Title: Heterojunction Bipolar Transistors (HBTs) for High-Speed Applications

Abstract:

The idea of using a heterojunction between different materials in a bipolar transistor originally stems from William B. Shockley`s 1951 US Patent, but some three decades were needed for the technology to come to fruition with the maturation of modern semiconductor crystal growth techniques first introduced in the late 1960`s. HBTs nowadays find applications in multiple important applications including high-efficiency smart phone transmitter power amplifiers (PAs), automobile anti-collision radars, to mixed-signal ICs critical in Terabit/sec optical communication links.

The presentation will begin by outlining the motivations and advantages of a wider energy gap emitter for the performance of bipolar transistors in general. Examples of single-heterojunction HBTs implemented in various material systems (e.g. SiGe/Si, GaAs and InP) will be considered.

The ever-increasing demand for higher speed communication systems drives transistor scaling to smaller dimensions in 3-D: smaller dimensions/thicknesses necessarily lead to lower breakdown voltages, and result in narrower “safe-operating-area” margins and lower output power levels. This speed vs. breakdown voltage trade-off led to the introduction of a second heterojunction with a wider energy gap material in the collector region in order to provide higher breakdown voltages while (hopefully) maintaining or improving cutoff frequencies. The resulting devices are known as double heterojunction bipolar transistors (DHBTs). For DHBTs to be advantageous, a widegap collector material with excellent transport properties and a high breakdown field is needed —these conditions are only met with Indium Phosphide (InP).

Although the use of a wider energy gap InP collector region in InP-based DHBTs in principle promises to marry short transit times and high breakdown voltages, its use comes with complications on how this is best done because the alignment of conduction bands in most material systems of interest tends to confine electrons to the base layer in NpN structures. A number of approaches to this design problem and their effect on device behavior/performance will be considered.

Finally, the state-of-the-art of HBTs will be reviewed.