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III-V Material Systems for Heterostructure Barrier Varactors

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Abstract– This paper presents the lattice matched and pseudomorphic $Al_{0.7}Ga_{0.3}As/GaAs$ and $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As/InP$ material systems for HBVs. HBVs with different mesa diameters have been fabricated and their DC characteristics have been measured. A comparison of the DC characteristics are presented for the two material systems.

I. Introduction

Heterostructure barrier varactor is an ideal device for direct tripling since the C-V characteristic is evenly symmetric and I-V chacteristics is anti-symmetric and only odd harmonic generation occurs under large signal excitation. An undoped high band gap semiconductor is sandwiched between two moderately n-doped smaller band gap semiconductors. The high band gap semiconductor behaves like a barrier which prevents electrons passing through the device.[1]

II. Device Design and Growth

Several different material systems have been proposed since the invention of the HBV. The most promising material system is $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As/InP$.[2] It offers a large conduction band offset, especially when AlAs layers are inserted between the two moderately doped InGaAs layers. High multiplier efficiencies with this material system has been recently reported. [3]

Table I: $Al_{0.7}Ga_{0.3}As/GaAs$ HBV material structure

Material	Thickness	Doping
GaAs	300 nm	$5x10^{18}$ cm^{-3}
GaAs	250 nm	$8x10^{16}$ cm^{-3}
GaAs	3.5 nm	Undoped
$Al_{0.7}Ga_{0.3}As$	20 nm	Undoped
GaAs	3.5 nm	Undoped
GaAs	500 nm	$8x10^{16}$ cm^{-3}
GaAs	3.5 nm	Undoped
$Al_{0.7}Ga_{0.3}As$	20 nm	Undoped
GaAs	3.5 nm	Undoped
GaAs	250 nm	$8x10^{16}$ cm^{-3}
GaAs	2000 nm	$5x10^{18}$ cm^{-3}
$Al_{0.7}Ga_{0.3}As$	500 nm	Undoped
GaAs	50 nm	Undoped
GaAs S.I Substrate		

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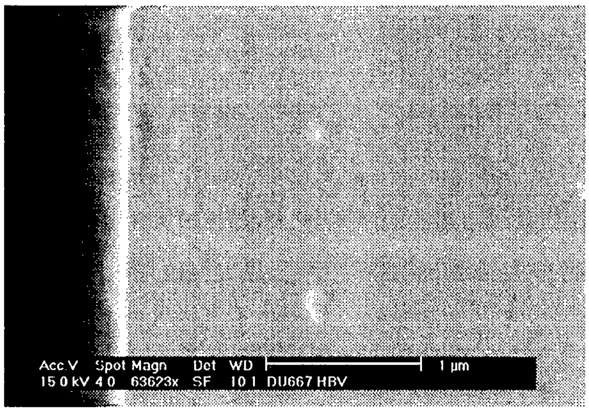

Fig. 1: SEM picture of the two barrier InP-based HBV epitaxial layer grown in University of Duisburg.

The $Al_{0.7}Ga_{0.3}As/GaAs$ material system grown on GaAs substrate has considerable attention due to simple process and cheapness of the substrate. The drawback of this material system is high conduction current due to self-heating and Gamma-X transition. [4] Table I shows the layer structure of double barrier $Al_{0.7}Ga_{0.3}As/GaAs$ HBV. Fig. 1 shows a SEM picture of a double barrier InP-based HBV structure where the double barriers are clearly seen.

III. Device Fabrication

The $Al_{0.7}Ga_{0.3}As/GaAs$ and InAlAs/InGaAs/InP HBV structures which are grown with Molecular–Beam Epitaxy are fabricated using standard photolithography techniques for isolation and ohmic contact patterning, and wet chemical etching of mesa isolation. The Ni/AuGe/Ni and Ti/Pt/Au ohmic contacts are evaporated for GaAs and InP HBVs, respectively. The HBVs with diameters of 10, 20 and 40 um are fabricated in the form of two columns with a total of four barriers, as shown in Fig. 2.

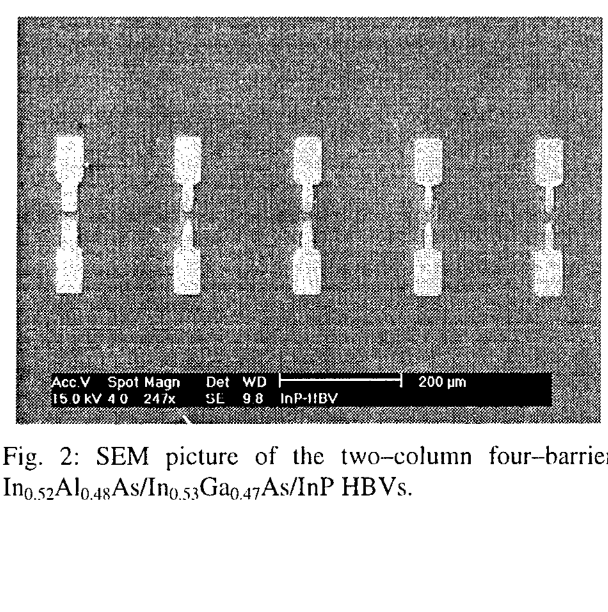

Fig. 2: SEM picture of the two–column four–barrier $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As/InP$ HBVs.

IV. DC MEASUREMENTS

The measured I–V and C–V characteristics of the HBVs are shown in Fig. 3 and 4, respectively. It is seen that the devices show extremely symmetrical characteristics which proves the quality of the epitaxial growth. The devices with $Al_{0.7}Ga_{0.3}As/GaAs$ material system exhibit a leakeage current of 2.3 $\mu A/\mu m^2$ whereas InAlAs/ InGaAs/InP material system exhibit much lower leakeage current of 0.23 $\mu A/\mu m^2$. The C_{max}/C_{min} ratio in the voltage handling ratio of 10 V for InP and GaAs HBVs are 3.5 and 2.5, respectively.

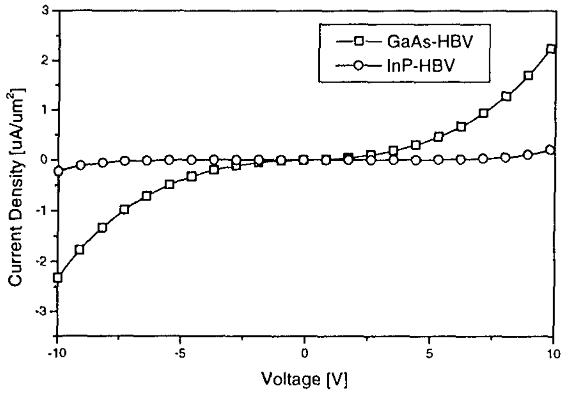

Fig. 3: Measured I–V characteristics of the AlGaAs/GaAs and InAlAs/InGaAs/InP HBVs.

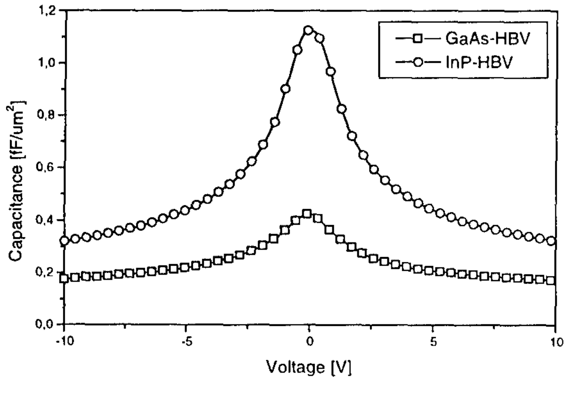

Fig. 4: Measured C–V characteristics of the AlGaAs/ GaAs and InAlAs/InGaAs/InP HBVs.

V. CONCLUSION

We demonstrated the DC performances of the two different epitaxial designs of the HBVs. It is obviously seen that InP based HBVs have a great potential for the future development of the varactors. The next generation HBVs should increase the power capability and bandwidth of operation frequencies.

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