Specific features of sublimation growth of bulk AlN crystals on SiC wafers

E. Mokhov\textsuperscript{1}, I. Izmaylova\textsuperscript{1}, O. Kazarova\textsuperscript{1}, A. Wolfson\textsuperscript{1}, S. Nagalyuk\textsuperscript{2}, D. Litvin\textsuperscript{2}, A. Vasiliev\textsuperscript{3}, H. Helava\textsuperscript{3}, Yu. Makarov\textsuperscript{2,3}

\textsuperscript{1}Ioffe Physical Technical Institute, Polytechnicheskaya 26, St. Petersburg 194021, Russia
\textsuperscript{2}Nitride Crystals Ltd., 27 Engels Ave, St. Petersburg 194156, Russia
\textsuperscript{3}Nitride Crystals Inc., 181 E Industry Ct Ste B, Deer Park, NY 11729, USA

AlN crystals are of interest in such application as wafers for optoelectronic devices, among them ultraviolet light emitting diodes. The given report informs about some specific problems of growth of AlN crystals on SiC seeds by the sublimation method.

It is noted that the main problems of sublimation growth of AlN, including insufficient repeatability of results, are due to the fact that in the vapor phase there are very few combinations of Al and N, which can function as a transporter, and equilibrium vapor above AlN consists only of extremely reactive aluminum vapor and extremely stable in terms of energy nitrogen molecules. High reactivity of Al vapor, as well as Si, combined with high growth temperature extremely limits the number of materials suitable for container manufacture. The materials practically used for AlN growth, among them graphite, W, BN and TaC, can not be considered as fully inert, since they interact with Al and Si and contaminate the growth surface.

The report gives results of comparative study of growth of AlN on SiC seeds in containers made of preliminary carbidized Ta or tantalum carbide. It is shown that in case of use of Ta containers, preliminary carbidized by high-temperature annealing in graphite, the quality and repeatability of AlN growth highly depend on conditions of temperature annealing of the containers. At medium temperatures of the annealing, when in the process of annealing a TaC layer is formed on the Ta surface and phases of variable composition of \( \text{Ta}_m\text{C}_n \) are formed inside, high growth quality is possible only until cracks are formed in the crucible. The degradation of the growth quality is associated with contamination of the growth surface with carbon and tantalum impurities. At higher temperatures of the annealing it is possible to transform Ta to TaC, however, these containers are very fragile and short-lived. Alternatively we used TaC containers, made by pressing and further thermal processing of TaC powder.

The stability of molecular nitrogen conditions low condensation coefficient by sublimation growth of AlN. It is observed that the value of the local condensation coefficient at various areas of the surface strongly differs, that leads to high dependence of the growth rate on the surface condition and structural defect occurrence. The condensation coefficient generally decreases near structural defects, that leads to occurrence of voids and micropipes on the growing crystal surface. The abnormal condensation mechanism is caused by occurrence on the growing surface of a liquid phase, including aluminum and silicon.

The denoted problems highly influence the repeatability of the process and the crystal quality. However, the implemented work on optimization of conditions of AlN crystallization gave a possibility to provide a controlled growth of very qualitative bulk AlN crystals up to two inches diameter and up to 5 mm thick.