【Grant-in-Aid for Scientific Research (S)】

Solution Growth Methodology for Ultra-Wide Bandgap Semiconductors: Scientific Principles and Processing

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Project Information	Project Number : 25H00412 Keywords : Crystal growth, Aluminum nitride, Thermodynamics, Melt properties	Project Period (FY) : 2025-2029

Purpose and Background of the Research

●Outline of the Research

This study develops a novel solution growth method for aluminum nitride (AlN) crystals, an ultra-wide bandgap semiconductor for next-generation devices. The project combines: (1) enhanced AlN solubility flux design inspired by metallurgy and (2) hybrid growth with high-temperature annealing to reduce defects. Using thermodynamic design and high-temperature observation techniques, this research aims to increase high-quality AlN substrate availability, enabling superior semiconductor devices beyond current SiC and GaN capabilities.superior properties compared to SiC and GaN, advancing semiconductor technology.

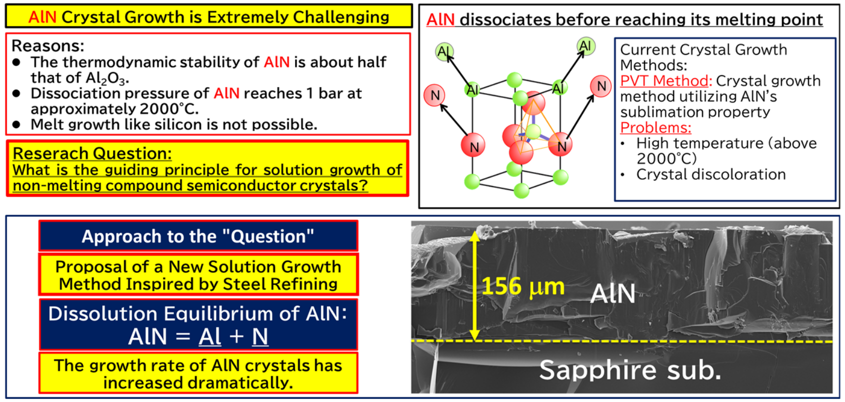

Figure 1. Technical barriers in AlN crystal growth and approaches to their solutions

●Application Fields of AlN Crystals

Aluminum Nitride (AlN) has a wider bandgap than SiC and GaN, offering better dielectric breakdown strength and thermal conductivity. It enhances deep UV LED efficiency and shows great potential for high-voltage power devices and high-frequency wireless components, making it ideal for next-generation electronics requiring superior performance.

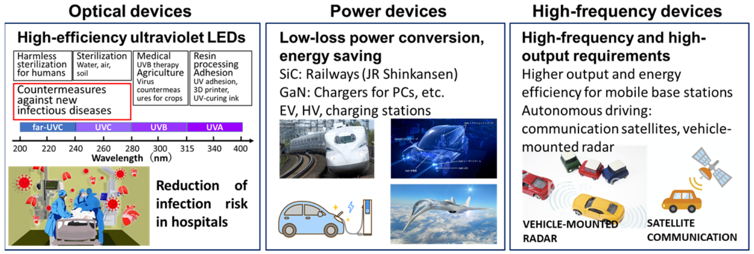

Figure 2. Application fields of AlN crystals with excellent potential

Expected Research Achievements

●Thermodynamic Analysis and In-situ Observation of AlN Crystal Growth

We will identify flux with high AlN solubility based on thermodynamic analysis and use it for AlN crystal growth experiments. Using electromagnetic levitation, we will observe AlN crystal formation on flux droplets reacting with nitrogen gas to determine optimal growth conditions.

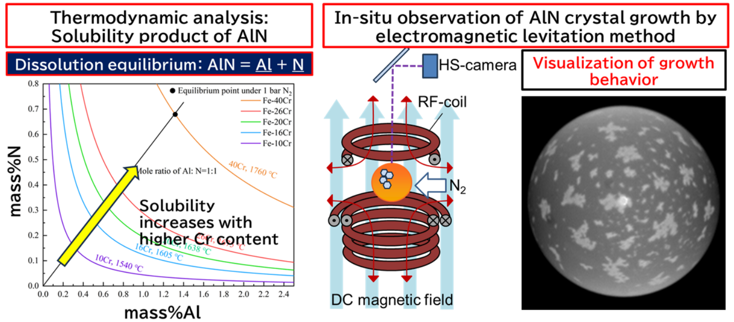

Figure 3. Thermodynamic analysis of crystal growth and in-situ observation

●Thermophysical Property Measurements for Crystal Growth Simulation

We will simulate reactor conditions to optimize crystal growth, measuring essential thermal properties using electromagnetic and aerodynamic levitation techniques developed over 20+ years. These measurements will provide necessary data for accurate growth process simulations.

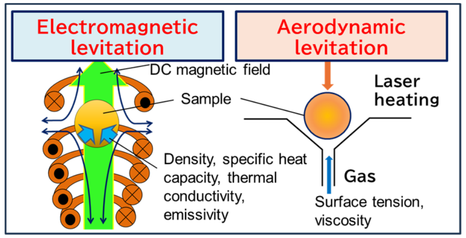

Figure 4. Thermophysical property measurements using levitation methods

●Crystal Evaluation

Crystal Strain and Impurities: We'll evaluate AlN crystal strain using synchrotron X-ray diffraction and analyze impurities/defects with soft X-ray absorption (NanoTerasu) and hard X-ray photoelectron spectroscopy (SPring-8).

Optical Properties: We'll measure band-edge emission intensity and decay lifetime using spectroscopy systems (Osaka University) to quantify crystal quality based on carrier lifetime and objectively rank crystal quality.

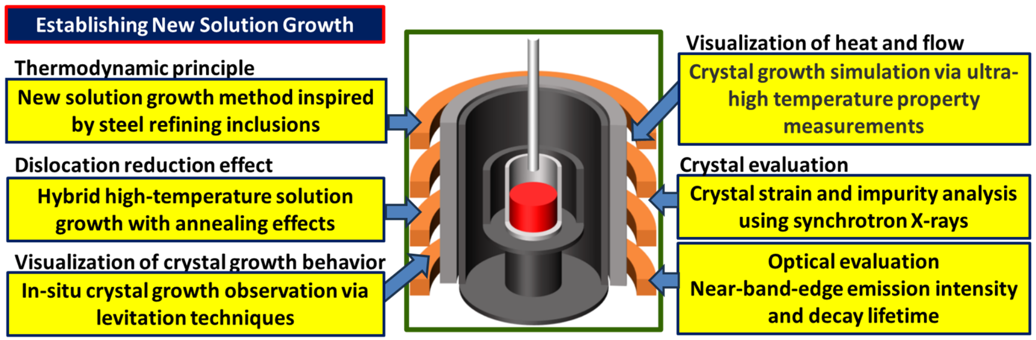

Figure 5. Research outline and components

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