1 Metallization

1.1 Aluminum technology

1.1.1 Aluminum and aluminum alloy

Because of its properties aluminum and its alloys are widely used for wiring in microchips:

- excellent adhesion on SiO2 and interlayers as BPSG or PSG
- excellent contacting with wire bonds (ie gold and aluminum wires)
- low electrical resistance (3 $\mu\Omega \cdot cm$)
- simple to structure in dry etch processes

Aluminum fulfills the requirements in electrical toughness and resistance against corrosion only partial. Metals like silver or copper have better properties, however, these metals are more expensive and cannot be etched in dry etching this easily.

1.1.2 Diffusion in silicon

The use of pure aluminum leads to a diffusion of silicon into the metal. The semiconductor reacts with the metallization at only 200-250 °C. This diffusion of silicon causes cavities at the interface of both materials which are then filled by aluminum. Thus leads to spikes which can cause short circuits if they reach through the doped regions into the silicon crystal beneath.

The size of these spikes depends on the temperature at which the aluminum was deposited onto the wafer. To avoid spikes there are several possibilities. A deep ion implantation - contact implantation - can be introduced at the location of the vias. Thus the spikes do not reach into the substrate.

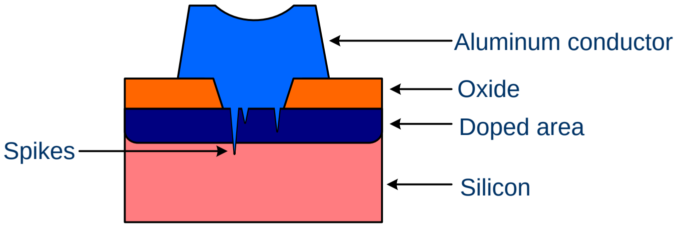

Fig. 1.1: Spikes

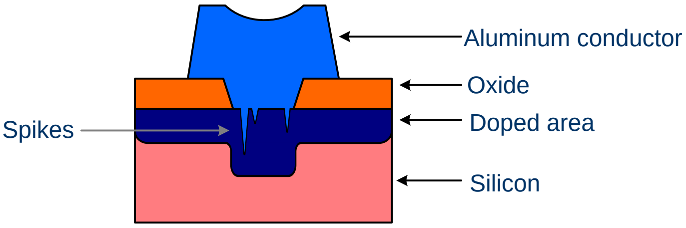

Fig. 1.2: Contact implantation

The disadvantage is that there has to be an additional process step, furthermore the electrical properties change because the doped regions are enlarged.

Instead of pure aluminum an alloy of aluminum and silicon can be used (silicon 1-2 %). Because the aluminum now already contains silicon there will be no diffusion out of the substrate. However, if the vias are very small, the silicon can drop out at the contact area and result in an increased resistance.

For contacts with a high quality a separation of aluminum and silicon is essential. A barrier of different materials (e.g. titan, titan nitride or tungsten) is deposited. To avoid an increased contact resistance at the interface of titan in silicon a thin layer of titan silicide is used.

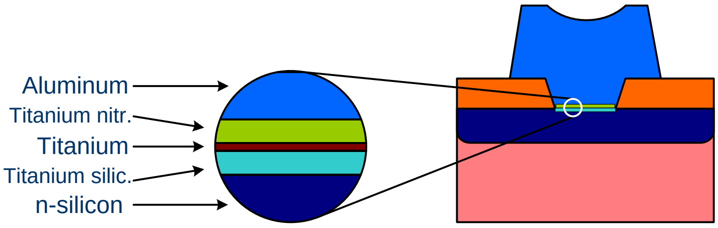

Fig. 1.3: Barrier layer between aluminum and silicon

1.1.3 Electromigration

A high current density results in a friction of electrons and fixed metal ions. The ions are moved due to collisions with the electrons. At locations with small cross sections the current density increases, thus more ions are moved and the cross section decreases which leads to a higher current density. In extreme case the aluminum wires can break.

1.1.4 Hillocks

Electromigration leads to moved material which is accumulated on locations with a lower current density. This hillocks can break through adjacent layers and cause short circuits. In addition moisture can penetrate into the material and cause corrosion. Another reason for hillocks are different coefficients of thermal expansion. Layers expand in different ways due to heating which causes stress. To minimize strain additional layers with an adjusted coefficient of expansion can be deposited between the other layers (e.g. titan, titan nitride).

Further problems which can occure during metallization:

- **Diffracted expose:** the metal layer can reflect light in that way that adjacent regions are exposed. To avoid reflections an anti reflective coating can be deposited
- **Bad edge coverage:** on edges there can be increased aluminum growth, while in corners there is a decreased growth. Therefore edges have to be rounded:

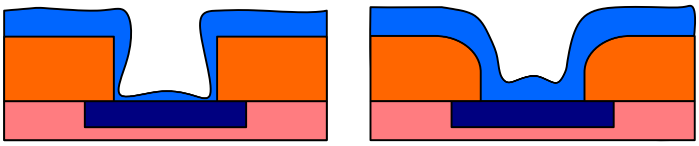

Fig. 1.4: Edge rounding

The layout of the wires has to be planned exactly to avoid these issues. A small additive of copper in the aluminum can increase the life time by far. However, the structuring of the aluminum-copper conductors is much more difficult. To avoid corrosion, the surface is sealed with layers of silicon oxide, silicon tetranitride or silicon nitride. The material of the packages for microchips is some kind of ceramics because synthetic materials are not as resistant.