Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

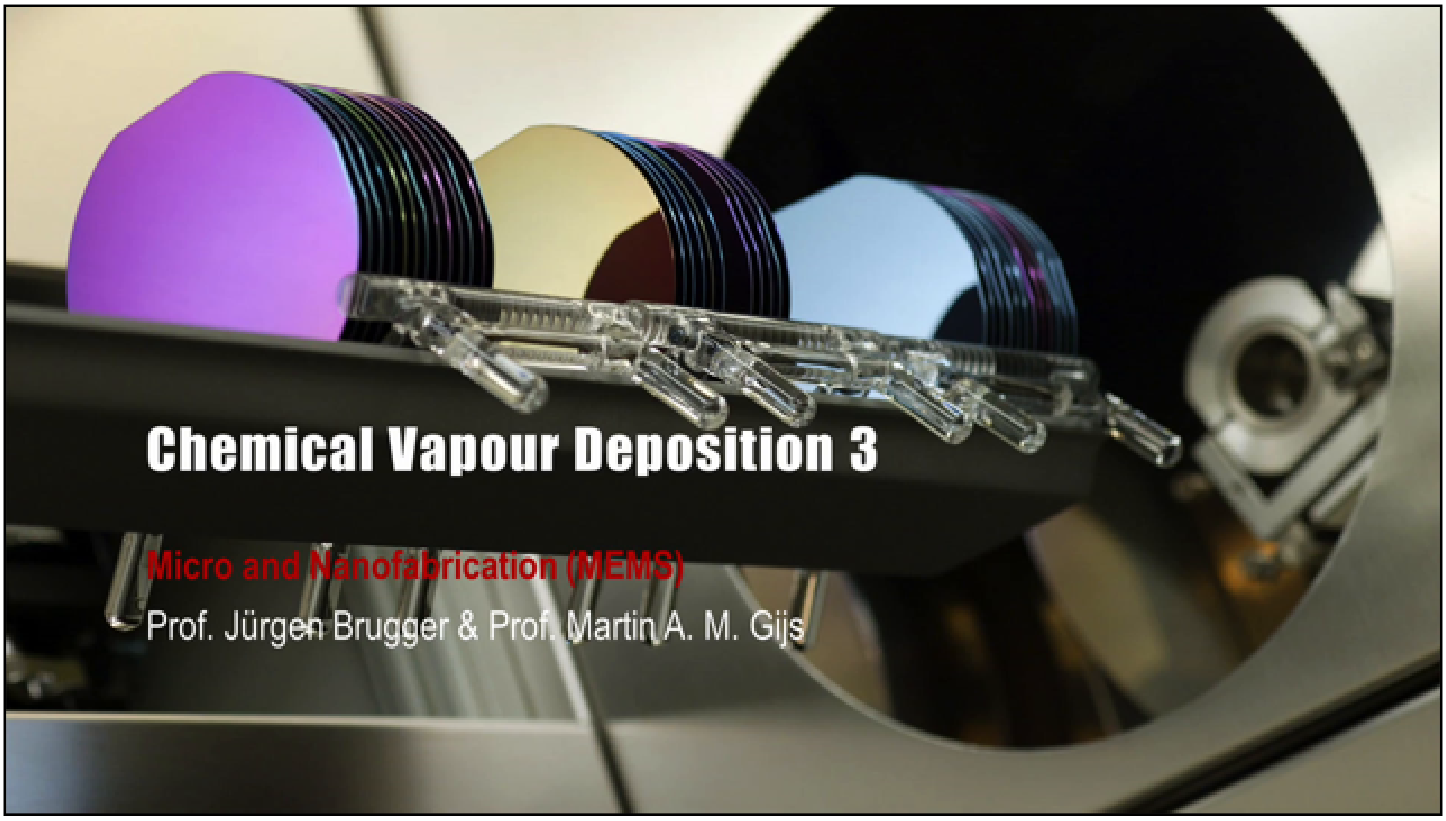
2.3 CVD Part.3

Concepts (extracted from automatically generated subtitles):

Surface of a silicon wafer. Thermal oxidation. Cvd type deposition processes. Atomic layer cvd. Deposition of the oxide material. Silicon dioxide. Chemical reaction. Types of thermal oxidation. Oxygen gas. Thin film. Thick oxides. Cvd process. High temperature. First type. Atomic layer.

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

to video

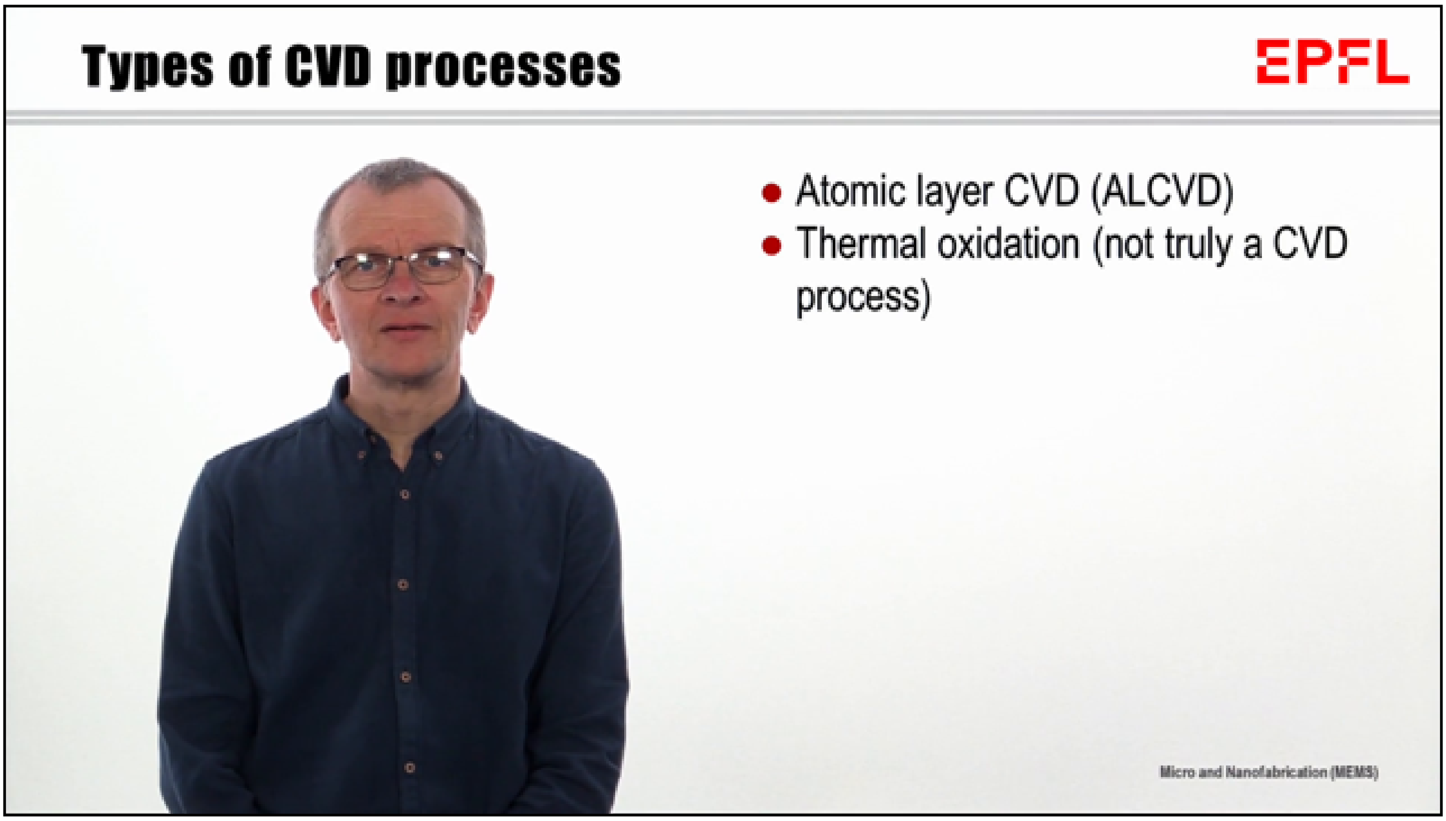


...

notes

summary

0m 0s



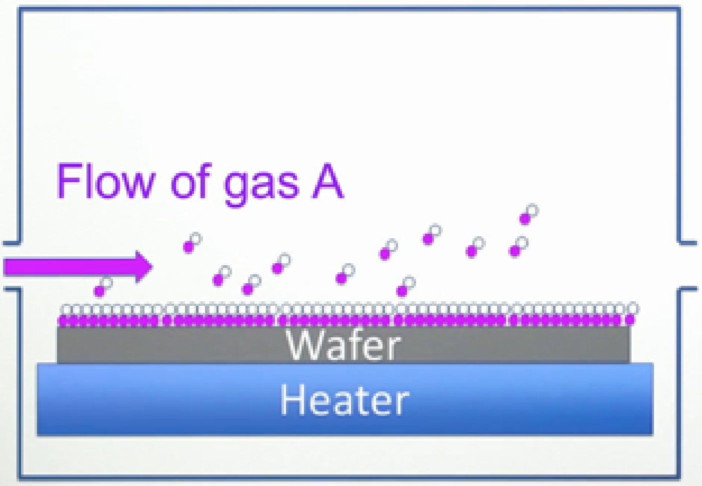
In this lesson, we will discuss two other CVD type deposition processes.

notes

summary

0m 1s

Atomic layer CVD (ALCVD)



- Individual application of two reactant gases A and B allowing sequential formation of layers
- Each of the two reaction steps is self-limiting → one molecular monolayer deposition at a time

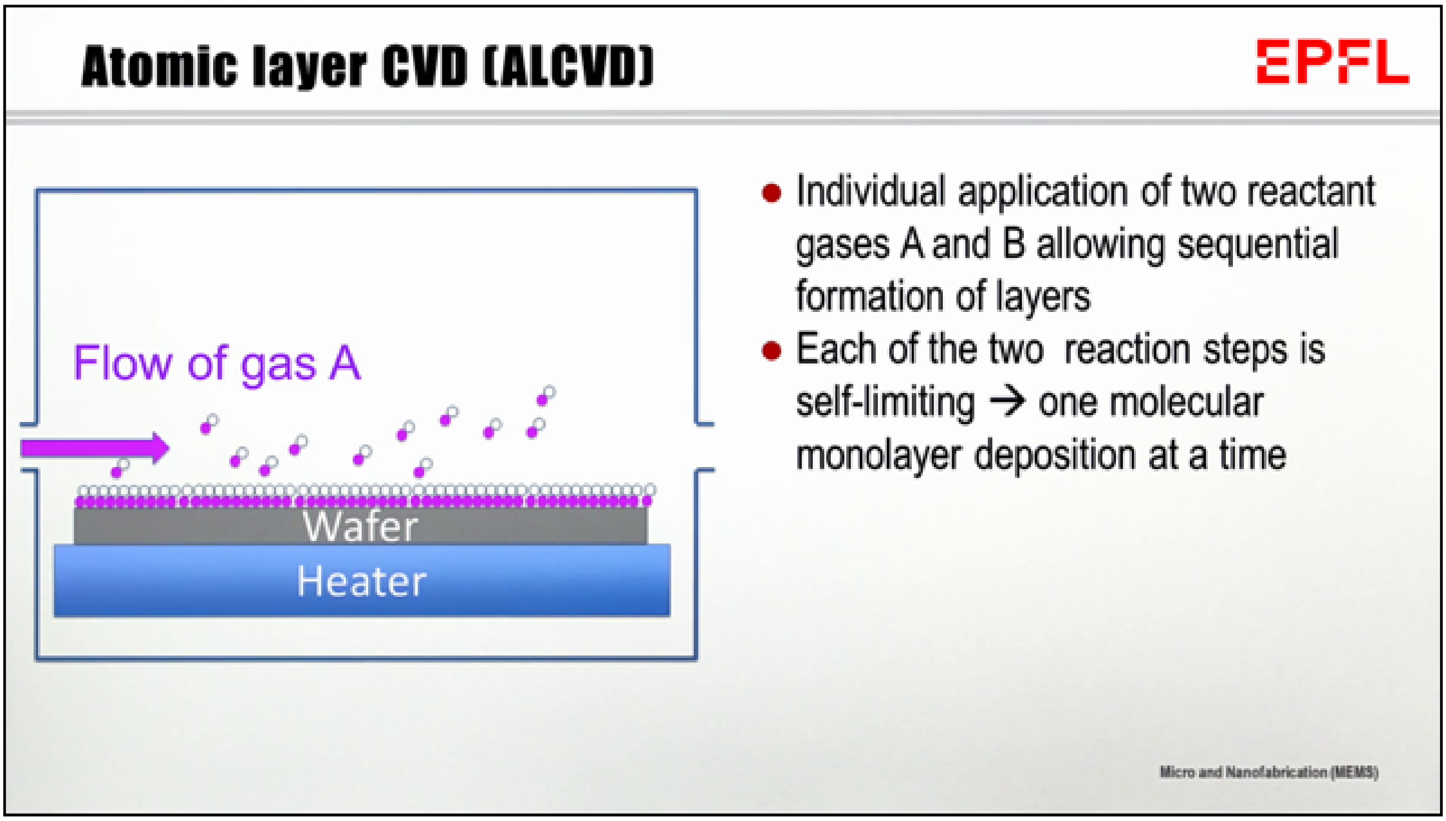
Micro and Nanofabrication (MEMS)

The first one is atomic layer CVD, a technique in which a thin film is deposited, atomic layer by atomic layer. This technique enables the deposition of extremely thin but continuous films without pinholes. The second technique is thermal oxidation. Here one leads oxygen gas into the reactor, which, at high temperature, oxidizes a surface of a silicon wafer. It is not truly a CVD process in the sense that the silicon top layer is transformed to silicon dioxide, rather than there is a deposition of the oxide material from the gas on top of the substrate. In atomic layer CVD, we still have a heated wafer on which a chemical reaction starting from a gas is performed.

notes

summary

0m 5s



The thin film is deposited by sequential deposition of atomically thin layers of two types of materials A and B.

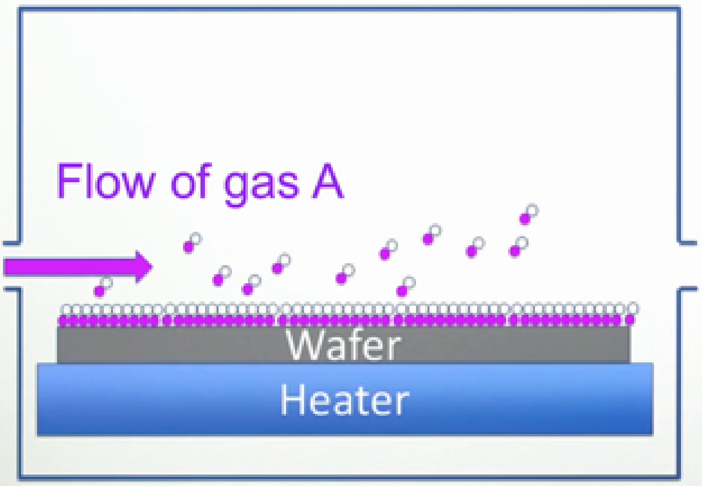
notes

summary

1m 1s

Atomic layer CVD (ALCVD)

EPFL



- Individual application of two reactant gases A and B allowing sequential formation of layers
- Each of the two reaction steps is self-limiting → one molecular monolayer deposition at a time

Micro and Nanofabrication (MEMS)

The characteristic of this process is that each of the two reaction steps is self-limiting.

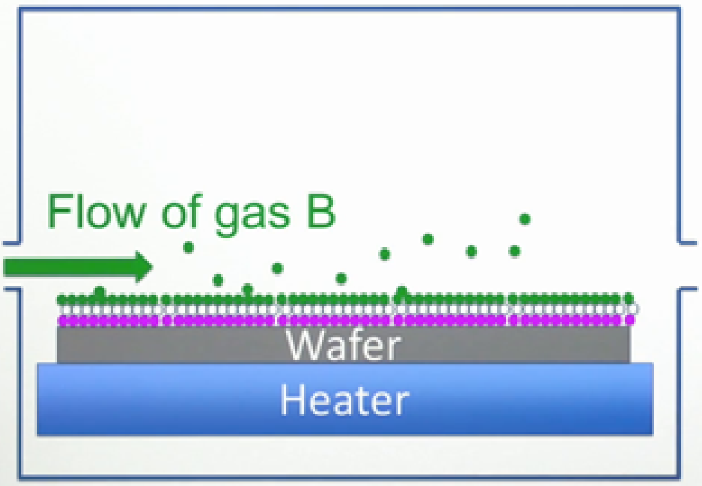
notes

summary

1m 13s

Atomic layer CVD (ALCVD)

EPFL



- Individual application of two reactant gases A and B allowing sequential formation of layers
- Each of the two reaction steps is self-limiting → one molecular monolayer deposition at a time

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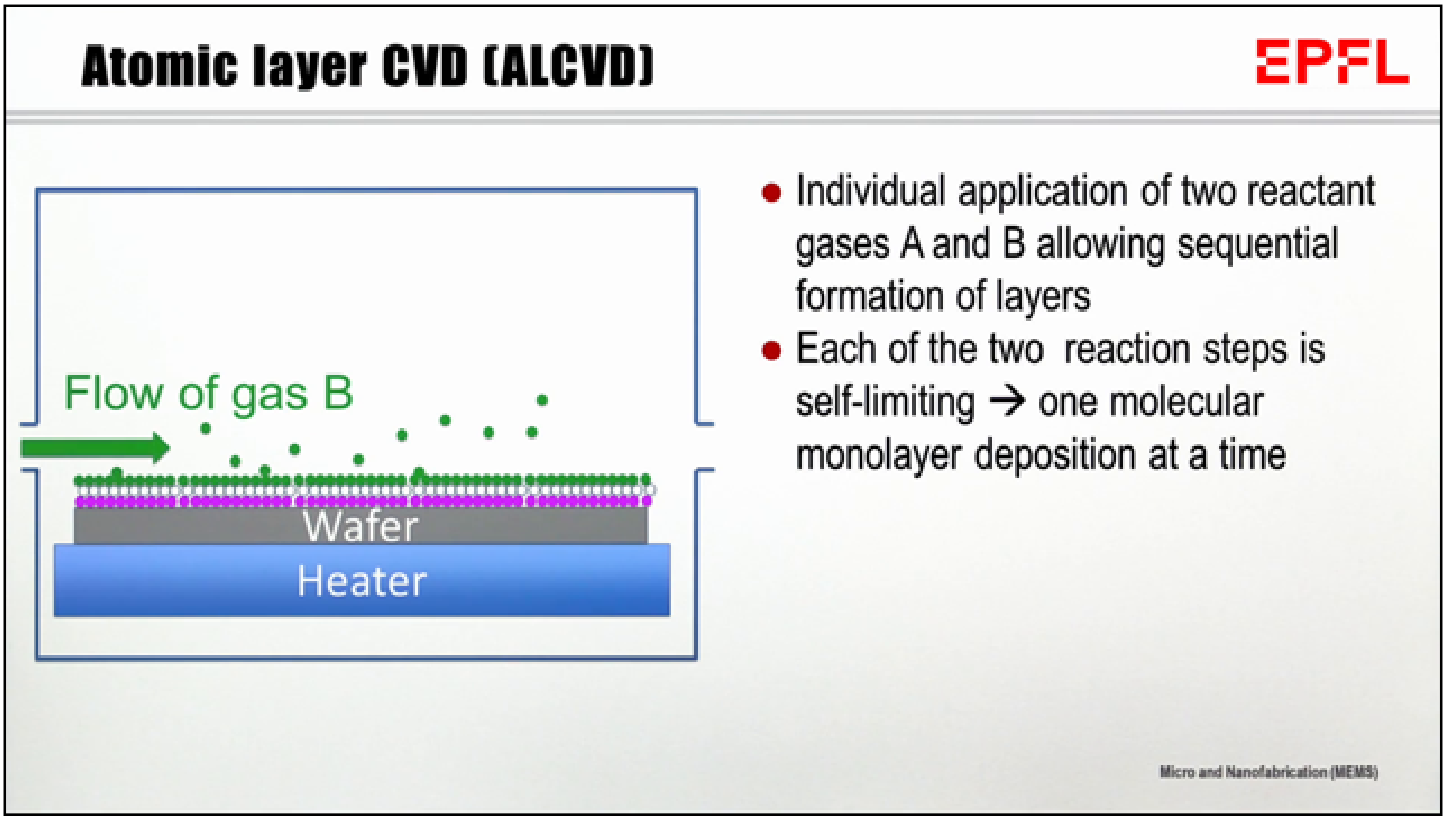
This means that once a monolayer is deposited, the reaction stops, like you see here, schematically for the gas A. When all the surface is covered with the molecules of type A, the residual gas within the reactor is purged by an external pump.

notes

summary

1m 21s



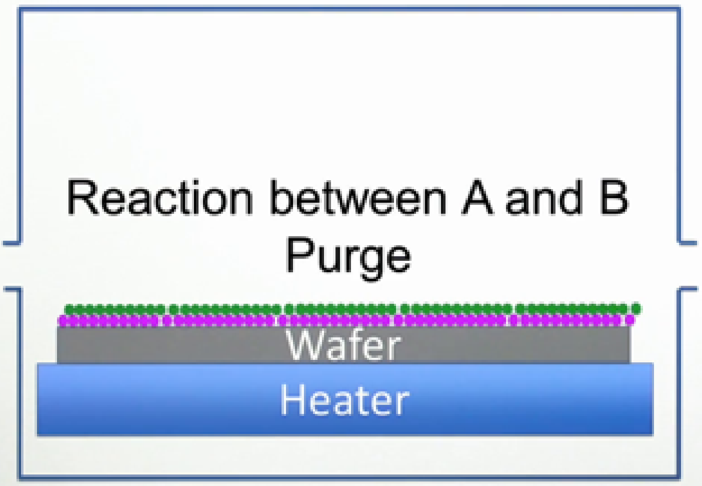
Next follows exposure of the substrate to a flow of gas B. Gas B is chosen so that it chemically reacts with gas A. A monolayer of the gas B reaction product is deposited.

notes

summary

1m 44s

Atomic layer CVD (ALCVD)



- Individual application of two reactant gases A and B allowing sequential formation of layers
- Each of the two reaction steps is self-limiting → one molecular monolayer deposition at a time

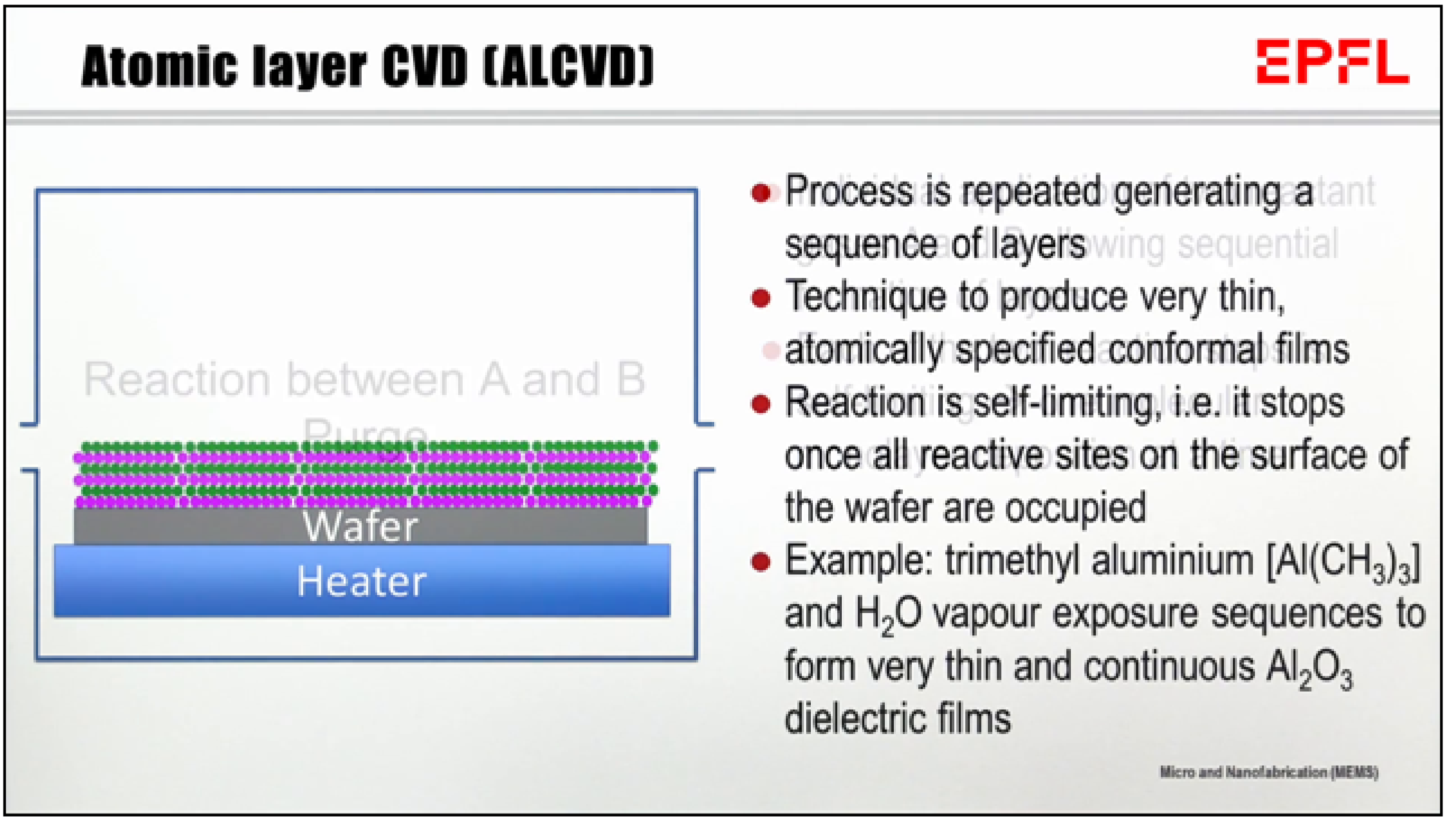
Micro and Nanofabrication (MEMS)

Due to the high temperature of the wafer, a chemical reaction between A and B occurs, and the gaseous reaction byproducts are pumped away from the reactor.

notes

summary

1m 57s

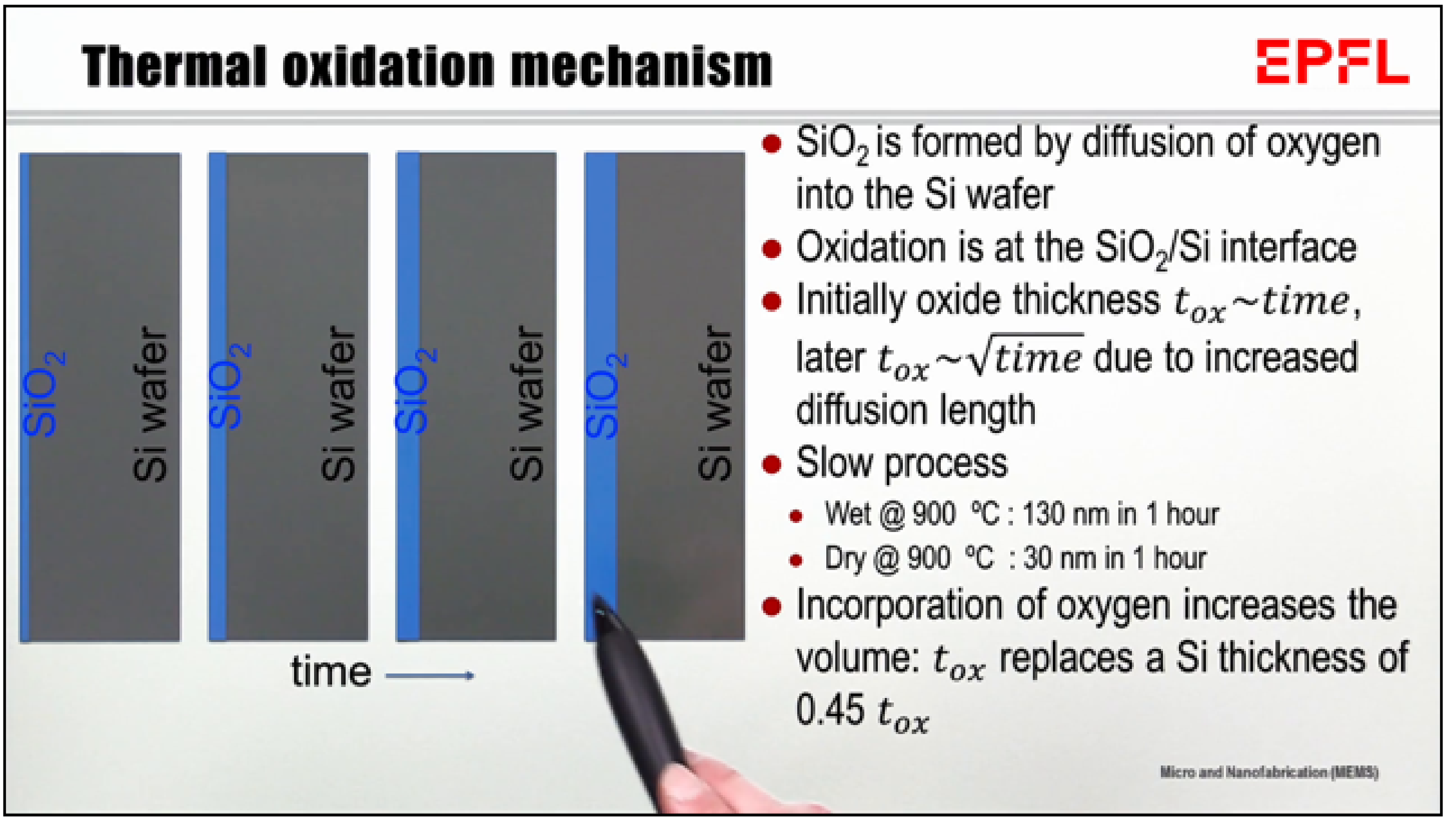


One has now deposited a continuous monolayer of the AB reaction product.

notes

summary

2m 13s



This process is repeated as many times as required for depositing an aimed film thickness. The technique is very interesting for production of very thin conformal films with an atomically well-defined precision. Each biolayer reaction is self-limiting. This means that the reaction stops once all reactive sites on the surface of the wafer are occupied. An example of atomic layer CVD is the use of three metal aluminum and water vapor exposure sequences to generate very thin aluminum oxide dielectric films. Silicon dioxide, or silica, is an extremely important material in microfabrication technology. Thin oxides are used as dielectric in transistors, while thick oxides are widely used as protective coatings and for electrical isolation. Two types of thermal oxidation exist. In the first type, called *wet oxidation*, silicon is exposed to water vapor at high temperature, so that it oxidizes to silicon dioxide under generation of hydrogen. In so-called *dry oxidation*, the silicon reacts with oxygen to give directly the oxide. The water vapor that is used in the chemical reaction results from a combustion process of hydrogen and oxygen gas in a torch, as we will see later. This slide shows schematically the thermal oxidation mechanism. In the beginning, the silicon atoms at the surface are easily oxidized. Later, when one continues in time, the oxide layer becomes thicker and thicker, and it becomes more difficult for the oxygen to diffuse through the thicker oxide layer, to reach the silicon surface. That is why, initially, the oxide thickness is proportional to the time of the process, but later oxidation is slower, and goes with the square root of *time*. Overall, it is a slow process. For wet oxidation, at 900 ºC, we have an oxidation rate of 130 nanometers in one hour, while for dry oxidation, it is only 30 nanometers for one hour. One should also note that because oxygen is incorporated in the silicon lattice, the volume

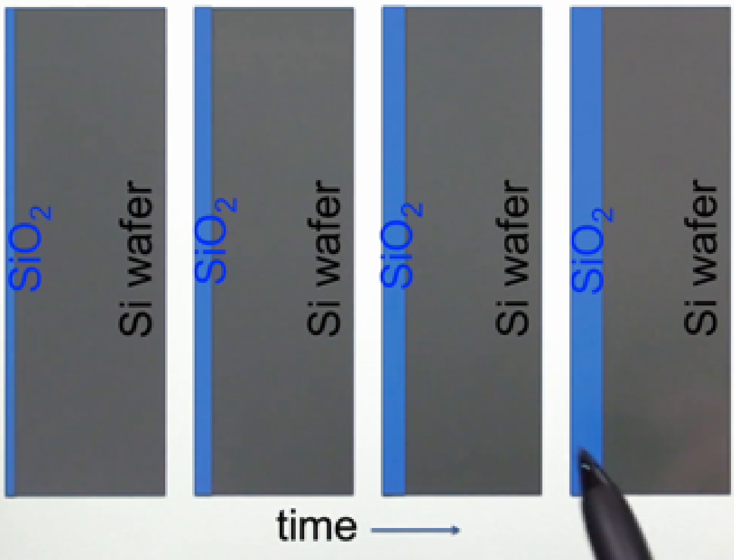
notes

summary

2m 20s

Thermal oxidation mechanism

EPFL



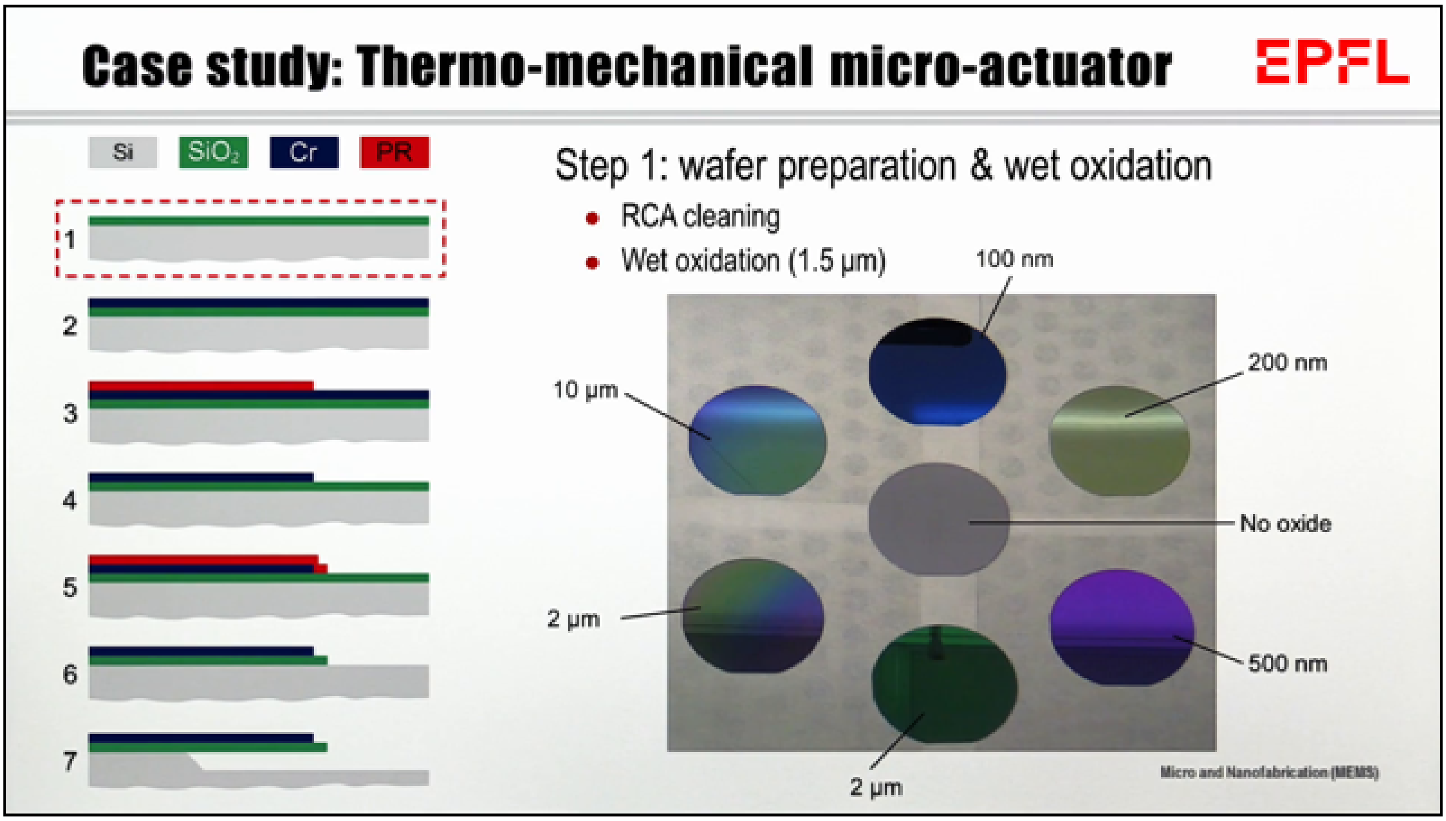
- SiO_2 is formed by diffusion of oxygen into the Si wafer
- Oxidation is at the SiO_2/Si interface
- Initially oxide thickness $t_{ox} \sim time$, later $t_{ox} \sim \sqrt{time}$ due to increased diffusion length
- Slow process
  - Wet @ 900 °C : 130 nm in 1 hour
  - Dry @ 900 °C : 30 nm in 1 hour
- Incorporation of oxygen increases the volume: t_{ox} replaces a Si thickness of 0.45 t_{ox}

Micro and Nanofabrication (MEMS)

of the material increases

notes

summary

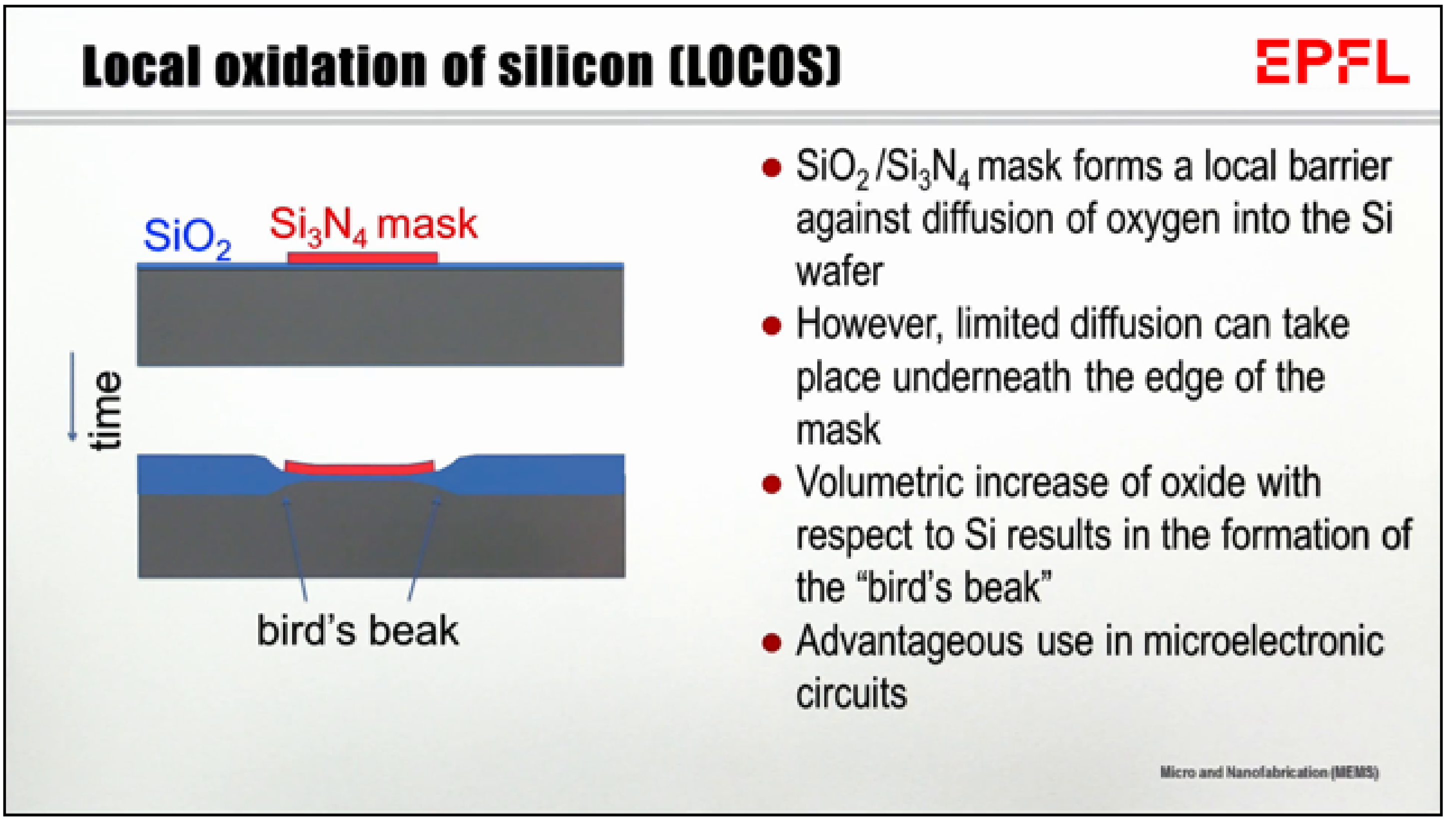


so that if one has an oxide thickness called *t-ox*, this corresponds to an initial silicon thickness of only 0.45 *t-ox*. So really the volume of the silicon is increased into a bigger volume of silicon dioxide. Here we show one slide that was discussed in our case study of the thermal mechanical micro-actuator. Thermal oxidation was used in this microfabrication process to generate the oxide material from the silicon wafer to form the beam on which later the chromium heating element was patterned. This slide is a reminder of the concern micro-fabrication step. In the picture, we see different oxide thicknesses. In the middle, the silicon wafer has no oxide. Different thicknesses can be well discriminated by the different colors

notes

summary

5m 25s

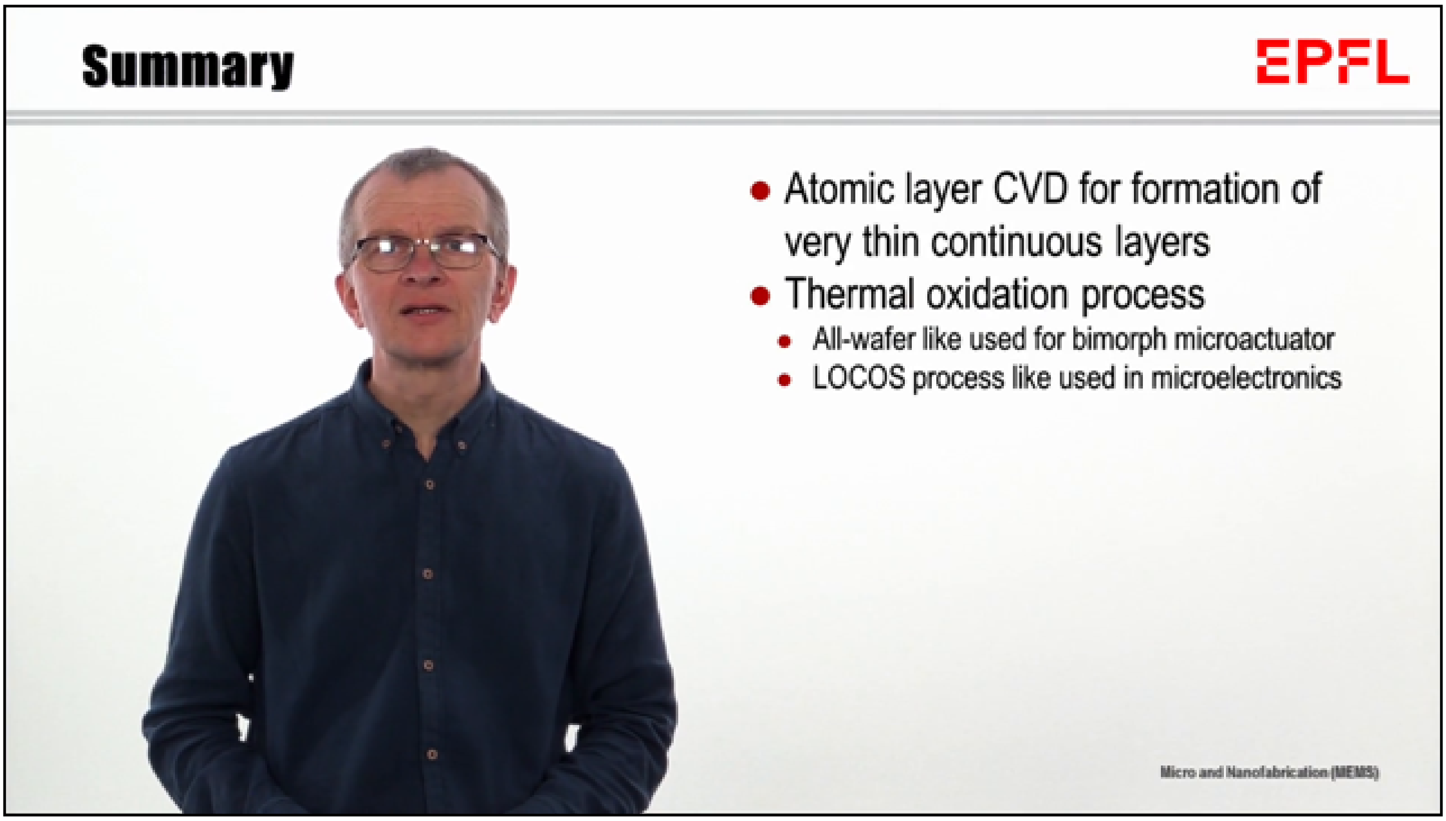


which originate from optical interference effects in the oxide layer. Thermal oxidation is also used in silicon integrated circuit technology. It can be used to define very thick oxide layers, the aim of which is to isolate the substrate from conducting layers. These conducting layers are deposited on the thick silicon dioxide and have then a low parasitic capacitance with the substrate due to the high thickness. To only locally deposit this thick oxide, one uses a silicon nitride mask. So here the silicon nitride mask is deposited on a very thin oxide layer. This mask is nontransparent to diffusing oxygen atoms; it is very inert. Because a thermal diffusion process is omnidirectional, one obtains an oxidation profile like shown in this scheme.

notes

summary

6m 37s



This particular shape is called the *bird's beak* in silicon technology. Due to the bigger diffusion distance, it becomes more and more difficult for the oxygen to penetrate underneath the silicon nitride mask, and this gives this oxide this particular shape. Because the oxidation is only at specific places, namely, those where there is no nitrite, this process is called *local oxidation of silicon*, or also the *LOCOS* process. In this lesson, we have seen two CVD type techniques. The first one is atomic layer CVD for formation of very thin continuous layers. And the second one is thermal oxidation, which is not a true CVD process, but is performed in the same type of equipment as a CVD process.

notes

summary

7m 37s