[I~15]

CBE growth and doping of InP and InGaAs lattice-matched to InP for high-speed electronic device application

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InP and related compound semiconductor materials are attractive for high-speed electronic device application, due to their excellent electrical properties compared with those of GaAs and related materials. InP-based devices including high electron mobility transistor (HEMT) [1] and heterojunction bipolar transistor (HBT) [2] having maximum cut-off frequencies over 200 GHz have already been reported.

Growth and doping of InP and $In_{.53}Ga_{.47}As$ were studied using a V80H chemical beam epitaxy (CBE) system. Cracked PH_3 and AsH_3 were used for group V elements and TEGa and TMIn were used for group III elements. Solid Si source was used for n-type doping and CBr_4 and solid Be were used for p-type doping. InP was grown for temperatures ranging from 480 °C to 520 °C with different growth rates and V/III ratios. InGaAs lattice-matched to InP was grown for temperatures ranging from 470 °C to 520 °C with different V/III ratios. Doping of InP with Si and Be and InGaAs with Si and CBr_4 was investigated.

$In_xGa_{1-x}As$ layers lattice-matched to InP within 150 arcsec measured by a double x-tal x-ray can be routinely grown. The good morphology of the grown layers was indicated by rms roughness of 3.2 Å and 1.7 Å measured by an AFM for undoped InP and InGaAs, respectively. A photoluminescence data measured at 9K for an undoped InGaAs sample grown at 500 °C showed a full width at half maximum (FWHM) of 4.8 meV. The background doping and mobility of the InGaAs layer measured by a Hall measurement were $3.4x10^{15}/cm^3$ (n-type) and 6,300 $cm^2/v{\cdot}sec$, respectively. Preliminary doping study shows that InP can be doped as high as $3x10^{19}/cm^3$ (n-type) and $4x10^{18}/cm^3$ (p-type) with Si and Be, respectively. InGaAs can be doped as high as $4x10^{19}/cm^3$ (n-type) and $>1x10^{19}/cm^3$ (p-type) with Si and CBr_4, respectively. These doping levels are close to the highest yet reported [3].

An experimental carbon-doped base InP/InGaAs HBT structure was grown and processed. Measurements show good breakdown characteristics of emitter-base and base-collector junctions and a common-emitter ac current gain of 70.

In conclusion, growth of high quality InP and InGaAs lattice-matched to InP and their doping by CBE were studied. The preliminary results demonstrate the potential of CBE for achieving high-quality, ultra-high doping InP and InGaAs layers suitable for high-speed electronic device applications.

References

[1] L.D Nguyen, IEEE Trans. Electron Devices, vol. 39, pp. 2007-2014, 1992.

[2] J.-I. Song, et al., IEEE DRC Technical Digest, 1994.

[3] Panish, et al, Gas Source MBE, Springer-Verlag, 1993.

Acknowledgments

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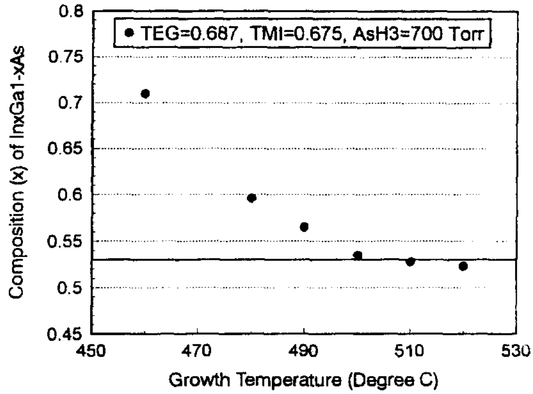

Fig. 1. Estimated dependence of In composition (x) of $In_xGa_{1-x}As$ on growth temperature. Pressures of TMIn, TEGa, and AsH_3 are assumed to be constant at 0.675, 0.687, and 700 Torr.

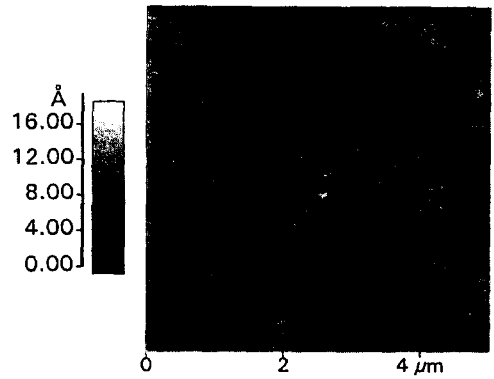

Fig. 2. AFM image of undoped InGaAs.

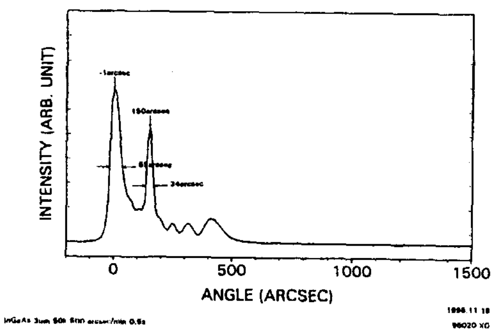

Fig. 3. X-ray rocking curve of undoped InGaAs layer grown at 500 °C.

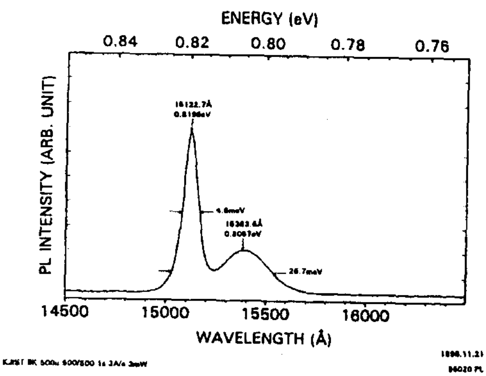

Fig. 4. 9K PL spectra for an undoped InGaAs layer grown at 500 °C.

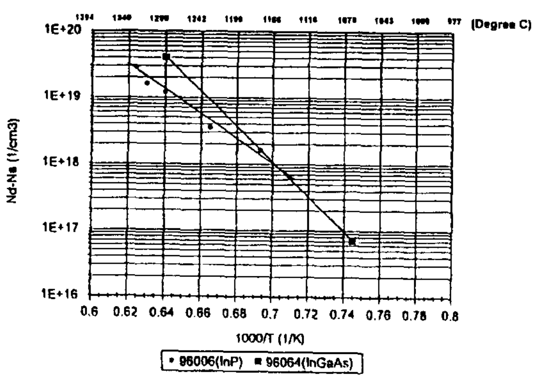

Fig. 5. Electron concentration of Si-doped InP and InGaAs grown at 500 °C as a function of Si cell temperature

Cap	150 nm	n++ InGaAs (Si)
Emitter	250 nm	n++ InP (Si)
Emitter	100 nm	n InP (Si)
Spacer	5 nm	und InGaAs
Base	70 nm	p++ InGaAs (C)
Collector	600 nm	n- InGaAs (Si)
Subcollector	500 nm	n++ InGaAs (Si)

S.I. InP Substrate

Fig. 6. Structure of CBE-grown carbon-doped base InP/InGaAs HBT.