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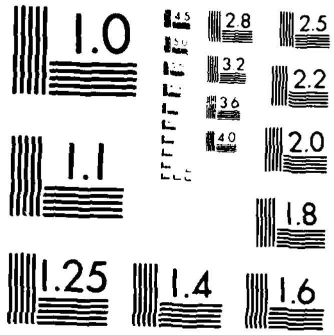

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A STUDY OF $Ga_{.47}In_{.53}As$ AND $Al_{.48}In_{.52}As$ FOR VERY HIGH FREQUENCY DEVICE APPLICATIONS

FINAL REPORT

L.F. Eastman

G.W. Wicks

D.W. Woodard

January 1985

U.S. ARMY RESEARCH OFFICE

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CORNELL UNIVERSITY
ITHACA, NY 14853-5401

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GaInAs/AlInAs modulation doped structures grown by molecular beam epitaxy (MBE) were studied. The parameters of the MBE growth were adjusted to give high room temperature mobilities (~12000 cm^2/v-sec) and high sheet electron concentrations ($2 \times 10^{12} cm^{-2}$). Because of higher electron velocities and high conductivities GaInAs modulation doped transistors should be significantly higher speed than those of GaAs.

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A STUDY OF $Ga_{.47}In_{.53}As$ and $Al_{.48}In_{.52}As$ FOR VERY HIGH FREQUENCY DEVICE APPLICATIONS

OBJECTIVE

The purpose of this program was the growth by molecular beam epitaxy (MBE) and characterization of $Ga_{.47}In_{.53}As/Al_{.48}In_{.52}As$ heterostructures for fast transistors. Initially these transistor structures were intended to be MESFET's but very early in the program, it was realized that modulation doped FET's (MODFET's) would be feasible in the GaInAs/AlInAs material system. Since MODFET's have the theoretical advantages over MESFET's of higher electron velocities and close proximity of the gate and the channel, this program has concentrated on modulation doped GaInAs/AlInAs heterostructures.

Major improvements have been accomplished under this program in the electrical characteristics of GaInAs/AlInAs modulation doped structures. Our initial attempts, as well as those of other laboratories, achieved room temperature mobilities (μ_{300K}) in the range of 8000-9000 cm^2/v-sec. One and a half years into the program, we reported μ_{300K} = 11000 cm^2/v-sec, and at the conclusion of this program the value is up to μ_{300K} = 12000 cm^2/v-sec. This mobility is the highest room temperature mobility of a two dimensional electron gas (2DEG) in any material system. Other electrical characteristics of interest are the 77K mobility which is typically $\mu_{77K} \gtrsim$ 60,000 cm^2/v-sec and the sheet concentration (n_s) of the 2DEG which is in the range of 1.3-2.1 x $10^{12} cm^{-2}$.

The room temperature characteristics of modulation doped structures of GaInAs are substantially better than those of similar structures of GaAs. In comparison to GaAs modulation doped structures, those of GaInAs exhibit greater than 50% higher room temperature mobility and $\geq$ 100% higher sheet electron concentration, resulting in a conductance 3.5 times greater. This would result in GaInAs MODFET's with higher extrinsic transconductances and higher current handling capabilities.

Results for mobility versus sheet concentration and spacer thickness show trends which are similar to those for GaAs/AlGaAs modulation doped structures. The same is true for temperature variable Hall results. The primary differences that exist appear to be due to the addition of alloy scattering at low temperatures ($T < 150K$) in the GaInAs/AlInAs materials system.

The photoconductivity effect in GaInAs MODFET's is very small (less than 1%) for the structure with a sheet concentration of $2.1 \times 10^{12}/cm^2$. However, the effect increases sharply with decreasing sheet concentration. A structure with a sheet concentration of $4 \times 10^{11}/cm^2$ has a photoconductivity effect of 300%, a number which is comparable to typical GaAs MODFET's. The fraction that is persistent increases similarly. The excitation for persistent photoconductivity is observed to occur at 1.41 eV, close to the AlInAs bandgap energy.

In addition to the above fundamental work on the MBE grown structure, a large effort was made in this program on improving the ohmic contacts to the 2DEG in modulation doped GaInAs. Without good ohmics, the potential advantages of the MODFET would not translate into high operating frequencies. A series of experiments were conducted with different metallizations and different annealing cycles in order to optimize the contact. The lowest reported trasfer resistance (0.06 ohm-mm) to date was achieved by means of controlled alloying of AuGeNiAg metallization. The metallization was chosen so as to reduce Ga loss from the semiconductor by incorporating Ag within Au, the quantity of which was limited in order to prevent substantial In outdiffusion caused by the large In-Ag affinity.

SUMMARY

In summary, the GaInAs/AlInAs modulation doped heterostructure has been grown by MBE, characterized and optimized. In addition, a scheme for fabricating extremely low transfer resistance ohmic contacts have been developed. With the success in these two areas, the GaInAs MODFET appears to be extremely promising for room temperature, high frequency applications.

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2. K.H. Hsieh, Ph.D., May 1984
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3. H.T. Griem, M.S., January 1985
"$Ga_{0.47}In_{0.53}As/Al_{0.48}In_{0.52}As$ Modulation-Doped Structures with Pinchoff Capabilities Grown via Molecular Beam Epitaxy"

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