Investigating the various effects of boron doping during the growth of Czochralski germanium ingots

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Most of the dopants except boron have a higher diffusion coefficient (D_A) in germanium than the Ge self-diffusion. Additionally, the rapid formation of the B-cluster (assumed) poses a major challenge to growing B-doped Cz-Ge ingots. Four B-doped Ge ingots were grown with varying B concentrations, 10^{16}, 10^{17}, 10^{18}, and 10^{19} cm^{-3} to investigate the effects related to B doping. All crystals were grown by the Czochralski method along the [100] direction. Boron was doped in the ingots by introducing B in the form of granules in the crucible with the Ge feed before melting. Parasitic nucleation due to dopant oversaturation in the melt is expected while growing HD-Ge ($C_0 \sim 10^{18}$-10^{20} cm^{-3}) ingots for any dopant. Particularly, such an effect was observed to be dominant in the case of B-doped Ge, even at lower dopant concentrations. A larger mono-crystalline volume in the B-doped Ge ($C_{0(B)} \sim 10^{19}$ cm^{-3}) was obtained when grown with faster-pulling rates (approximately 60 – 80 mm/h) (Fig 1a). When grown with slower pulling rates of around 20-30 mm/h, an increased number of particles (assumed to be B-O complex particles) were observed on the melt surface. These particles upon interaction with the growing crystal resulted in the poly-crystallinity of the ingot. As reported by the previous studies, several B-particle clusters were incorporated into the crystal already during dash necking. The formation of such clusters was observed to occur much earlier when using pre-doped feed material for growth. Preliminary investigations showed a largely mono-crystalline solidified fraction in the B-doped ingot grown with a faster pulling speed. The resistivity measurement using the 4-point probe is shown (Fig 1c). This work aims to investigate the various effects related to B incorporation of the grown Ge ingots. Results from several ongoing measurements will be discussed in detail. Furthermore, in efforts to grow heavily-doped monocrystalline Cz-Ge (HD-Ge) ingots, a co-doped Ge ingot with B and Ga (initial concentrations, $C_{0(B)} \sim 10^{19}$ cm^{-3} and $C_{0(Ga)} \sim 10^{19}$ cm^{-3}) was attempted.

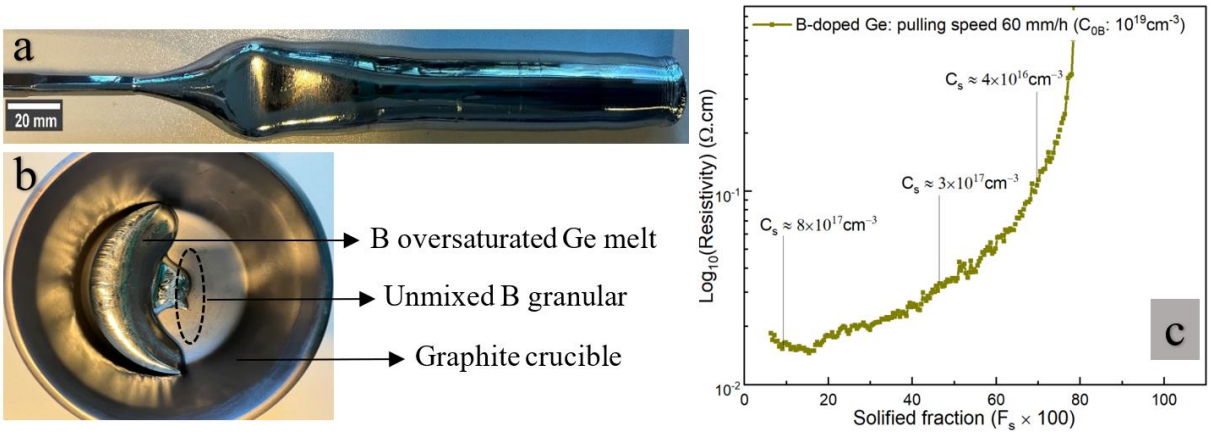

Figure 1: (a) B-doped Cz-Ge ingot with $C_{0(B)}$ 10^{19} cm^{-3}, (b) Oversaturated B-Ge melt along with unmixed B-granules, and (c) Resistivity measurement of the B-doped ingot shown in (a) using 4-point probe method

References

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Acknowledgements
The authors would like to thank Nikolay V. Abrosimov for his valuable support and advice. The authors thank the Deutsche Forschungsgemeinschaft (DFG) for the financial support through a research project (grant No. 509113935).