1 Deposition

1.1 Physical deposition methods

1.1.1 Molecular beam epitaxy

The deposition characteristics are similar to the silicon vapor phase epitaxy (see CVD), but the deposition technique differs.

The process takes place under ultra-high vacuum (UHV, 10^{-8} Pa), the wafer is held upside down at the top of the chamber, the native oxide is removed at 600 to 800 °C.

With an electron beam highly purified silicon is evaporated and deposes on the wafer. Dopants can be evaporated as well and reach the surface together with the silicon. By selective temperature control and with covers the particle beam can be controlled precisely. This process allows layers of different materials whose dimensions are different and thus can't be deposited with other methods. E.g. a layer of silicon and germanium can be created which is necessary for high frequency devices or in bipolar techniques.

However, the effort to create the ultra-high vacuum is very high. To achieve this pressure, which is less than 10^{-12} of atmospheric pressure, one needs several vacuum pumps and a long time to pump down. Only one wafer can be processed simultaneously, the growth is only about 1 micron per hour.

1.1.2 Evaporating

Also metallic layers, such as aluminum, can be deposed on the wafer. The material is placed in a crucible, made of a hardly meltable metal like tantalum, and heated till evaporation. The vapor reaches the wafer in perpendicular orientation, therefore edges are not covered well, the film is polycrystalline. Alternatively the metal can be evaporated using an electron beam instead of a crucible. Compared with the thermal

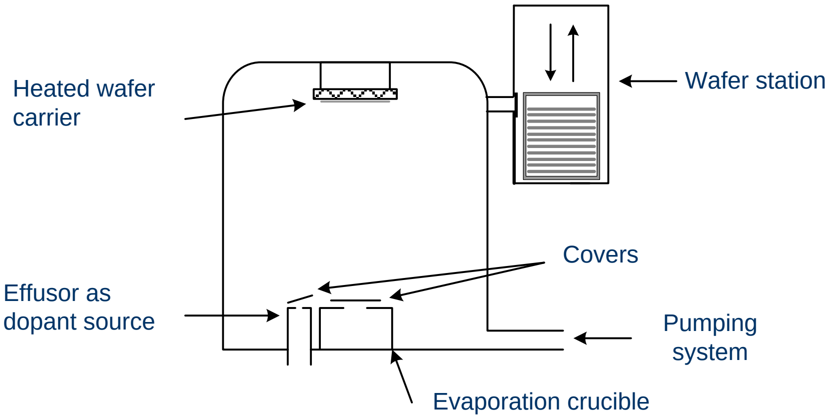

Fig. 1.1: Illustration of a MBE chamber

process, the electron beam allows a precise growth. Because of the bad edge coverage both methods are mostly used for backside deposition for final contacting.

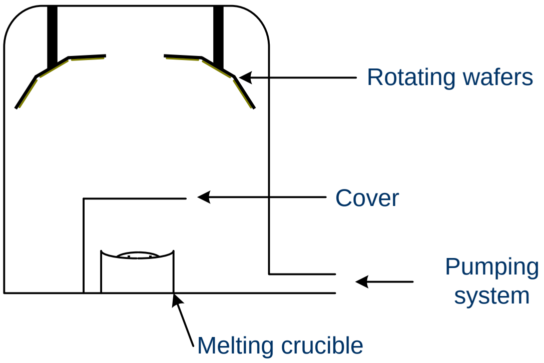

Fig. 1.2: Illustration of an evaporating chamber

1.1.3 Sputtering

In sputtering ions are accelerated onto a target to strike out atoms or molecules. The target consists of the material which shall be deposited. The mean free path is a few millimeters which means that the particles often collide with each other and therefore also vertical surfaces are covered well. Primarily the noble gas argon is ionized by gas discharge. The disposed particles form a porous film which can be densified by annealing. Sputtering can be devided into passive (inert) and reactive sputtering.

By passive sputtering only the material of the target is disposed on the wafers, accord-

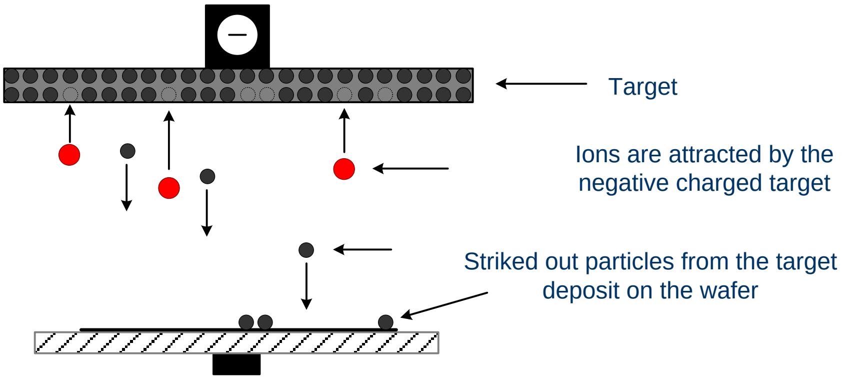

Fig. 1.3: Illustration of the sputter process

ing to the material of the target high-purity films can be created as the mix ratio of the substances in the target can be chosen precisely. In the reactive sputtering an additional reactive gas (e.g. oxygen O2) is added, which reacts with the particles of the target and deposits on the wafer. If one uses a metallic target (e.g. aluminum Al), non-metallic layers like the insulator aluminium oxide are possible:

$$4\,\mathrm{Al} + 3\,\mathrm{O_2} \longrightarrow 2\,\mathrm{Al_2O_3}$$

To create metallic layers, the DC sputtering is used. Thereby the ions are accelerated with up to 3 kV onto the target where they are discharged. To dissipate the charges, only a conductive target can be used. For non-metallic layers the reactive sputtering has to be used. If one wants to create an insulating layer right out of the target the RF sputtering is used.

In RF sputtering a voltage is applied to both electrodes behind both the target (cathode) and the wafer (anode). During the positive half-wave on the target, the electrons were attracted to it, thus the target gets negatively charged. The negatively charged target attracts ions which strike out particles from it. To increase the deposition rate one can attach magnets behind the target to deflect the electrons into a circular path. Thus more ions will be ionized and strike out additional particles from the target. Because the anode is connected to the process chamber its potential difference compared to the plasma is much less than the potential difference of the cathode to the plasma. Thats why the ions are accelerated to the target only and not onto the wafer.

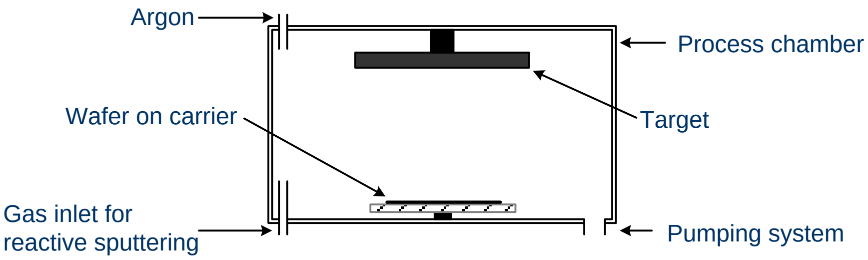

Fig. 1.4: Illustration of a sputter chamber

To increase edge coverage the BIAS sputtering is used. A negative voltage is applied to the substrate, so that here particles are striked out at well, which planishes the surface. However, one has to take care that there is no abrasion of the substrate. This so called back-etch process is the principle of most dry etch processes.

Sputtering is suitable to create metallic films with high conformity and very good reproducibility. The effort is little, the low pressure (5 Pa) can be achieved easily.