Bulk Growth of AlN-SiC Mixed Crystals with Homogeneous Composition on Aluminum Nitride Substrates

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Recently we reported on bulk growth of AlN-SiC mixed crystals with high aluminum content by physical vapor transport (PVT) in tantalum carbide crucibles [1]. Growth was performed on SiC seeds, and the SiC source was constituted mainly by partial evaporation of the seed at initial stages of growth. Variation of growth temperature, seed orientation, or faceting [2] led to substantial changes in optical absorption and cathodoluminescence. However, a depletion of the SiC source during growth is observed leading to a decrease of Si and C content with growth time and thus to inhomogeneous properties across the crystal volume.

In this study, off-oriented aluminum nitride single-crystalline substrates of 10 mm in diameter are used as seeds, whereas the source consists of pre-sintered AlN-SiC ceramic. Growth is performed at approx. 1950°C under low thermal gradients in tantalum carbide crucibles. Under these conditions, up to 2 mm thick bluish single-crystalline layers are obtained. The crystal surfaces appear faceted (terraced) and no macroscopic growth defects are observed. In contrast to crystals grown on SiC seeds, the obtained layers are also completely crack free. The silicon, carbon, and oxygen concentration in one of the samples was determined by mass spectrometry to $2.5 \cdot 10^{21}$ cm^{-3}, $1.5 \cdot 10^{21}$ cm^{-3}, and $1.3 \cdot 10^{18}$ cm^{-3}, respectively. Note that crystals grown on SiC seeds under comparable growth conditions yield very similar values at initial stages of growth, i.e., before SiC source depletion starts. However, optical absorption and cathodoluminescence measurements on wafers and longitudinal cuts of the crystal grown on AlN seeds indicate that silicon and carbon are homogeneously distributed across the whole crystal volume. We conclude that the AlN-SiC ceramic acts as infinite source during growth and thus allows for preparation of bulk AlN-SiC mixed crystals with homogeneous composition on AlN substrates.

Finally, the origin of coloration, luminescence and UV absorption bands in AlN-SiC mixed crystals is further investigated. Optical absorption is clearly correlated to a luminescence band at 1.9 eV [1] and accompanied by changes in thermally stimulated luminescence. On the other hand, changes in coloration do not correlate to silicon, carbon, or oxygen content in the samples. As it stands, the optical properties are not so much affected by the SiC content itself, but by deviations in the silicon-to-carbon content ratio, probably accompanied by formation of intrinsic defects.

[1] M. Bickermann et al., phys. stat. sol. (c) (2010) in press, DOI: 10.1002/pssc.200983423.
[2] O. Filip et al., Mater. Sci. Forum 615-617 (2009) 983–986.