Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

3.4 PVD 3, Sputtering, Intro and plasma formation

Concepts (extracted from automatically generated subtitles):

High voltage. Different plasma zones. Only measurable current. Current increases. Ion bombardment. Sputter chamber. Sufficient energy. Partially ionized gas. Dc voltage. Plasma. Inert gas. Slight increase. Vacuum pump. Background ionization. Low voltages.

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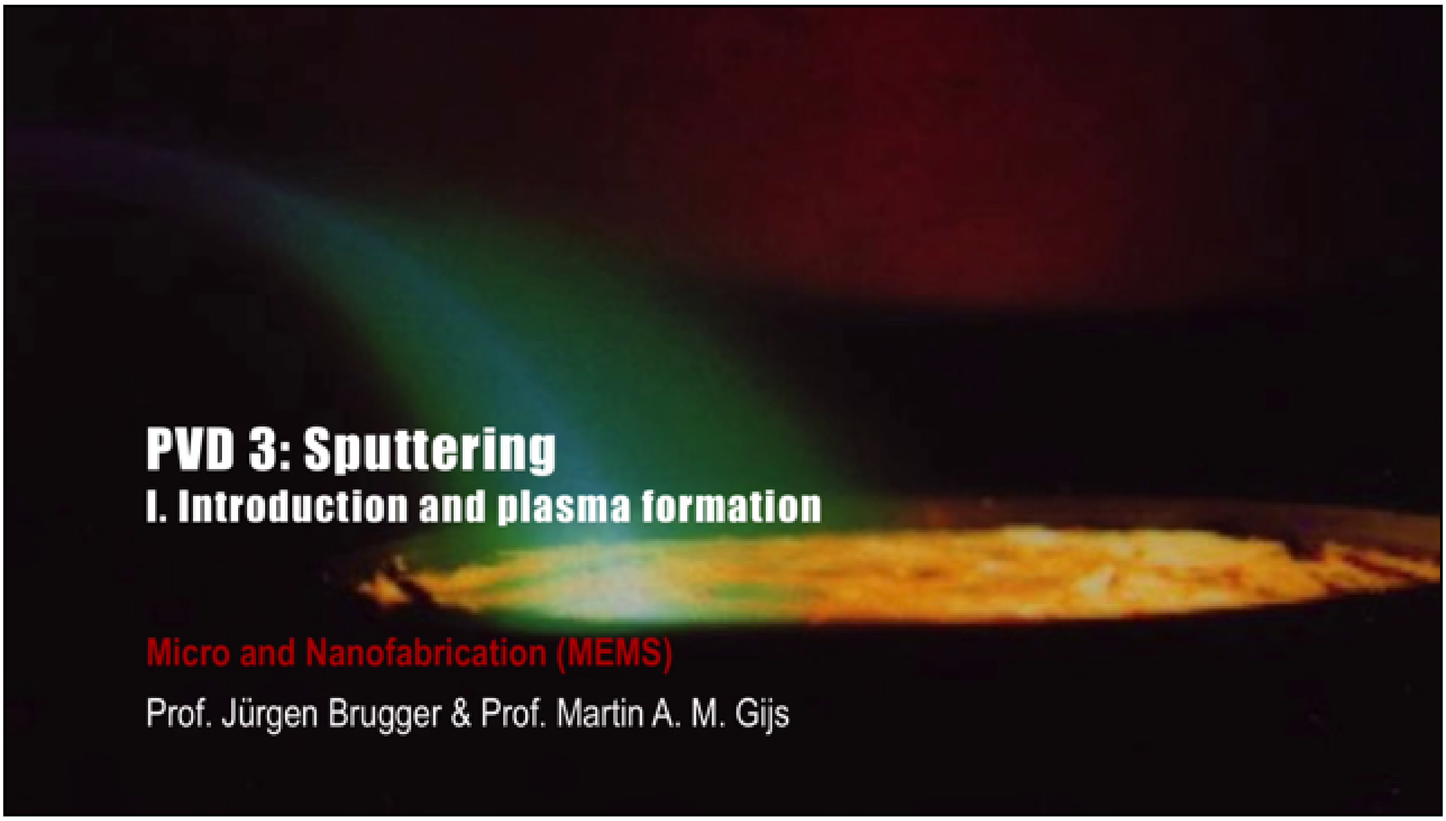
(within Micro and Nanofabrication (MEMS).)

to video



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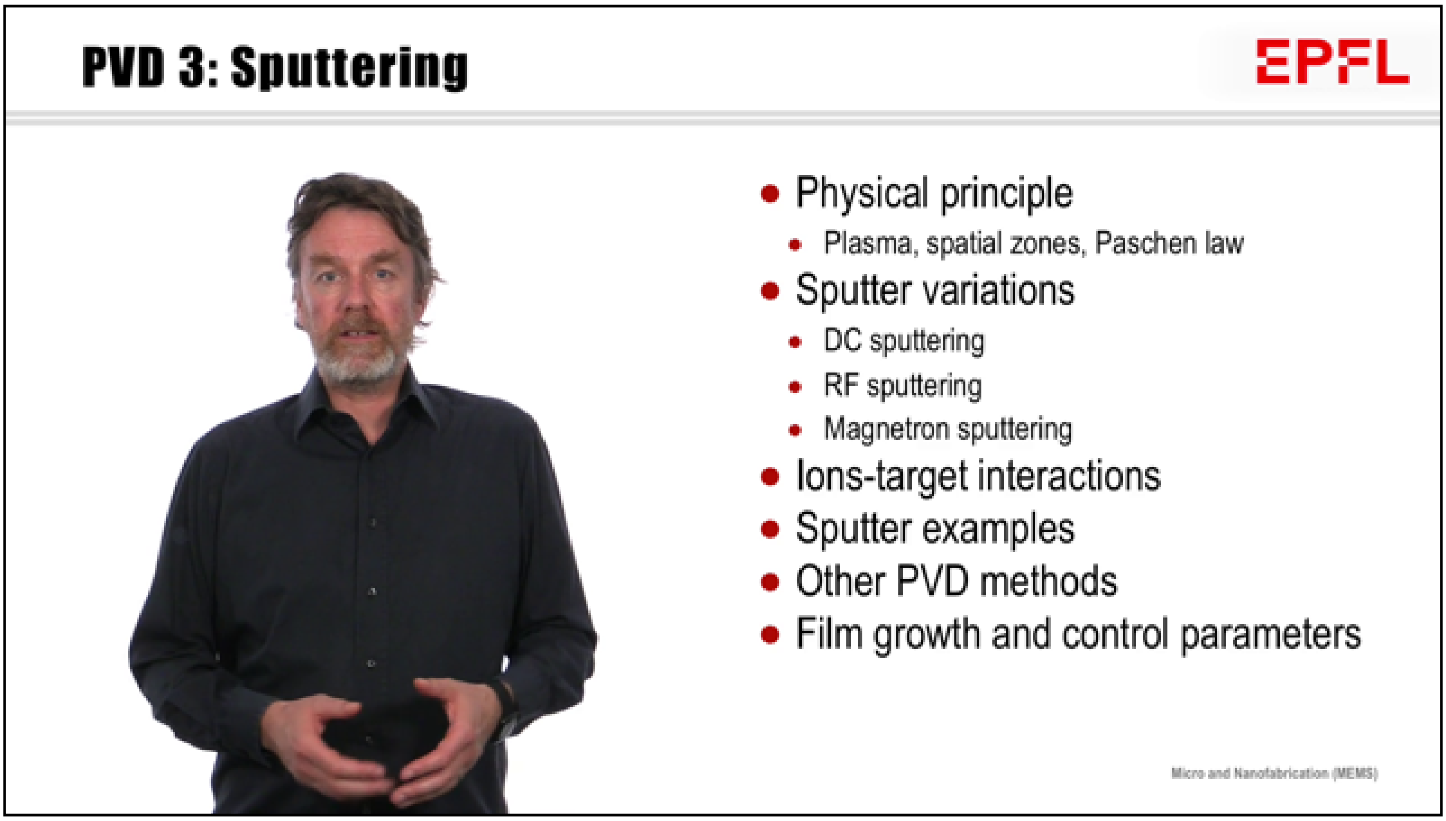
notes

summary

0m 0s



In this lesson, I will introduce the second PVD technique

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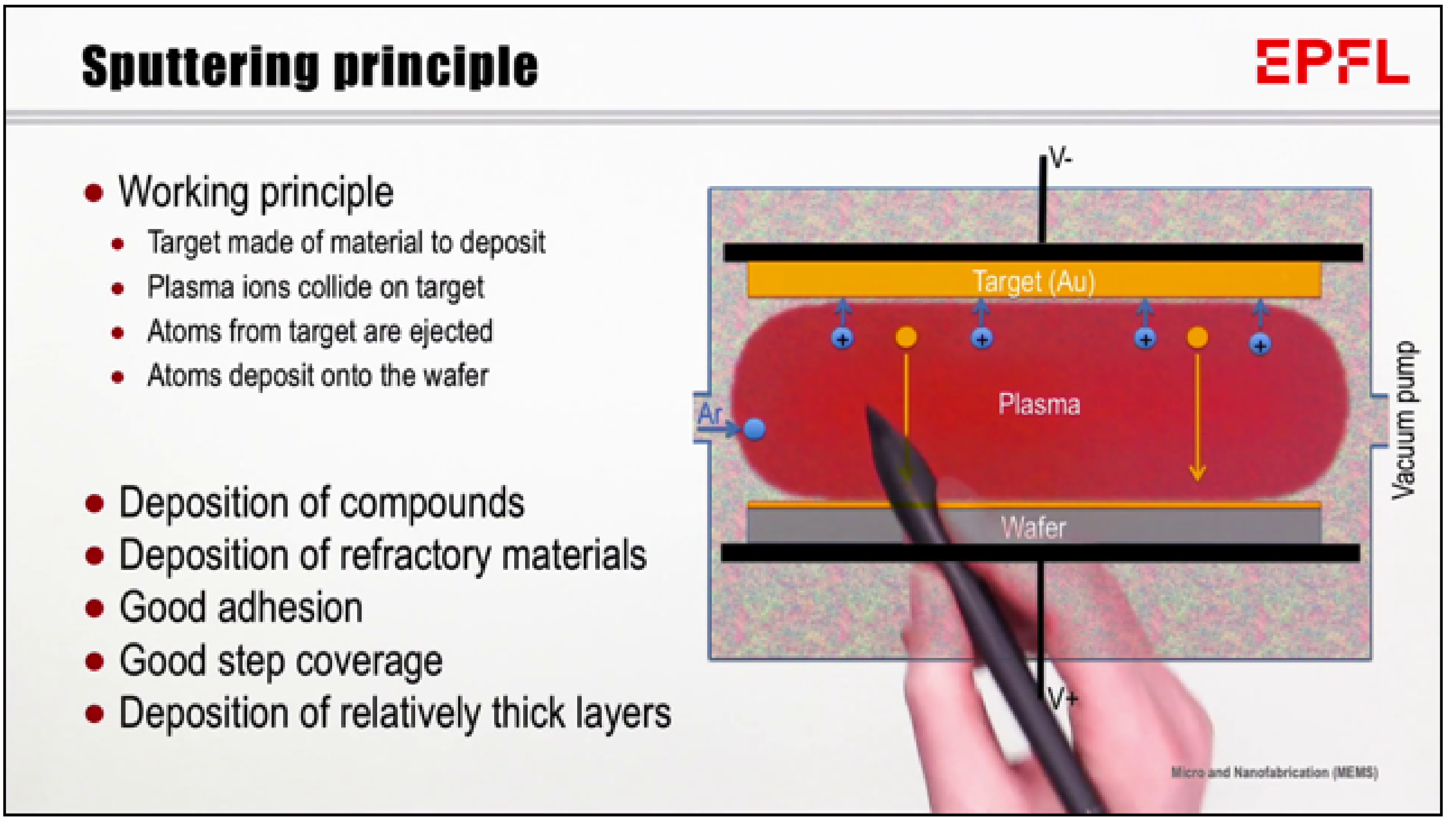

that is called sputtering, and which allows for a whole variety of thin film materials to be deposited. In fact many more than for thermal evaporation. I will first show some basic physical principles on how a plasma is created for our purposes, show the different plasma zones in the sputter chamber, and how to optimize it for efficient sputtering and also introduce the Paschen law. The goal of the sputter process is to remove physically material from a target and deliver it to the receiving substrate or wafer. This is done by ion bombardment in the plasma. Ions that hit the target with sufficient energy eject atoms from the target. These atoms are then deposited as a thin film on the wafer placed adjacent to the target. So how is this done exactly? Let's have a look. First, the air is pumped out of the chamber to create a vacuum. It is shown here, this is the chamber with the vacuum pump that evacuates this area from air. That chamber is then filled with argon, an inert gas, until the pressure reaches values in the order of a couple of hundred mTorrs. A plasma is then created by applying a high voltage of about 1500V between two electrodes, shown here. The positive argon ions in blue are accelerated towards the cathode which is the negatively biased electrode and hits the target here, so the target - in this case we choose gold as a material - and here is the wafer on which we want to deposit the gold. The target is in fact made of the material that we want to deposit and it is mounted directly onto the cathode.

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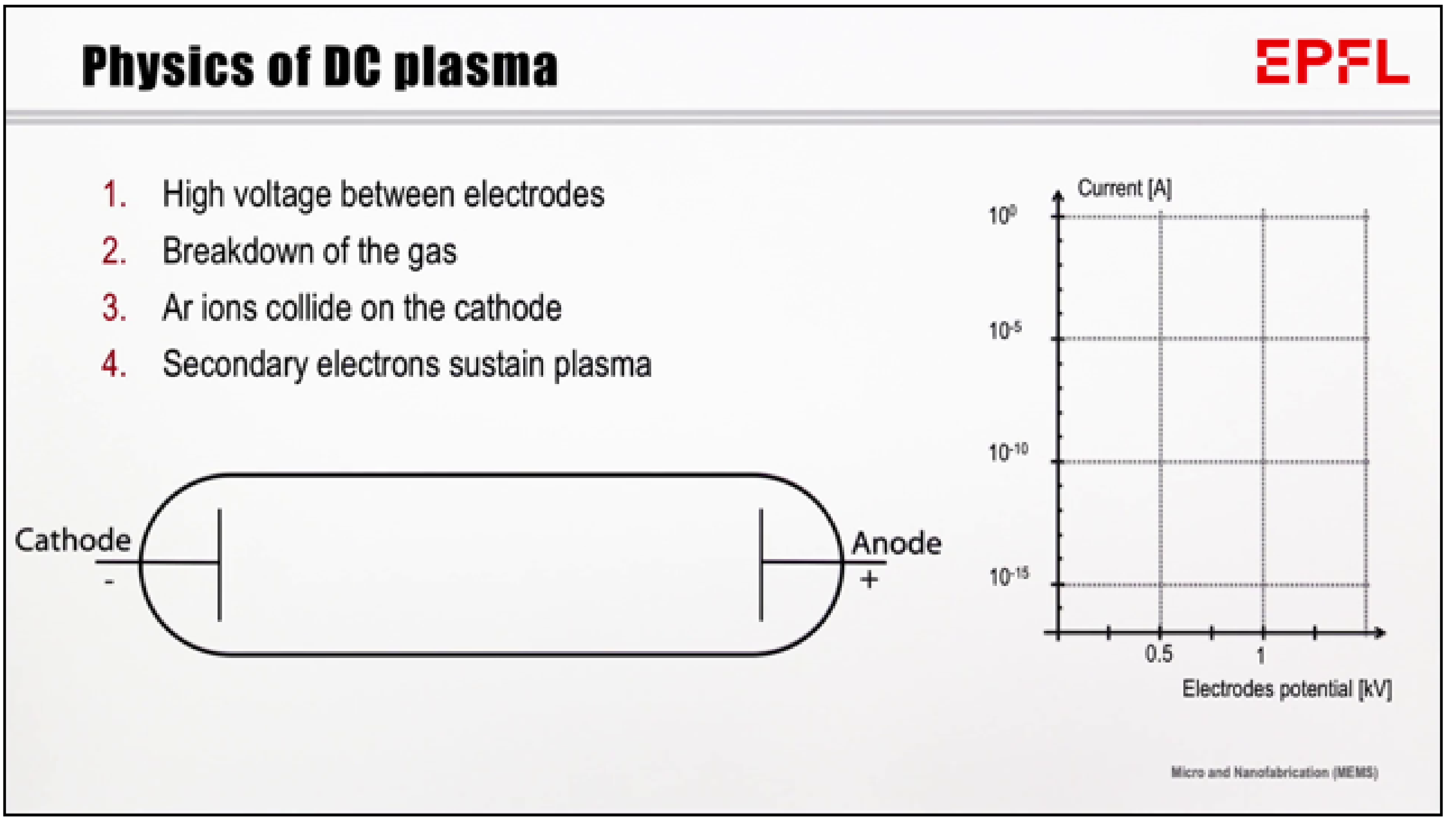
0m 5s



With the impact energy, atoms are ejected from the target, here in yellow, travel through the plasma, and finally deposit on the wafer as a thin film. Sputtering allows to deposit all kinds of materials including metals, compounds as well as refractory materials. The deposited thin film has a generally good adhesion and excellent step coverage. We will come to these details later in this lecture. Let's have a short look at what plasma is and how it works for our purpose here. Plasma is defined as a partially ionized gas that is neutral, and thus has the same number of ions and electrons. It is commonly also referred to as the fourth state of matter. By the way, plasma is also used for dry etching processes that my colleague, Martin Gijs, will cover in detail in his corresponding lesson. The simplest form of plasma for our purpose, the DC plasma, is created as follows.

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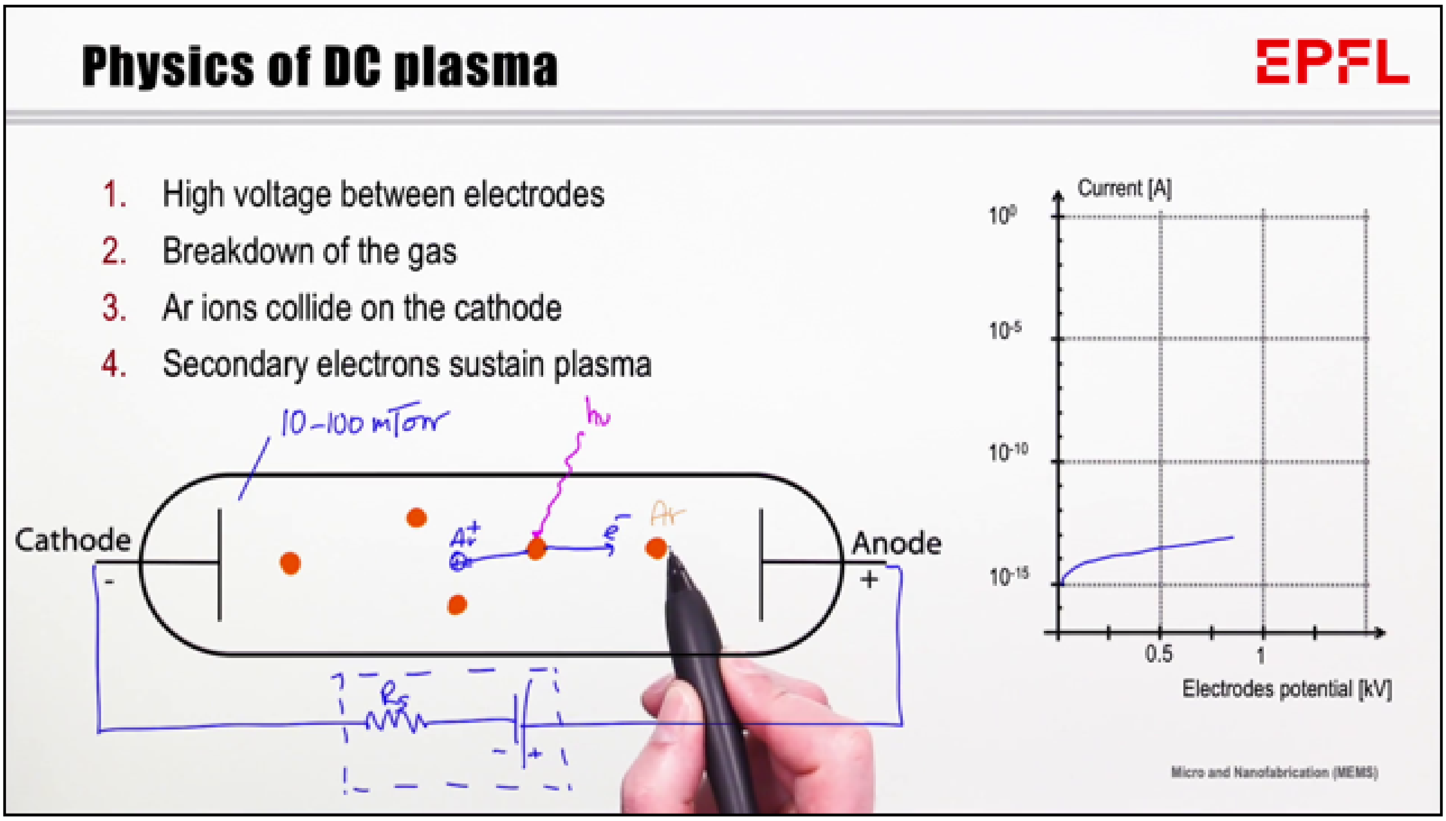
2m 1s



First, the chamber is pumped down and filled with argon gas to reach a deposition pressure in the order of 10 to 100 mTorr. It is shown here, some argon atoms in the chamber. Second, a DC voltage can be applied between these two electrodes, shown here. So with the source... with the thermal resistance, and here the potential that can be applied to the cathode and the anode. At low voltages, the only measurable current comes from the so-called "background ionization", which is always present, but often negligible. The origin of this background ionization comes for example from a photon that hits one of the argon atoms and ionizes it. The result of this ionization is that we get an electron and an argon ion. This current is very low and the voltage on the electrodes is about the same as the voltage of the source as there is nearly no voltage drop over Rs. If you increase the voltage, the current first remains constant since the voltage does not affect the background ionization. We can draw here a typical curve, how this current increases if you increase the potential between the electrodes. There is a slight increase, but it is not very drastic because it is only based on the available ions due to the background ionization. When the voltage is further increased, over 600V approaching 1kV, depending on the gas and the pressure, electrons and ions resulting from the background ionization gain enough energy to ionize other atoms. So this electron, for instance, can ionize this argon atom

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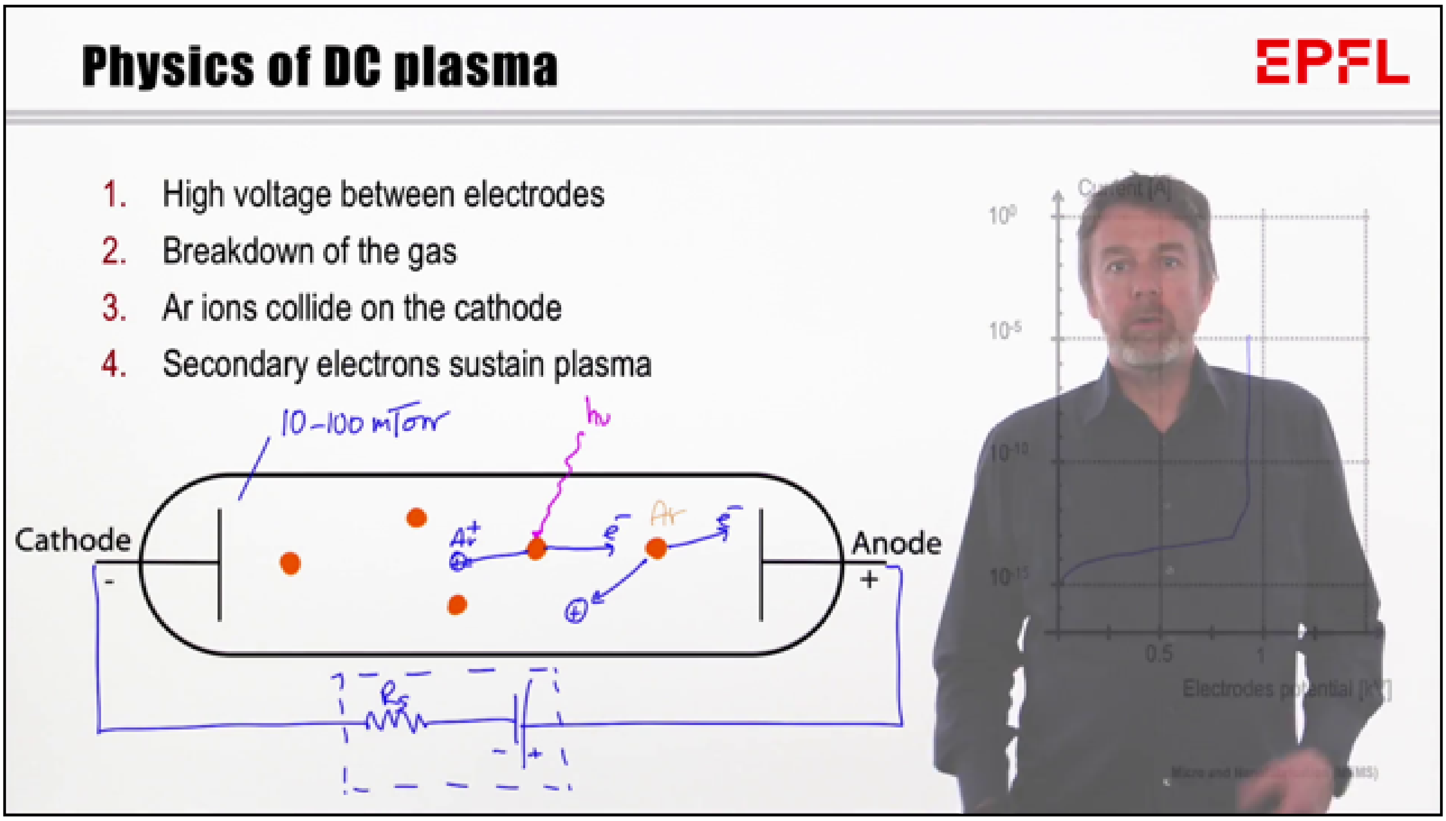
3m 1s



which would release another electron, and be able to release another argon ion. As a result, the current increases exponentially with the voltage. So, now we are increasing drastically the current for the given voltage. The regime described here is called "dark discharge" as no light is generated. It is not used for microfabrication applications as plasma in this regime is neither energetic nor stable.

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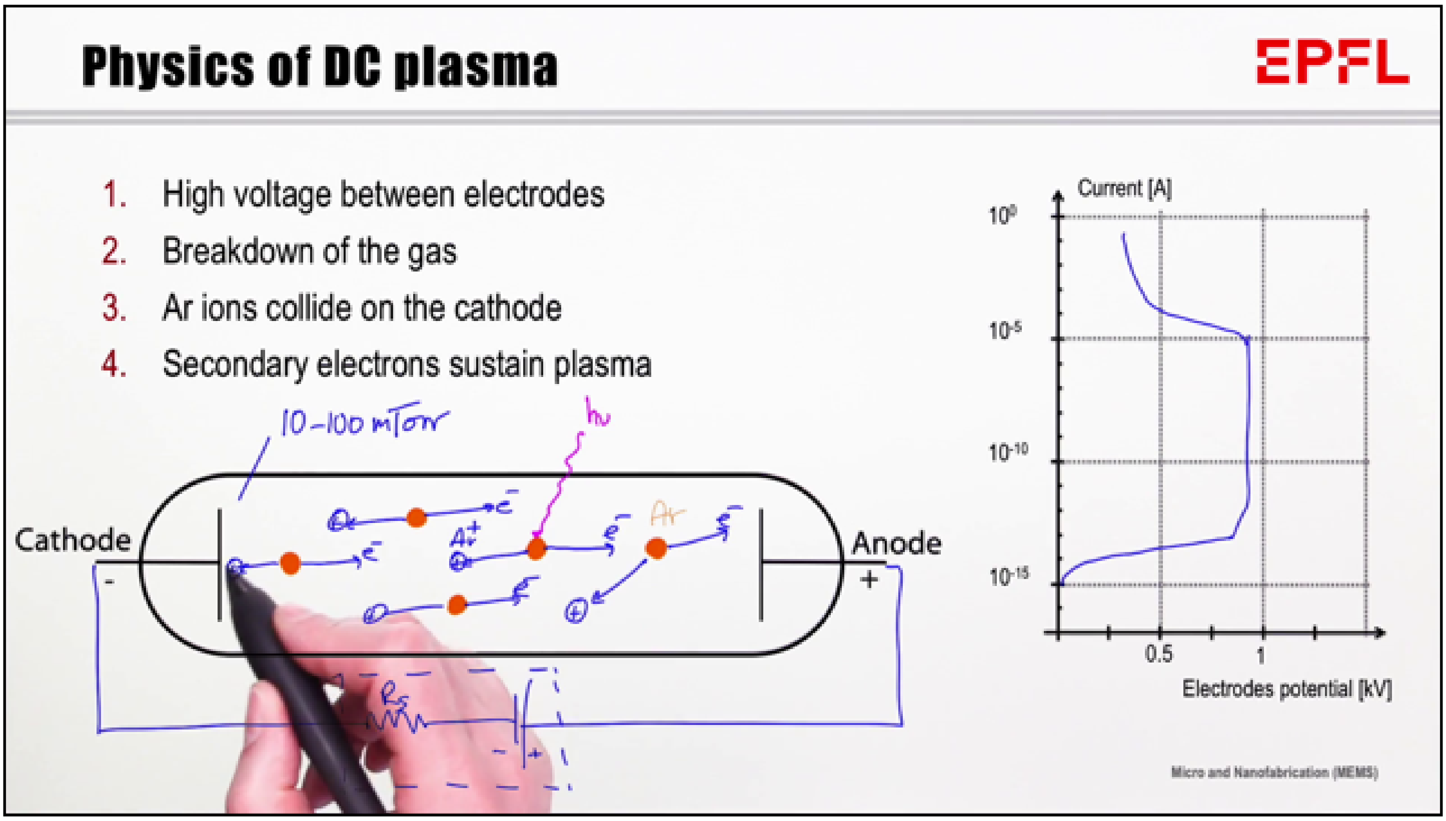
summary

5m 13s



When the electric field between the two electrodes is further increased, breakdown of the gas occurs. The medium becomes ionized, and an avalanche of inelastic collisions between electrons and ions appear. So now, even argon atoms that have not been ionized by the background radiation, can be ionized by the strong electric field between the two cathode and anode. So, one can create here electrons, and here argon ions with all the available argon atoms in the chamber. And this is creating an avalanche effect, because they can then ionize other argon atoms that are available. That means we suddenly have a very strong current that can be installed between the cathode and the anode. So, this is also shown here in the curve, where we now get a very strong current, up to a couple of hundred milliamperes but with a drop in the voltage. Indeed, as the current increases, the voltage drop in the source resistance becomes very important. When argon ions collide on the cathode,

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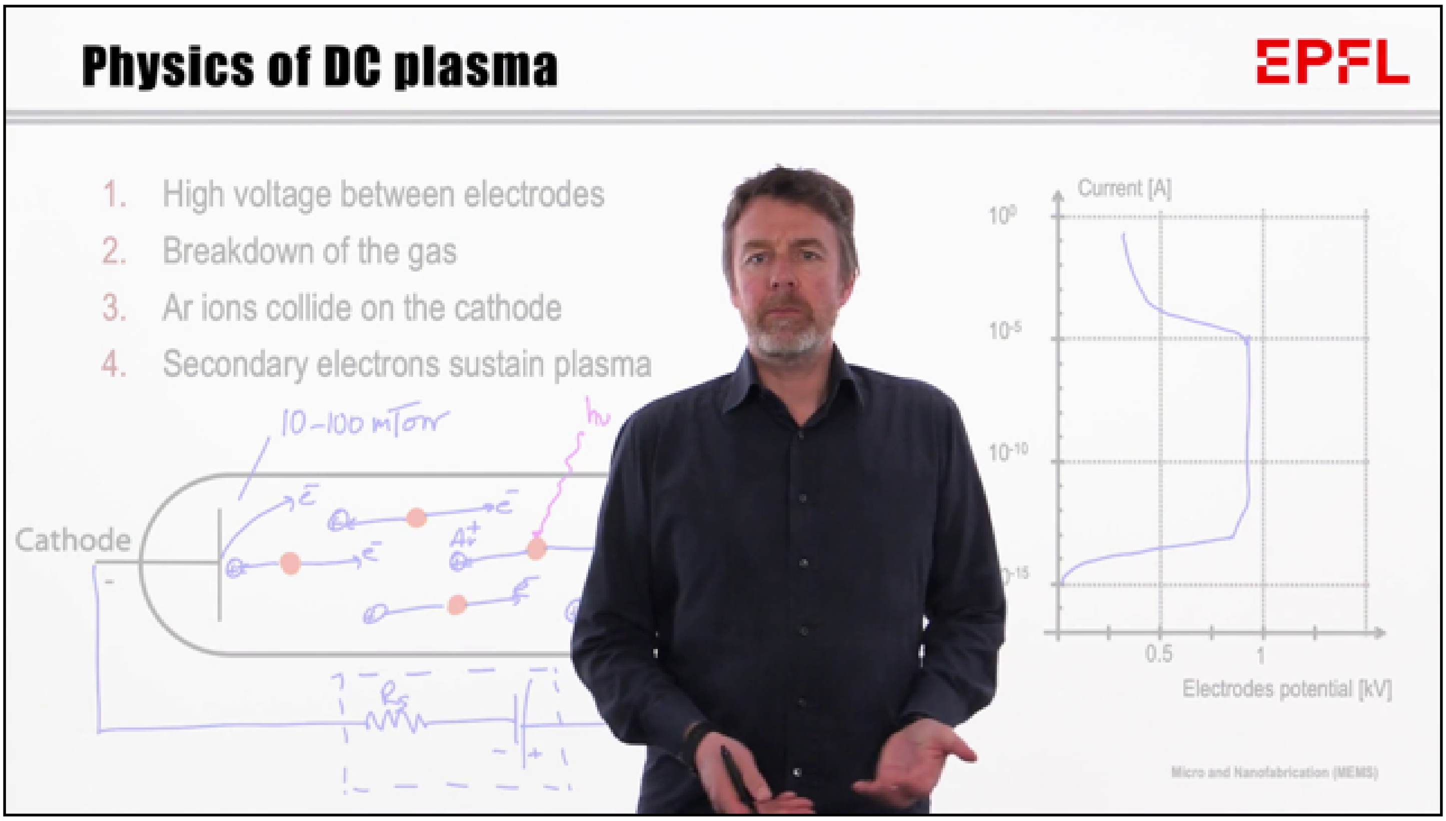
5m 50s



secondary electrons are ejected and sustain the plasma. Without these electrons, the plasma would rapidly vanish. Finally, the plasma reaches a steady state and the loss and gain of electrons is equal. In this regime, electrons have enough energy to excite atoms to an energy level where they emit light, when they relax, to a lower energy level. The plasma is luminous, and this regime is called "glow discharge". In this regime, the plasma is stable and energetic enough to be used in microfabrication technology, either for sputtering or for etching. Typically, to achieve this regime, a voltage of about 1.5kV is applied between electrodes separated by 15cm, which results in an electric field in the order of 100V/cm. In this photograph, you can see the glow of the plasma in one of out sputter equipment. We will see more of this later when we go and see what the equipment looks like.

notes

summary

7m 13s