CHAPTER I
INTRODUCTION

The opening quote for this thesis was taken from Dr. Kroemer's introduction into Heterostructure Bipolar Transistors and Integrated Circuits [1]. He proved theoretically in 1957 that a transistor with wide band gap emitter overcomes "conventional" transistors for current amplification and high speed operation [2], [3]. In 1963 he also proposed the principle of the heterojunction laser. Dr. Alferov was also the first to successfully grow lattice matched AlGaAs compound semiconductor on top of GaAs crystal with clear interface in 1967 [4]. The first patent that was set forth about bipolar transistors was by William Shockley, filed 26 June 1948, within his patent application for the "conventional" transistor [5]. Shockley was awarded the Nobel Prize in Physics already in 1956 with his co-workers Bardeen and Brattain for the development of the semiconductor transistor [6].

The basic work on information and communication technology that was honored once again by the Nobel Prize in Physics has made possible the wide use of communication links, e.g., for internet and telephony, the actual skeleton of the modern information society. As the need for mass produced compound semiconductor devices have increased, progress has been made also on wafer size and integration level. Portable communication systems need to be small, light weight and cheap. To fulfill mass production needs, gallium arsenide industry has moved forward to 6" wafer sizes. Traditional small scale GaAs-processing with mesa isolation techniques have been accompanied by "high integration" GaAs-processes. Since the very early efforts towards good quality heterointerfaces at late 60's, the science of heterojunction bipolar technology has matured to a well respected commercial level. In the beginning of year 2000 it was already easy to find over 30 commercial manufactures for, e.g., heterojunction bipolar transistors (HBTs). Among the others, one could choose between EiC Corporation, Fujitsu FCSI, Matsushita, Motorola, NEC, Philips, RF Micro Devices, Raytheon, Rockwell, Siemens, TRW, Thomson, Toshiba, or TriQuint to contact with. Even the high voltage applications are no longer a bottle neck for HBTs [7].

Nowadays, the fabrication of wide band gap emitter heterojunction bipolar transistors (HBT) has been developed. Because the electron mobility of these compound semiconductors is much higher than that of Si as seen in Fig. 1.1, the frequency response of these corresponding devices is therefore higher. Moreover, we can improve the transistor performance with the use of emitter-base heterojunction [8]. First, single heterojunction bipolar transistor (SHBT) with N-GaAlAs emitter and p^+-GaAs base was interesting due to the high injection efficiency inherent in the structure. However, SHBT has several disadvantages especially for their applications in most ICs which the collector should be on the top and similar to that of emitter to reduce the complexity of IC fabrication as seen in Fig. 1.2.

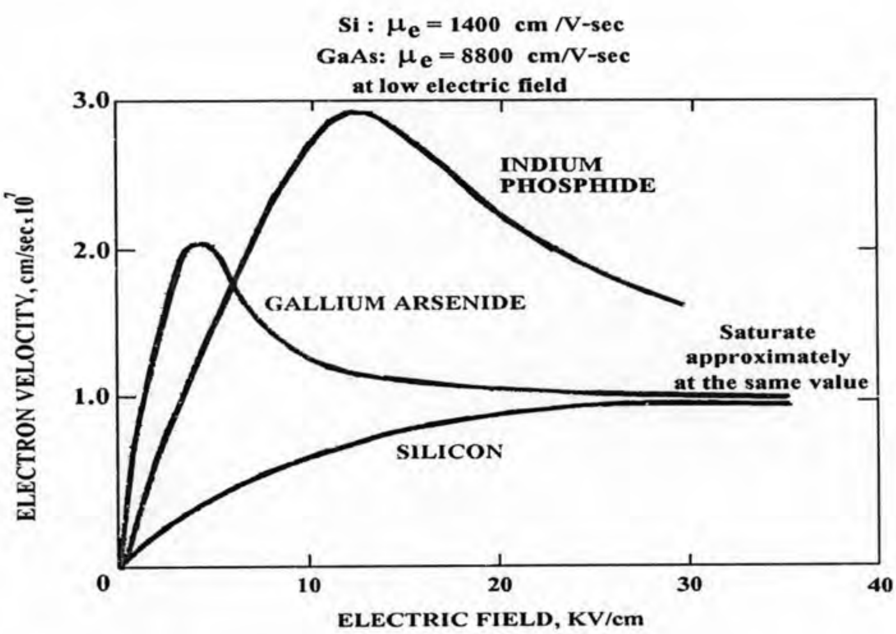

Fig. 1.1 Electron velocities versus electric field characteristics for III-V compounds semiconductors and silicon

SHBTs have the asymmetry between the emitter-base heterojunction and the collector-base homojunction. Therefore, the interchangeability between emitter and collector is impossible. Furthermore, the offset voltage in SHBT is high due to the difference between two junction voltages; this causes plenty of useless power. Hence, the collector-base homojunction should be replaced with the heterojunction similar to that of emitter-base. Double heterojunction bipolar transistors (DHBTs) were then proposed to exhibit the symmetrical characteristics [9].

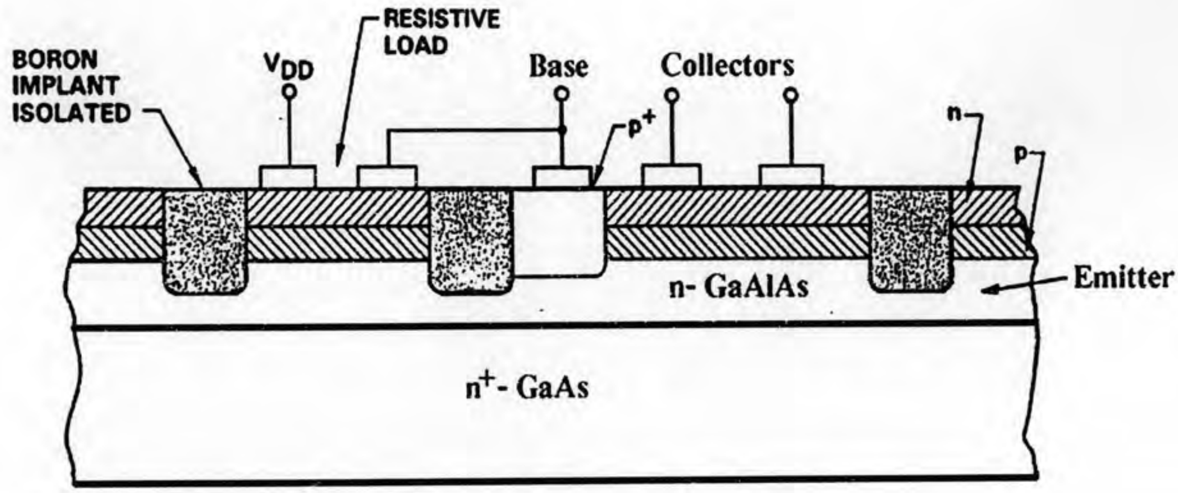

Fig. 1.2 Structure of Collector -up transistors

Moreover, mesa structures are essentially required to realize these transistors. This is because the collector, base and emitter epilayers are sequentially grown and then contacted by sequential etched. This structure is certainly physically asymmetric. Recently, the Zn doped planar structures have been used to obtain the symmetrical DHBTs. Nevertheless, other problems are emerged. The resulting leakage currents degraded their performances of the DHBTs [10]. The aim of this thesis is to obtain a symmetrical characteristic between emitter-base and collector-base DHBT with p^+ regrown base and opened tube Zn diffusion process. These designed structures can be developed not only to the symmetrical transistors but also the collector-up transistor structures. Moreover, these transistor structures with regrown base and diffuse base lead to an extremely low base resistance and result in high maximum frequency response.

Hence, GaAlAs/GaAs Heterojunction Bipolar Transistors (HBTs) are designed and fabricated by Liquid Phase Epitaxy (LPE) technique to exhibit a symmetrical I-V characteristic. In other words, they operate both in normal and inverted modes with a sufficient gain and a low offset voltage.