

1 Fundamentals

1.1 Bipolar transistors

1.1.1 General layout

The second important type of transistors, next to the field-effect transistor, is the bipolar transistor. Its mode of operation is based on both charge carriers (thus bipolar), electrons and holes. Bipolar transistors are faster than field-effect transistors, however, they require more space and are therefore more expensive in mass production.

Bipolar transistors consist essentially of two mutually connected p-n junctions with the layer sequence n-p-n or p-n-p. The connections of the bipolar transistor are emitter (E), base (B) and collector (C). While emitter and collector have the same doping, the very thin base layer in-between is doped contrarily.

In this article an NPN transistor in standard buried collector (SBC) construction is described, the mode of operation of PNP transistors is analog (the signs of the applied voltages have just to be reversed).

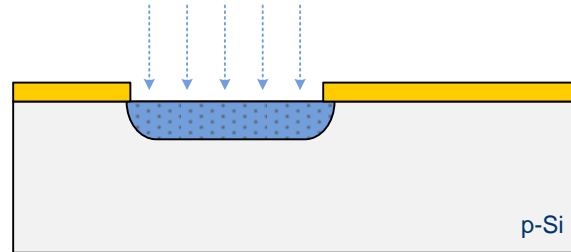
1.1.2 Construction of an NPN bipolar transistor

1. Substrate: Basis for an NPN bipolar transistor is a p-doped (boron) silicon substrate, a thick oxide layer (e.g. 600 nm) is deposited on top.

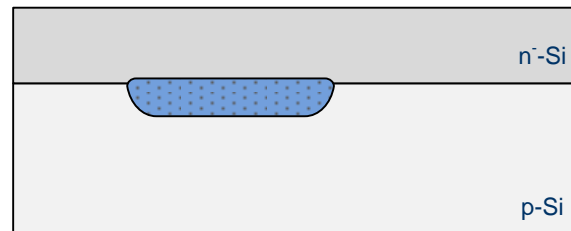


2. Buried Layer Implantation: The oxide serves as an implantation mask. As dopant

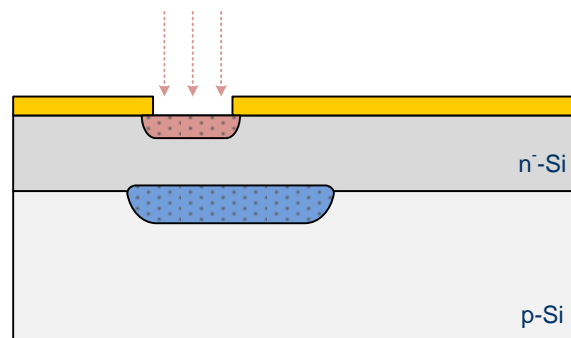
antimony (Sb) is used, since its diffusion coefficient is lower than of phosphorus, and therefore the dopant won't diffuse as much in subsequent processes. The highly n^+ -doped buried collector serves as a low-resistance contact surface for the collector port.



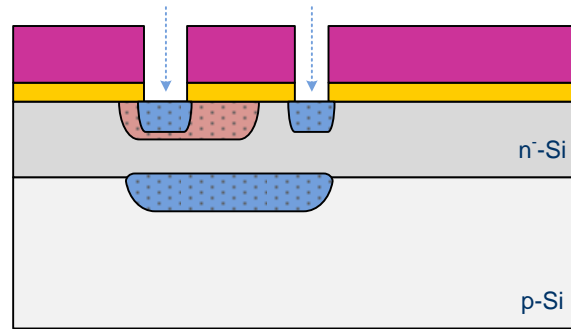
3. Homoepitaxy: In an epitaxial process a high-impedance (low n^- -doped) collector layer is deposited (typically 10 microns).



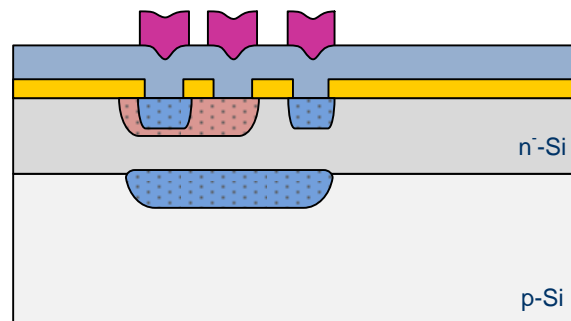
4. Base implantation: With boron the p-doped base is introduced, a subsequent diffusion step magnifies its dimensions.



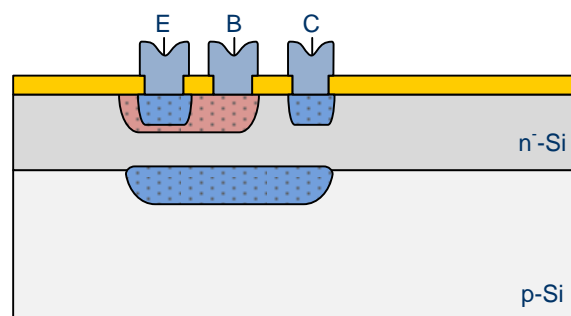
5. Emitter and collector implantation: With phosphorus both highly n^+ -doped emitter and collector junctions are introduced.



6. Metallization and photolithography: Aluminum is deposited in a sputtering process for contacting and a resist layer is patterned on top of it.



7. Etching: Finally, the connectors for emitter, base, and collector are structured in an anisotropic dry etch process.



Due to many improvements, bipolar transistor do have more than three layers (nnp or pnp). Nowadays the collector region consists out of at least two variable doped zones. The terms nnp and pnp just describe the active area, not the actual filmstack.

1.1.3 Mode of operation

The two p-n junctions are hereinafter named as EB (emitter-base) and CB (collector-base). Without an external voltage a depletion zone forms at the interfaces of EB and CB. If a negative voltage is applied to the emitter and a positive voltage is applied to the collector, the depletion zone at EB decreases, while the depletion zone at CB increases. If a positive voltage is now applied to the base, EB becomes conductive - electrons can reach the base layer. As this layer is very thin, the charge carriers can be injected into the collector, where they are extracted due to the positive external voltage. Thus, a current flow from emitter to collector is established. Almost all electrons (>95 %) can reach the collector if only a small voltage is applied to the base, which means that with a relatively small base current (E to B) a very large collector current (E to C) is possible.

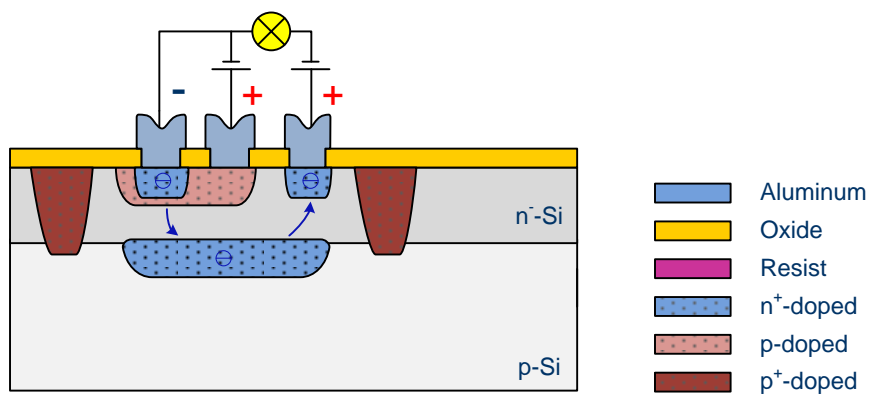


Fig. 1.1: SBC bipolar transistor

The two deep p^+ -doped regions are used for lateral isolation from other components. In addition to the transistor a resistance (not in graphics) is needed, since bipolar transistors can not be controlled currentless.