

GROWTH OF S-DOPED 2" INP-CRYSTALS BY THE VERTICAL GRADIENT FREEZE TECHNIQUE

U. Sahr^a, I. Grant^b and G. Müller^a

^aCrystal Growth Laboratory, University Erlangen-Nuremberg, Martensstr.7, D-91058 Erlangen, Germany

Phone ++49-9131-85-27722, Fax ++49-9131-85-28495, e-mail uwe.sahr@ww.uni-erlangen.de

^bWafer Technology Ltd., Tongwell, Milton Keynes MK158HJ, UK

Phone ++44-1908-210444, Fax ++49-1908-210443, e-mail igrant@wafertech.co.uk

Abstract

Indium phosphide is an important substrate material for optoelectronic applications. For this, InP substrates with a high quality, i.e. a very low defect density and high bulk crystal uniformity, are required.

A high pressure furnace (fig.2) was developed for the growth of 2" InP-crystals. To avoid twinning a so called flat bottom crucible without a cone region is used. The advantage of reducing the dislocation density by diameter expansion in the conical part is lost in this arrangement. Consequently, conditions of low thermal stress during the seeding process are required.

InP crystals (fig.1) were grown in <100>-direction with this furnace set-up. The process is "semi-open", i.e. the crucible with melt and crystal is placed in a closed silica ampoule, but the ampoule has a small hole at the cold end of the furnace to allow for a pressure balance and condensation of excess phosphorus. Further graphite parts are used to minimize convection inside the furnace. The seeds used, up to now, were grown by the LEC-method. The EPD varied between $3 \cdot 10^4 \text{ cm}^{-2}$ and $5 \cdot 10^4 \text{ cm}^{-2}$. The seeding is controlled using two thermocouples. During growth the InP is fully encapsulated by a liquid B_2O_3 -film. Nitrogen (pressure of 37 bars) is used as the ambient gas.

With this VGF-furnace set-up single crystals with 2" diameter and a length of 9 cm were grown at a rate of 2 mm/h. The carrier concentration varied between $3\text{-}8 \cdot 10^{17} \text{ cm}^{-3}$.

The VGF-furnace was designed by the aid of numerical simulation. Using the computer code CrysVUn++, quasi-stationary and time-dependent simulations were performed. First the temperature distribution in the furnace (shown in fig.1) was modeled. The position and the shape of the solid liquid interface were determined at various time steps during the crystal growth process.

Furthermore temperature fluctuations during the crystal growth process were calculated. The experimental temperature data measured at nine heater control-thermocouples were used as input data for the numerical modelling. Fig. 3 shows the calculated temperature in one point at the crucible edge in an earlier furnace set-up. The amplitude of the temperature fluctuation is 0.2 K. For the new designed furnace set-up the calculated temperature fluctuation is 0.03 K if one uses the same fluctuation amplitude at the control-thermocouple (figure 4).

The material from the single crystal was sliced to (100)-wafers. The slices were etched with the Huber etchant. The etch-pit-density at the seed end is 1500 cm^{-2} , and 105 cm^{-2} at the tail end. The carrier concentrations for the measured slices are $3.6 \cdot 10^{17} \text{ cm}^{-3}$ and $7.3 \cdot 10^{17} \text{ cm}^{-3}$.

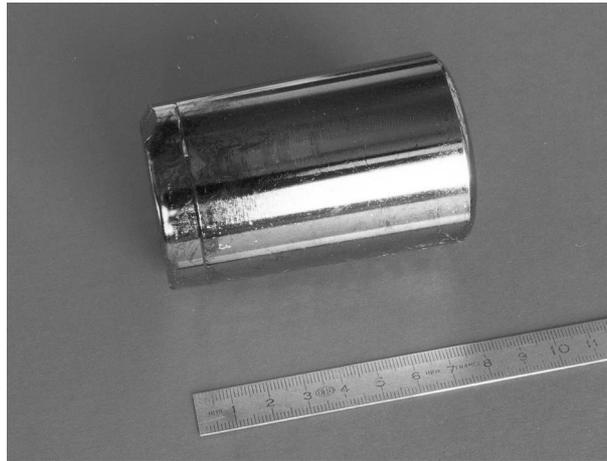


Fig.1 2" InP-single crystal, grown in <100>-direction, S-doped (carrier concentration is $3\cdot 8\cdot 10^{17} \text{ cm}^{-3}$)

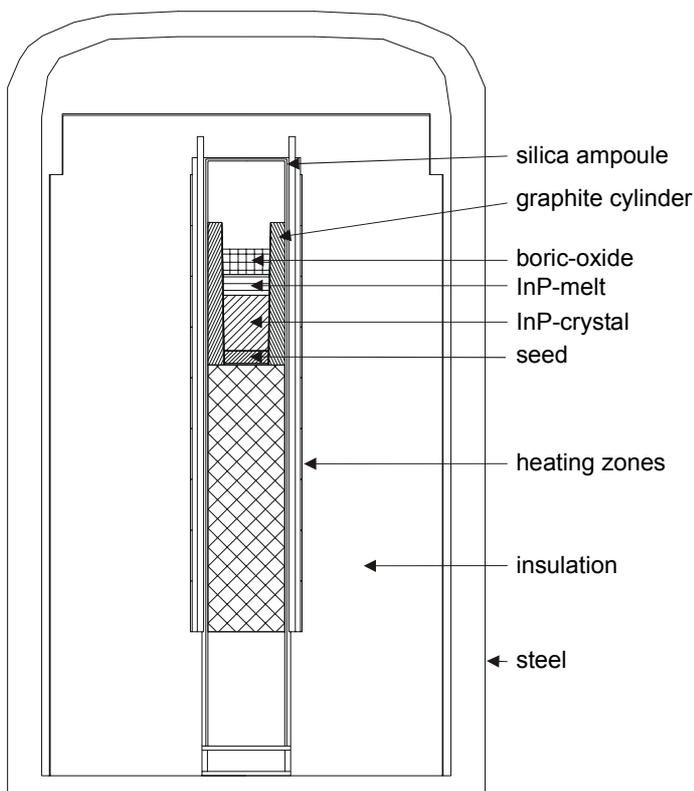


Fig.2 VGF furnace set-up

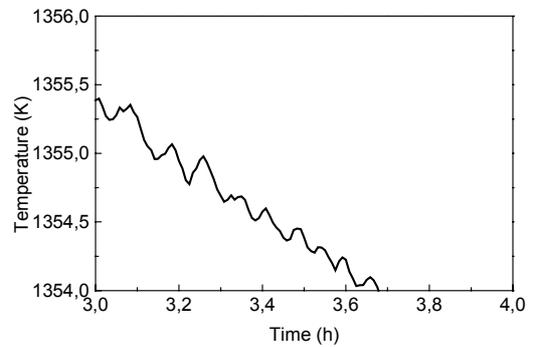


Fig.3 Calculated temperature at the crucible edge for the earlier furnace set-up

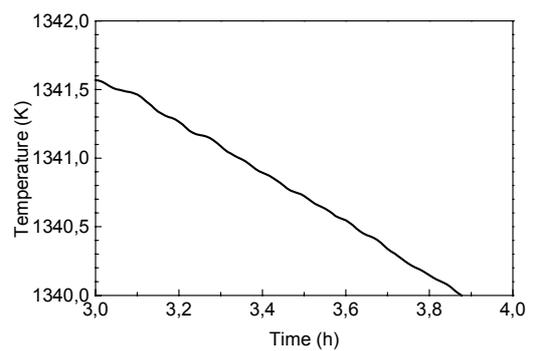


Fig.4 Calculated temperature at the crucible edge for the new furnace set-up