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B-5-1 Epitaxial GaAs Hall Sensors for High Temperature Applications

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This paper describes epitaxial GaAs Hall sensors designed for use as a digital pulsing transmitter from rotation at high temperature above 100°C. High temperature characteristics of the devices are emphasized. No Hall sensor commercially available functions at this temperature range because of the narrower band gap of the materials than that of GaAs.

The devices were fabricated utilizing epitaxial n-GaAs grown on semiinsulating GaAs. The thickness and the carrier concentration of the epitaxial layers which determine the Hall voltage V_H and the device resistance R_d, were designed accordingly. Table 1 is a list of the devices fabricated and the characteristics of the wafers from which the devices were produced.

A top view of a device chip after separation is shown in Figure 1. Mesa etching isolates and forms the devices on the semiinsulating substrate. Ohmic contacts are formed using Au-Ge alloy.

Figure 2 is temperature dependence of the Hall voltage measured at 5 Kgauss. Except #154 in which the Hall voltage decreased rapidly above 150°C, the devices function with good stability up to 280°C that is limited by the contact metal structure. Temperature coefficients of the Hall voltage, $\frac{1}{V_H} \times \frac{dV_H}{dT}$ are about -1.8×10^{-4}/°C at 100°C and -0.5×10^{-4}/°C at 150°C, which are tenth of that of Si Hall sensors at these temperatures.

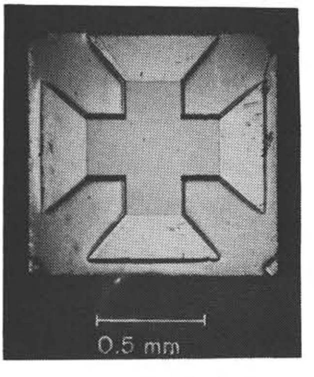

Fig. 1. Top view of a Hall sensor chip.

In #154 device, the reduction of the Hall voltage coinsides with that of the device resistance as is shown in Figure 3. Figure 3 is the temperature dependence of V_H and R_d in a device #154-1 along with the data taken with a device #154-2 in which a major part of the epitaxial layer has been etched off to make the effect conspicuous.

Sample No.	Carrier Conc. (cm^{-3})	Thickness (μm)	Calculated (1) V_H(5kG) (mV)	R_d (Ω)	Observed V_H(5kG) (mV)	R_d (Ω)
#154	9.0×10^{15}	0.7	449	3,360	430~480	3,260~3,580
#157	4.6×10^{15}	1.6	385	2,780	362~410	2,690~3,020
#162	1.9×10^{16}	5.0	29.8	257	25~31	200~290
#151	8.6×10^{16}	1.3	25.3	287	23~27	250~280

$I_c = 1$ mA

Table 1. List of wafers and devices fabricated.

The activation energy calculated from the slopes in V_H vs. T and R_d vs. T curves gives a donor level lying at 0.8 eV from conduction band, which has been assigned to Oxygen.[2]

Carrier concentration profiles of the layers were measured at high temperature using C-V data of Schottky barrier formed on the epitaxial layer. In the layer #154, it was observed that a frequency dependence of the carrier concentration and a thickening of the conductive layer. A profile of electron mobility in the layer was also measured at room temperature with a Hall specimen with a Schottky gate formed on current path.[3] There was a definite correlation between an appearance of the low mobility region at the boundary and the phenomena stated above. Discussions which brought about a conclusion that the incorporation of Oxygen from a possible leak into the epitaxial layer will be reported.

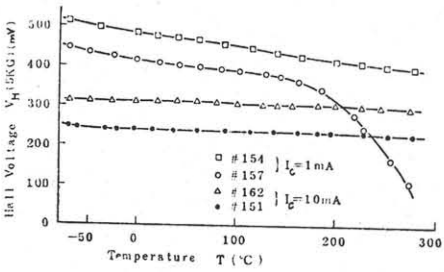

Fig. 2. Temperature dependence of V_H at 5 Kgauss.

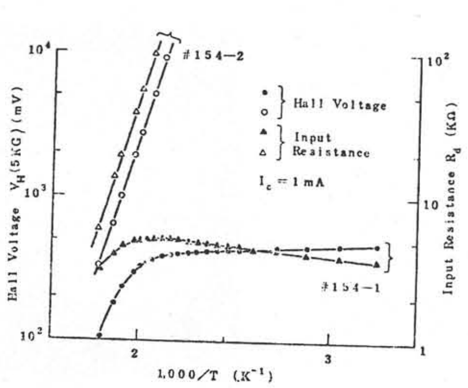

Fig. 3. Temperature dependence of V_H and R_d in the samples #154.

To realize cost down of the devices, (1) mass production of GaAs layers by C.V.D., (2) utilization of low quality (high etch pits density) substrates and (3) optimization of specifications for a high yield, have been investigated with satisfactory results.

In table 2, characteristics of the epitaxial GaAs Hall sensors are summerized.

device resistance R_d (Ω)	3,000
control current (typ.) I_c (mA)	10
hall voltage @5kG @I_c V_H(5kG) (mV)	4,000
sensitivity (mV/mA·kG)	80
max. magnetic flux density sensitivity (V/kG)	3
linearity $V_H(B)/V_H(1kG)$ @R_L = ∞ (%)	<1
temperature coefficients @150°C (%/°C)	-0.5×10^{-2}
residual voltage $V_H(0)/V_H(5kG)$ (%)	<2
operational temperature range °C	-70~200

Table. 2. List of typical characteristics of epitaxial GaAs Hall sensor.

References:

(1) H. J. Lippmann and F. Kuhrt: Z. Naturforsh 13a 462 (1958)

(2) Vorob'ev, Yr. V., Yu. I. Karkhanin and O. V. Tretyak: Sov. Phys. (Semicond.) 5 254 (1971)

(3) A. C. Ipri: J.A.P. 43 2770 (1972)