Course material

Course:

## Micro and Nanofabrication (MEMS)

Video:

## 3.7 PVD 5, Sputtering, Ion target interactions

Concepts (extracted from automatically generated subtitles):

**Target material. So-called primary ion. Kinetic energy. So-called ejection rate. Vapor pressure. Sputtering yield. Thermal energy. Ions. High energy. Type of ion. Different metals. Energy range. Electron beam evaporation. Ejection rate w. Closer look.**

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

to video


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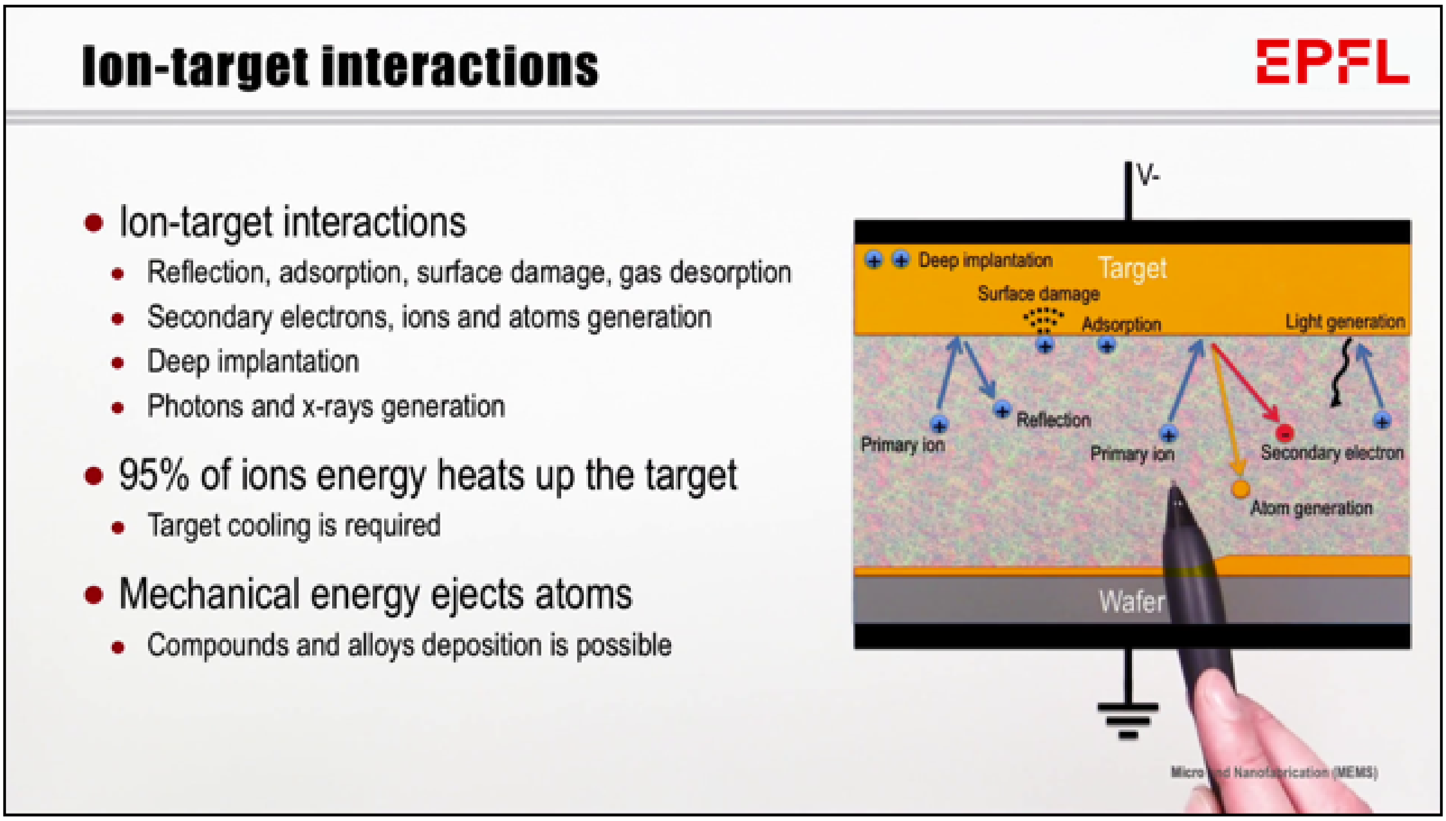
notes

summary

0m 0s




So in this lesson, we will now have a closer look at how ions are interacting with the target material in order to remove the material from the target, and to sputter it on the substrate. When a so-called primary ion collides with a target, made of the material to deposit, several interactions may occur, as illustrated in the figure on the right side of the slide. The interaction depends primarily on the ion kinetic energy, the type of ion, and the target material. Negatively charged electrons in the cathode will then neutralize the positive ion, argon in most cases. When the energy is low, smaller than 10 eV, ions hitting the cathode may be reflected, adsorbed, or may migrate on the surface. During the impinging, it can induce some surface damage such as point defects, or topographical changes. It may also induce some chemical reactions on the surface. Ions with high energy, 10 keV or more, will penetrate deeply into the target material and form an implant or compound like shown here. When ions are in the energy range between 10 eV and 10 keV, they will eject atoms from the target like the ones shown here. This is the action that we want for sputtering. By doing so, they will simultaneously create secondary electrons, and secondary ions. Finally, ions interacting with the target can also result in the emission of photons and x-rays. 95% of colliding ions transmit the energy as heat to the target, therefore cooling is required. Finally, it is worth noting that in sputtering, the deposition of compounds such as carbide, nitrite and oxide is indeed possible, because mechanical energy is used to eject atoms from the target. This differs significantly from the case of the thermal or electron beam evaporation where thermal energy is used to vaporize the solid target material. So once again, on the drawing you see here the target material in

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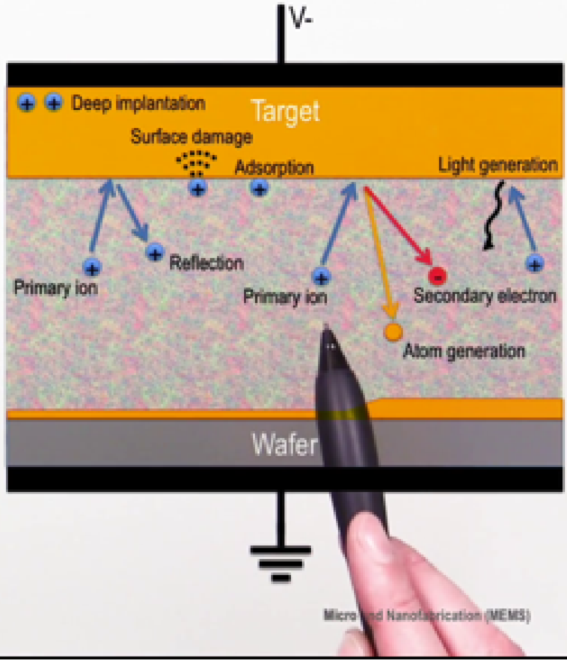
summary

0m 1s

# Ion-target interactions

- Ion-target interactions
  - Reflection, adsorption, surface damage, gas desorption
  - Secondary electrons, ions and atoms generation
  - Deep implantation
  - Photons and x-rays generation
- 95% of ions energy heats up the target
  - Target cooling is required
- Mechanical energy ejects atoms
  - Compounds and alloys deposition is possible




orange, which is biased negatively. And the wafer in grey, that is biased, positively on ground.

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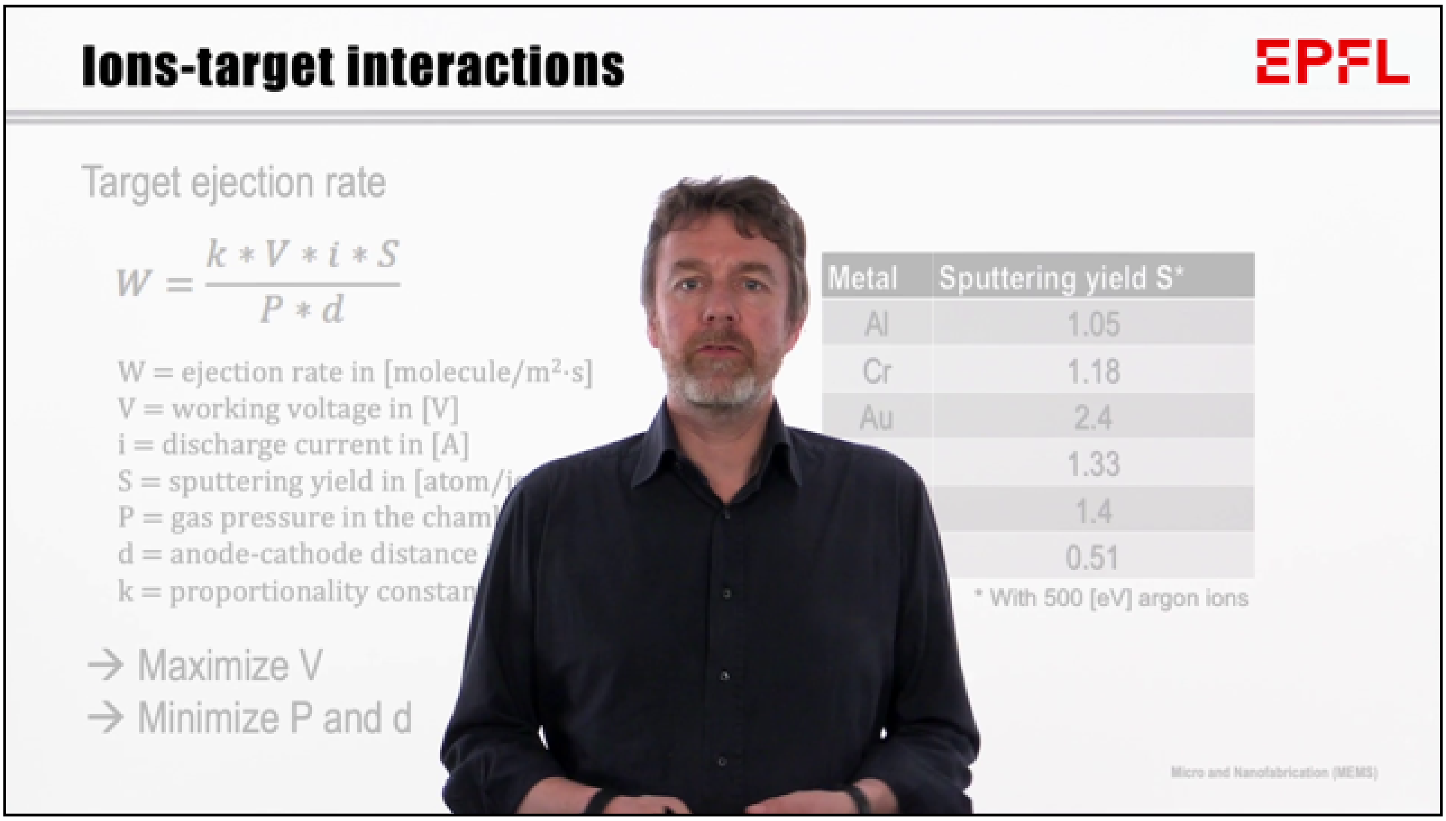


And now, a primary ion, with a correct energy will hit the target material, will remove atoms from the target, which then fly through the vacuum and will land on the wafer and form the thin film of the target material. Unlike for evaporation,

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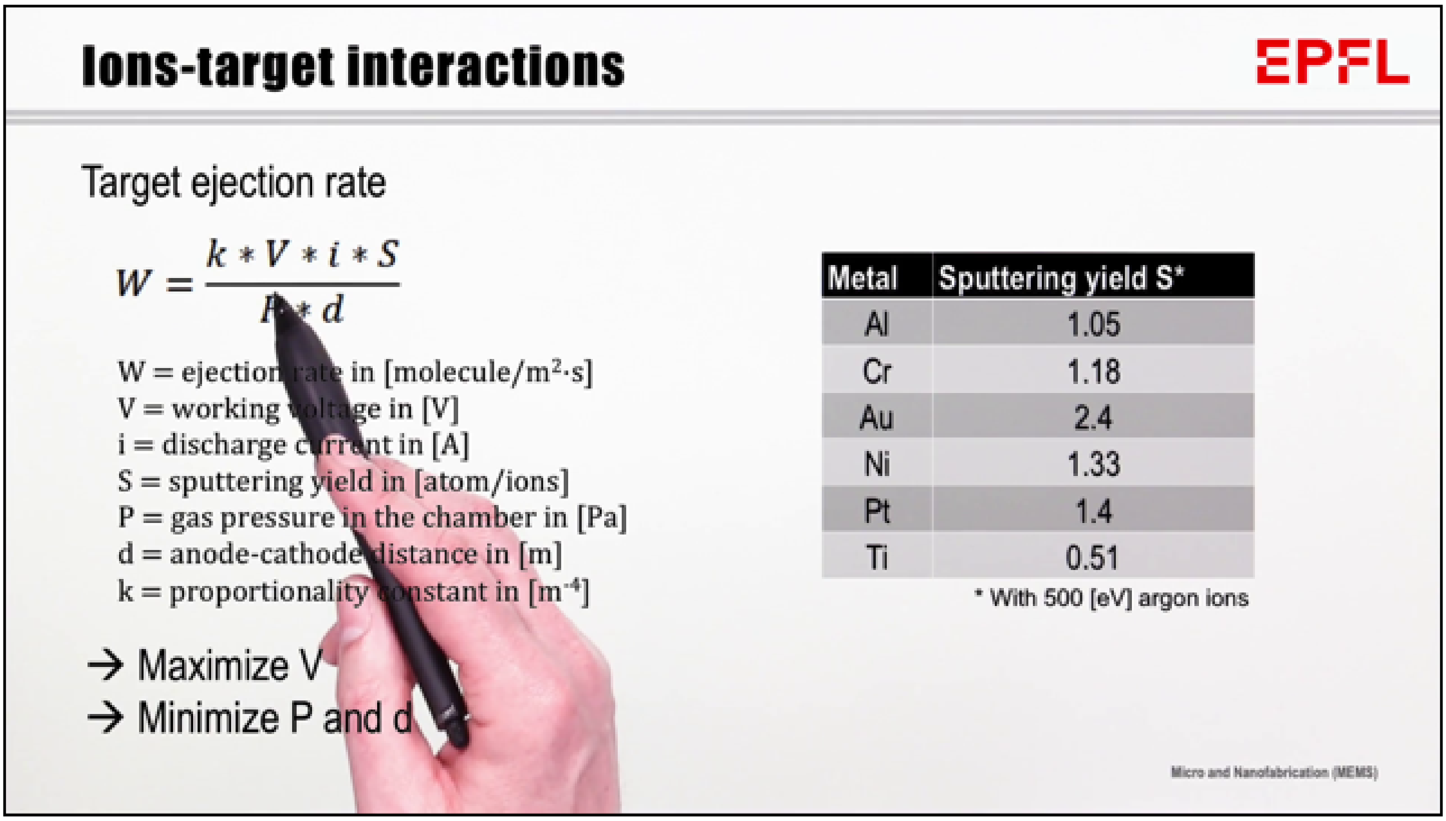
summary

2m 25s




the amount of material ejected from the target does not depend on the vapor pressure, but is given by the so-called ejection rate, W. The ejection rate W depends on parameters such as the sputtering yield, the voltage between the electrodes, the discharge current, as well as the pressure and the inter-electrode distance. From the equation on the left side here on the slide, we see that the target ejection rate

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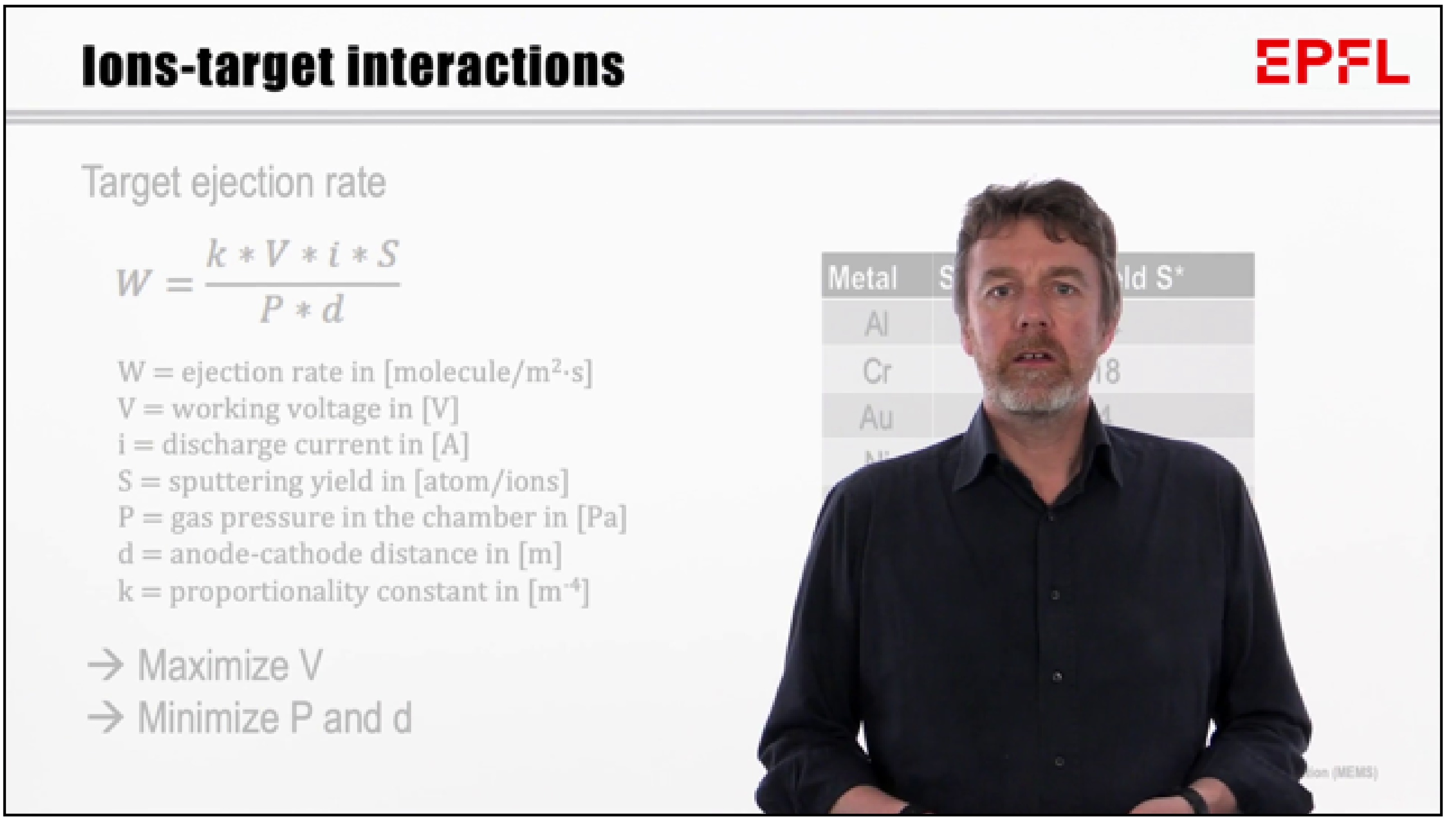
summary

2m 41s




increases with the voltage, but is inversely proportional to the pressure and the inter-electrode distance d. This can be explained as follows.

notes

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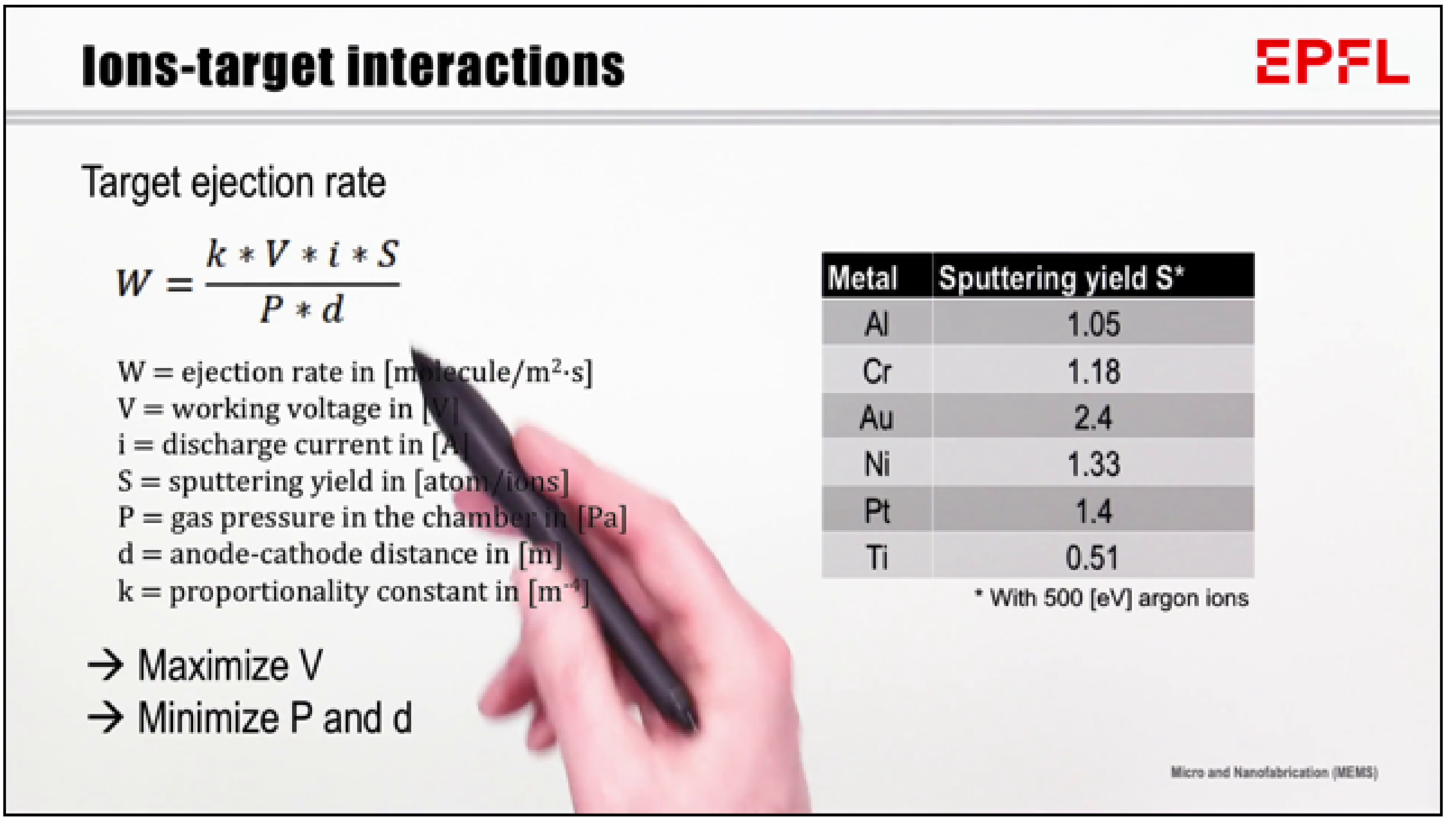
3m 13s




When increasing the voltage, argon ions are accelerated more rapidly and strike the cathode with more kinetic energy. On the other hand, when decreasing the pressure, the argon mean free path is increased, and when decreasing the inter-electrode distance, argon ions will collide with less argon, before striking the cathode. As a consequence, argon ions impact the cathode with more kinetic energy. Finally, the target ejection rate also depends on the sputtering yield, S,

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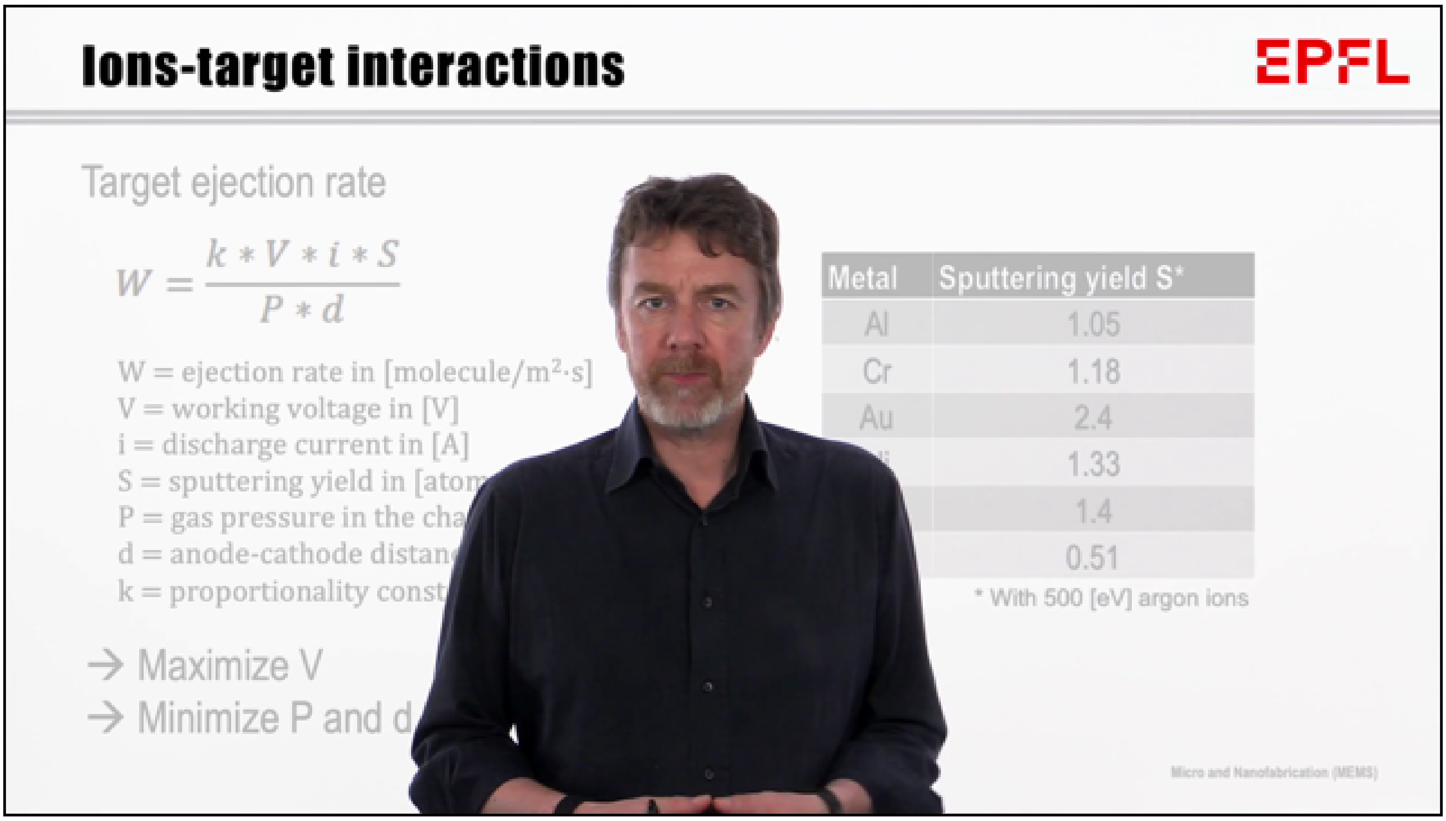
summary

3m 23s




which is the ability of one ion of a specific gas to eject an atom from the target made of the specific material.

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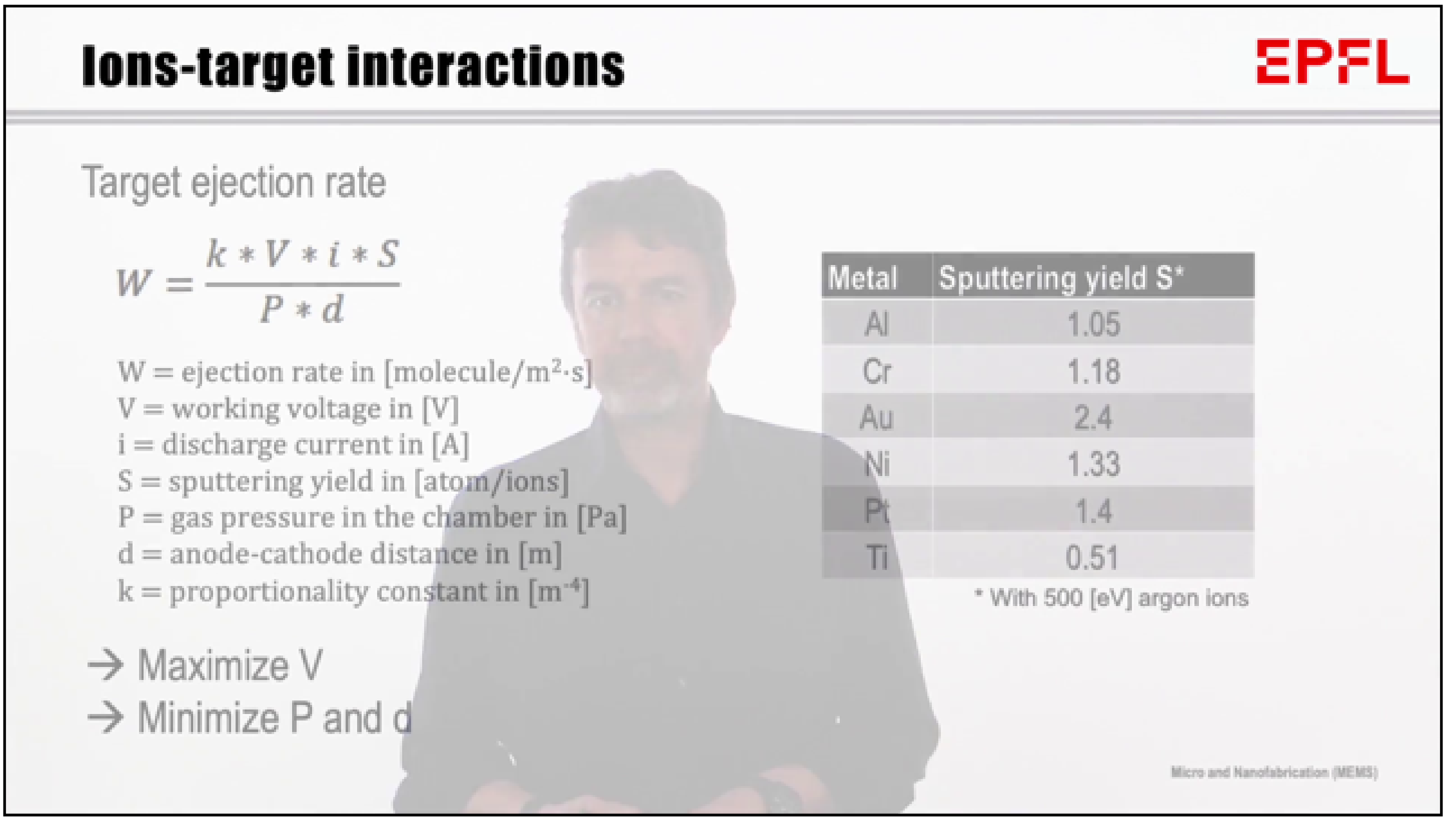
summary

4m 1s




Obviously, the sputtering yield depends on the ion energy which itself depends on the voltage, the pressure, and the distance. But it is also related to the type of gas in the reactor, and to the target material. In general, heavier ions usually have larger sputtering yields and harder target materials result in lower sputtering yields.

notes

summary

4m 11s

# Ions-target interactions

EPFL

## Target ejection rate

$$W = \frac{k * V * i * S}{P * d}$$

W = ejection rate in [molecule/$m^2$·s]
V = working voltage in [V]
i = discharge current in [A]
S = sputtering yield in [atom/ions]
P = gas pressure in the chamber in [Pa]
d = anode-cathode distance in [m]
k = proportionality constant in [$m^{-4}$]

→ Maximize V
→ Minimize P and d

| Metal | Sputtering yield S* |
|---|---|
| Al | 1.05 |
| Cr | 1.18 |
| Au | 2.4 |
| Ni | 1.33 |
| Pt | 1.4 |
| Ti | 0.51 |

* With 500 [eV] argon ions

Micro and Nanofabrication (MEMS)

A few typical sputtering yield values for common materials are shown in the table on the right side here. The different metals, with their corresponding sputtering yield.

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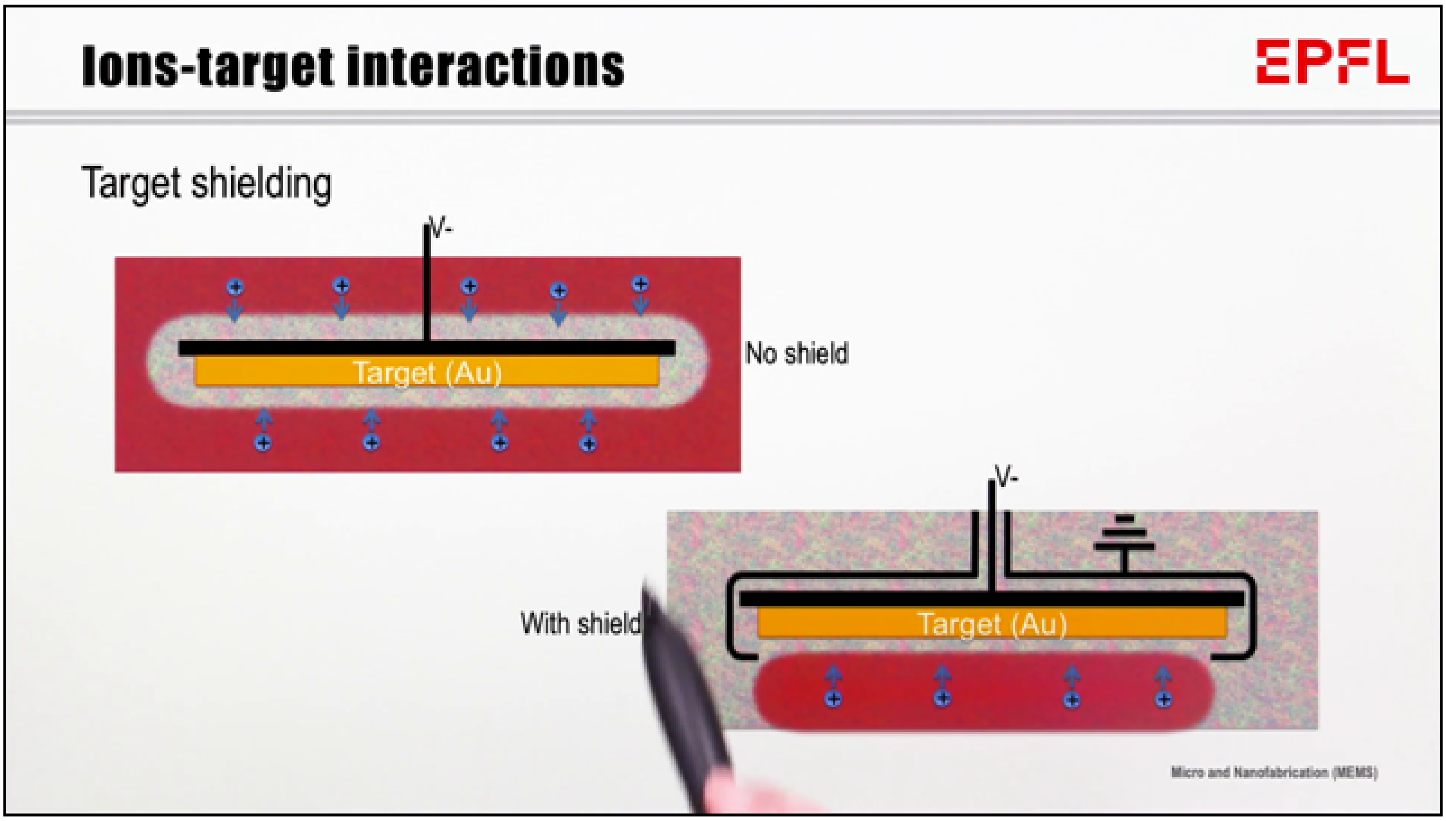
summary

4m 34s




So here, the target is bombarded with 500 eV argon ions. We can see for instance that the titanium sputtering yield is significantly lower than that of for example gold, because titanium is much harder than gold. As explained previously, only the target should be bombarded by energetic ions. To avoid sputtering of other surfaces than the cathode, the anode as well as the entire chamber, is grounded to increase, in fact, the anode area. Still, this would not be enough to prevent sputtering on the backside of the cathode. Indeed, when all the walls of the chamber are grounded, a plasma will still install between the two electrodes, as wanted, but also between the walls and the backside of the cathode as shown here, on the top left image.

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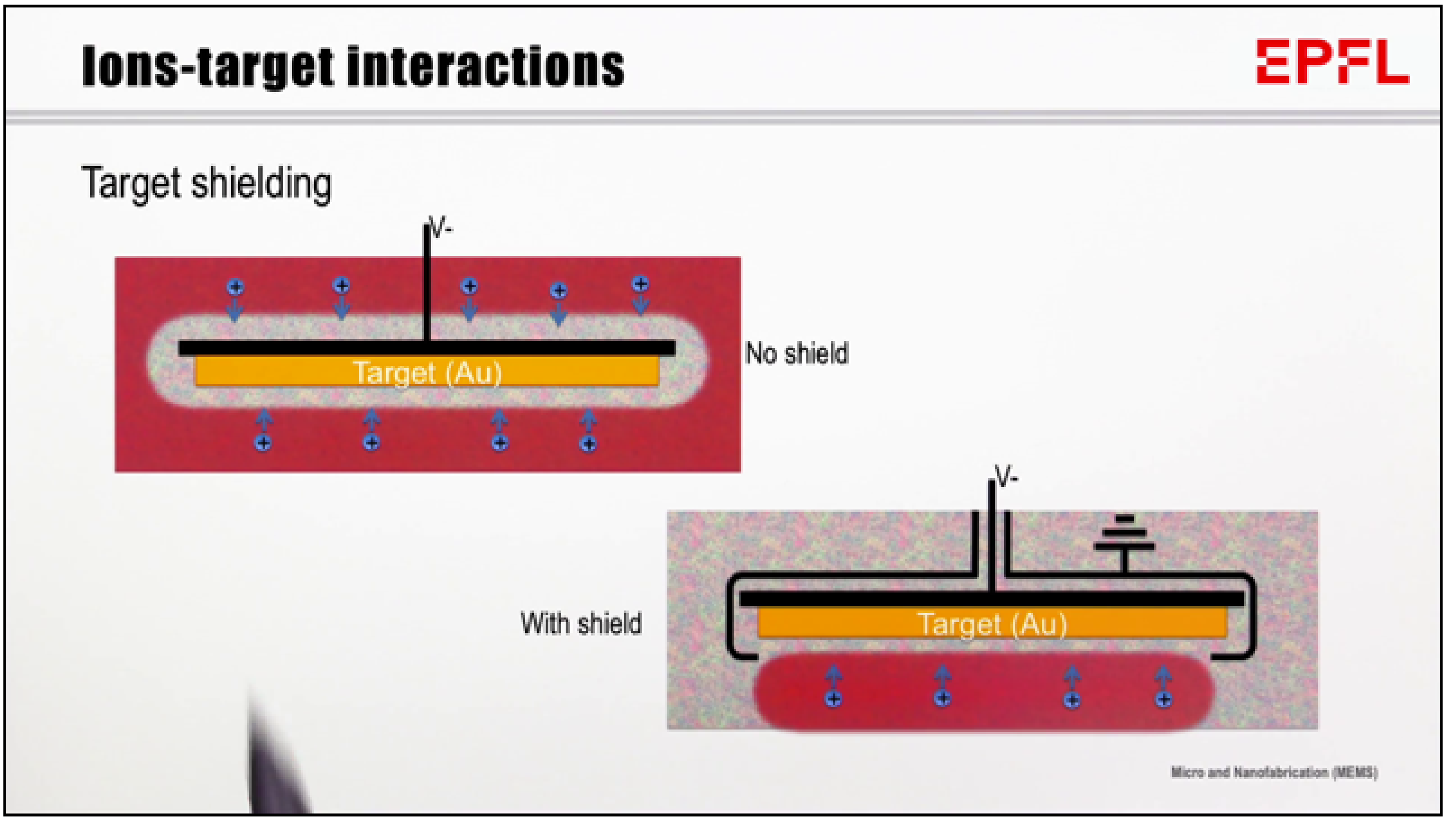
summary

4m 49s




In this case, energetic argon plus ions, shown here in blue, will also sputter the backside of the cathode and deteriorate it. To prevent sputtering of the structural elements of the cathode, a grounded shield is placed at a distance less than that of the plasma sheath as shown here on the lower right illustration. This way, the space between the shield and the cathode is too small to allow plasma formation and the plasma is contained in front of the target.

notes

summary

5m 48s