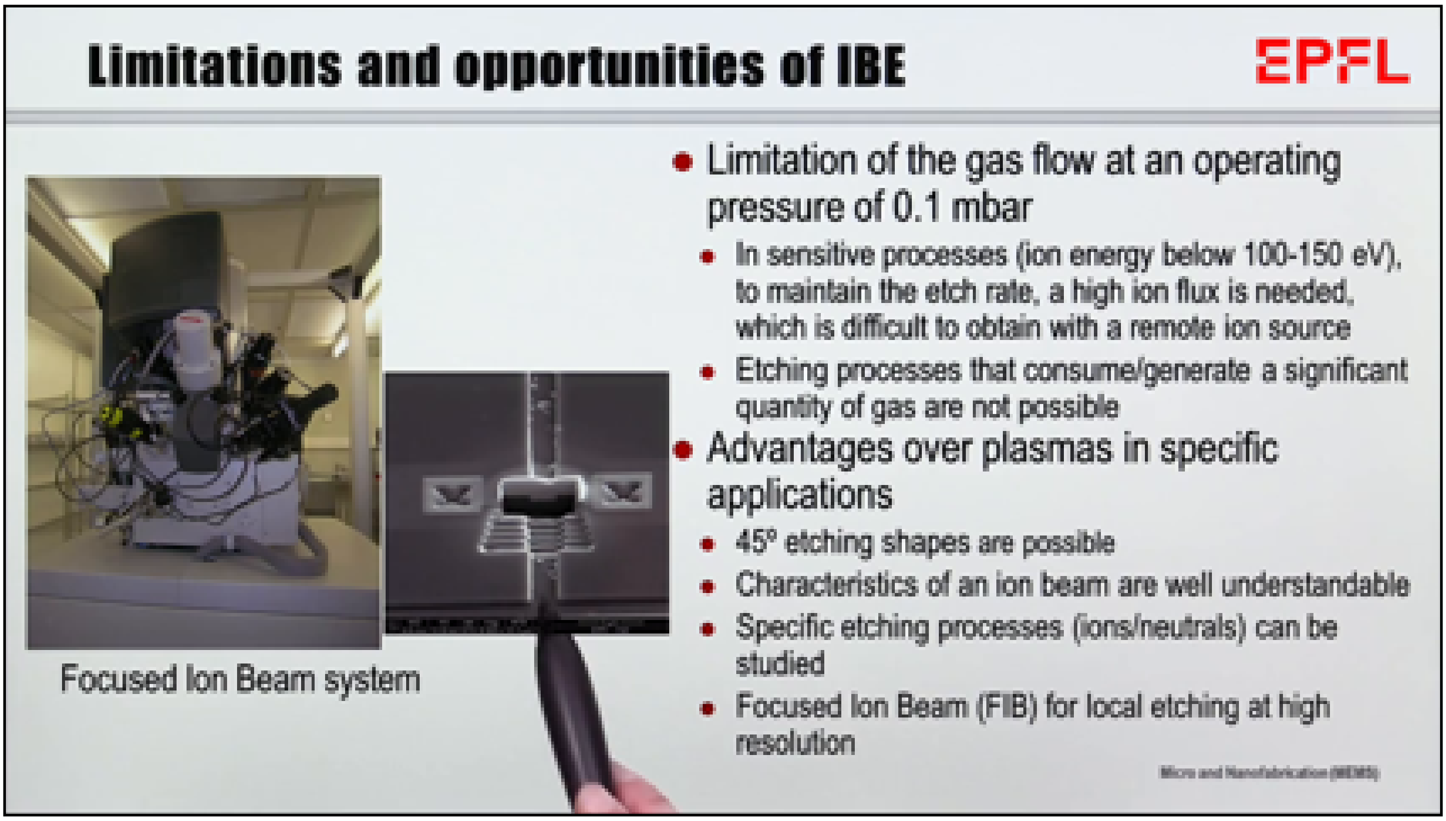
Micro and Nanofabrication (MEMS)

The wafer is mounted on a fixture that can be rotated, so one can change the angle of impact on the wafer. The lower schematic diagram

notes

summary

3m 57s

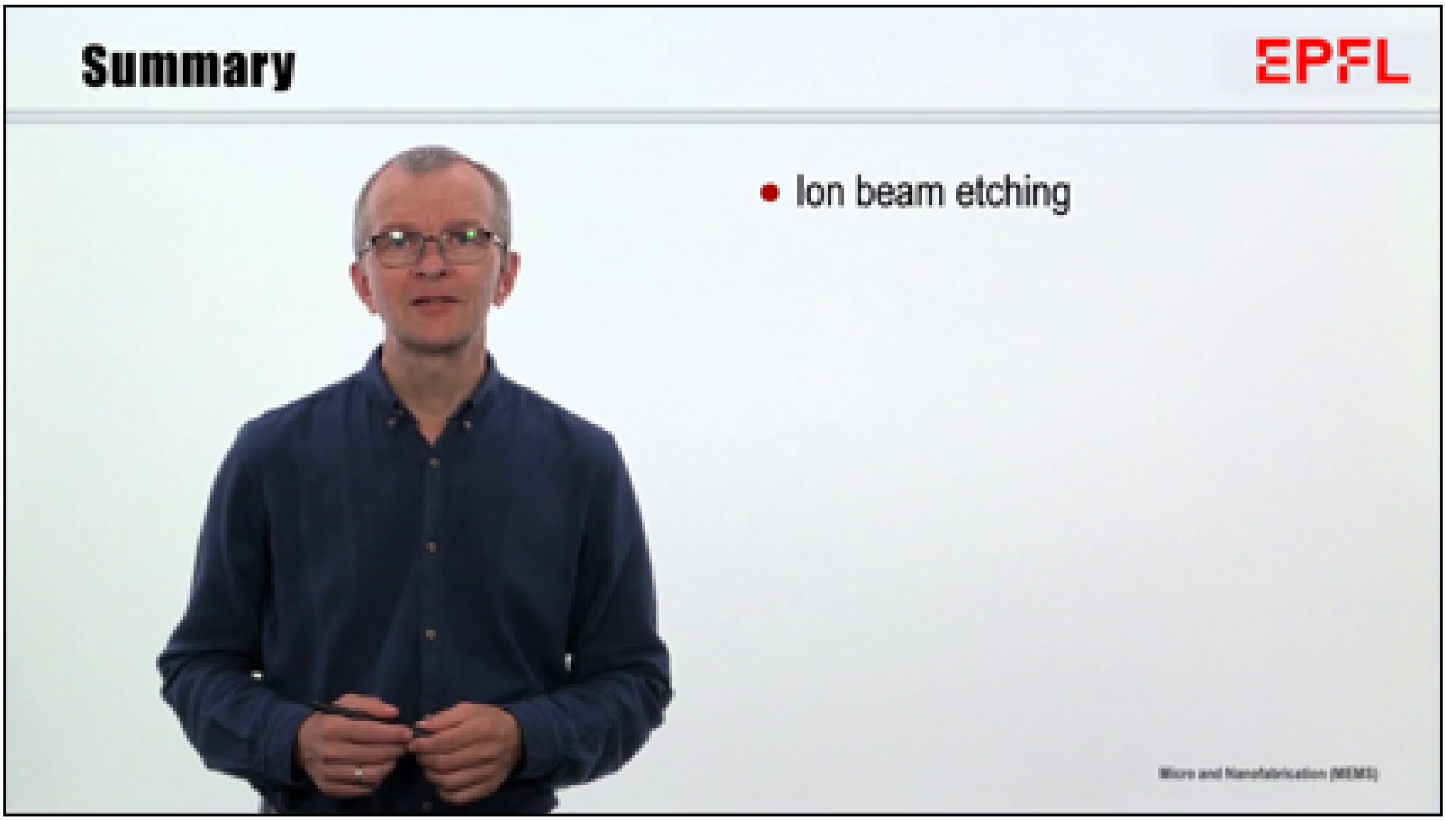


details the voltages applied to the three grid structures that are here. The first grid is for capturing electrons. The second one, for acceleration of the ions. And a third grid for slowing down the ions before being lead into the reaction chamber. What are the limitations and opportunities of ion beam etching? A clear limitation is posed by the low gas flow when the operating pressure needs to be as low as 0.1 millibar. To maintain a high etching rate under such conditions, one needs a high ion flux while one does not want to enhance too much the ion energy for applications where this can cause damage to the wafer with possibly sensitive devices. Another limitation is that etching processes that consume or generate significant quantities of gas are not possible. An advantage of an ion beam source over a plasma reactor is found for special applications. For example, the ion beam has the possibility to expose the substrate at an angle. Also, etching in an ion beam system is more easy to understand as the number of species and possible chemical reactions are limited, contrary to what happens in a plasma reactor. It is possible to study specific etching processes where one applies, in a controlled way, ions and neutrals. Finally, we mention the existence of focused ion beam systems for the local etching at high resolution. The picture shows such a focused ion beam system. Such a system has a very narrow, single ion beam, and it has not the wide area uniform beam that we showed before for the etching of a complete wafer. The narrow ion beam allows local etching and sputtering of certain parts or devices on the wafer, like shown in this picture.

notes

summary

4m 7s



So here one has selected a specific spot on the wafer and there, one has locally applied the focused ion beam to make a cross section through the interior of the wafer. A focused ion beam is therefore an important tool for process control as one can have access to any part of the wafer one wants, and one can analyze technological device aspects on a local scale. In this lesson we introduced the technique of ion beam etching, which is operated at low pressure and offers special possibilities in microfabrication, and fundamental studies of dry etching.

notes

summary

6m 37s