Semiconductor Technology from A to Z

Wafer Fabrication

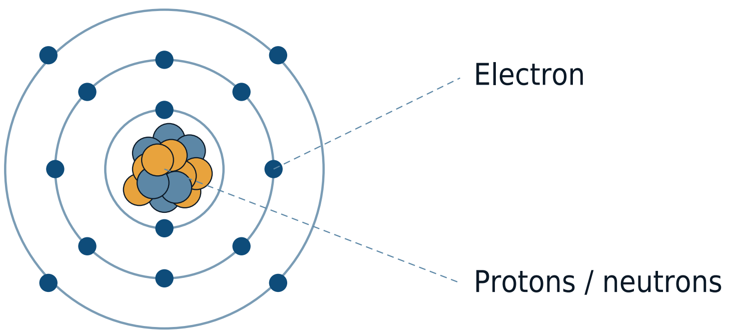
Silicon

Properties of Silicon

Silicon is the chemical element with atomic number 14 in the periodic table; it belongs to the 4th main group and the 3rd period. Silicon is a classic semiconductor, meaning its conductivity lies between that of conductors and insulators. In nature, silicon (from Latin silex/silicis: pebble) occurs exclusively as an oxide: as silicon dioxide (SiO_2) in the form of sand and quartz, or as silicate (compounds of silicon with oxygen, metals, and others). Silicon is therefore, quite literally, as abundant as sand on a beach, making it an extremely inexpensive starting material whose value is only determined through processing. Other semiconductors, such as germanium or the compound semiconductor gallium arsenide, offer in some respects substantially better electrical properties than silicon: charge carrier mobility, and the resulting switching speeds, are significantly higher in germanium and GaAs. However, silicon has decisive advantages over other semiconductors.

This dominant position applies to integrated circuits, not to semiconductor technology as a whole. In power electronics, silicon carbide and gallium nitride have secured a firm place for themselves, since they can withstand higher voltages, higher temperatures, and faster switching. And for anything intended to emit light, silicon is unsuitable: its band transition releases energy as heat rather than as light, which is why light-emitting diodes and lasers are made from compound semiconductors instead.

Bohr atomic model of silicon



Oxide layers can be produced very easily on a silicon crystal; the resulting silicon dioxide is a high-quality insulator that can be deposited on the substrate in a targeted manner. For the semiconductors mentioned above, germanium and

GaAs, producing similarly good insulating layers is, by contrast, very costly. The ability to precisely alter the conductivity of pure silicon through doping is another reason this metalloid is so significant. Other materials are, in some cases, highly toxic, and compounds formed with these elements are not as durable and stable as those based on silicon. A prerequisite for using silicon in semiconductor manufacturing, however, is that it be present in an ultra-pure, single-crystal form. This means that the silicon atoms in the crystal lattice are arranged in a perfectly regular pattern, with no undefined foreign atoms present in the crystal.

In addition to the single-crystal form, there is also polysilicon (poly = many) and amorphous silicon (a-Si). While single-crystal silicon, in the form of wafers, is the foundation of microelectronics, polycrystalline silicon is deposited as a layer on the wafer in various areas to fulfil specific tasks (e.g. as a masking layer, as the gate in a transistor, and others). It can be produced easily and patterned with ease. Polysilicon is made up of many individual single crystals arranged irregularly with respect to one another. Amorphous silicon has no regular lattice structure at all, but rather a disordered one. In chip manufacturing it plays only a minor role; outside of it, however, this is by no means the case: because it can be deposited over large areas and at low temperatures onto glass, the switching elements behind every flat-panel display are built from it, and it is also used in thin-film solar cells.