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Chloride VPE of $Al_xGa_{1-x}As$ by the Hydrogen Reduction Method Using a Metal Al Source

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Aim----- Vapor phase epitaxial growth of AlGaAs is possible only by MOCVD at the present moment. This method, however, has some serious disadvantages such as use of highly toxic arsine, and expensive system and operational cost. The purpose of this work is to investigate the possibility of growing AlGaAs by the chloride VPE method, which is widely used for the production of GaAs epi-layers, using a solid metal Al source.

Experimental----- A schematic diagram of the growth apparatus is shown in Fig.1. The system is essentially the same as that of the flat temperature zone chloride VPE method (1) for the growth of GaAs, except for a new addition of the Al source chamber. The temperatures of the Ga source zone and the deposition zone are kept at 750°C, which is the growth temperature of GaAs, but the metal Al source is kept at 650°C in order to prevent melting. The quartz reactor tube was coated with carbon to prevent $AlCl_3$ from attacking the wall. $AsCl_3$/He and $AsCl_3$/He+1%H_2 are introduced into the Al source and Ga source chamber, respectively. At the growth region, H_2 gas is added resulting in the deposition of AlGaAs by the following reaction:

$$4AlCl_3 + As_4 + 6H_2 \text{ === } 4AlAs + 12HCl$$
$$4GaCl^3 + As_4 + 2H_2 \text{ === } 4GaAs + 4HCl$$

Results and Discussions----- Growth rates of $Al_xGa_{1-x}As$ were 1 to 2μm/hr. The Al content could be changed from $x=0.15$ to 0.54 by changing the flow rate of the Ga-side $AsCl_3$(-5°C) from 100 to 50cc/min. Figure 2 shows an example of the composition profile measured by a sputtering Auger Electron Spectroscopy. Though the surface is oxidized somewhat, Al seems to be distributed quite uniformly up to near the bulk. The rise in the Al content near the bulk interface can be attributed to the growth procedure, i.e., the Al-side $AsCl_3$ was supplied a few minutes prior to the Ga-side $AsCl_3$.

Hall effect measurements of $Al_{.15}Ga_{.85}As$ showed a carrier concentration of 2.1×10^{18} cm^{-3} and a mobility of 1400cm^2/Vs at room temperature. The high carrier concentration is probably because a 4 nine aluminum source was used in the initial experiments. Therefore, by grading up the purity of the metal aluminum, lower carrier concentrations should be obtained. Nevertheless, the mobility of 1400cm^2/Vs is comparable or higher than those of LPE grown AlGaAs layers with the same carrier concentrations.

Figure 3 shows the room temperature and 77K photoluminescence signals from a 1.3μm n-$Al_{.15}Ga_{.85}As$ layer. Though no special care was taken to shut out air from the reactor such as the use of a glove box, the sample showed interband photoluminescence at 77k as well as at room temperature. The broad IR luminescence is inferred to be due to the so called self-activated center from the temperature dependence of its spectrum and intensity.

Impact----- Chloride VPE of AlGaAs, which does not need to use neither toxic AsH_3 nor metalorganic sources has become possible for the first time. The reasons are as follows:

1) The Hydrogen Reduction Method was used.
2) The metal Al source was kept below the melting point to keep a large unoxidized surface.

Reference: 1) A.Koukitsu, H.Seki et al., Japan. J. Appl.Phys.,17, (1976),1591 and 23,(1984), 951.

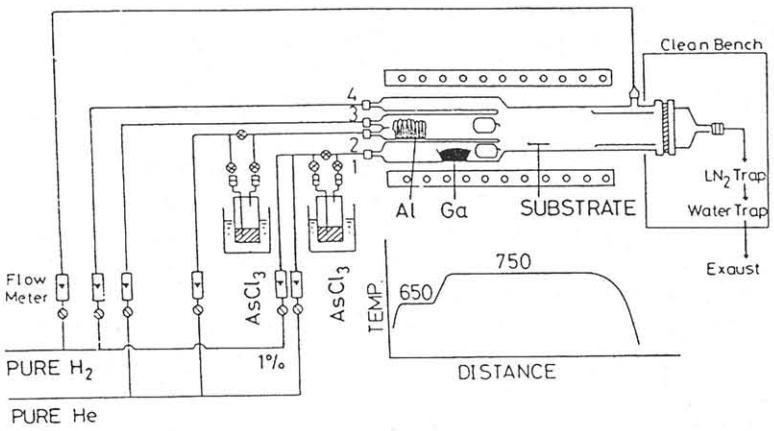

Fig.1 Schematic diagram of the Hydrogen Reduction Chloride VPE system used in this experiment

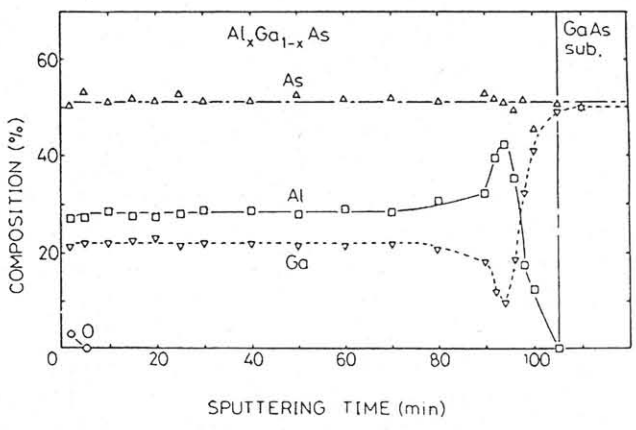

Fig.2 Composition Profile of an AlGaAs layer measured by a sputtering AES

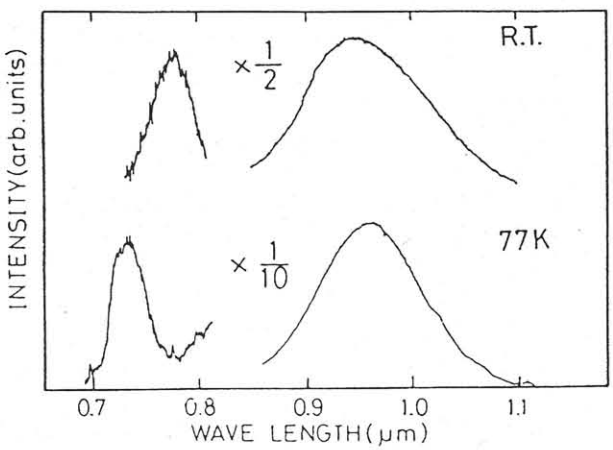

Fig.3 Room temperature and 77K PL-spectra of $Al_{.15}Ga_{.85}As$ layer grown by the Hydrogen Reduction Chloride VPE method