Crystals growth of Boron Nitride and their quantum applications

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Generally, in single-crystal synthesis processes under ultra-high pressure, impurity control is not straightforward, and constraints such as sample space limitations make achieving high purity or large sample sizes challenging. Conversely, while synthesis processes for single crystals and similar materials under ambient pressure are constrained by limitations such as decomposition of samples or solvents at high temperatures, high-pressure synthesis processes can suppress this decomposition, not only enabling the synthesis of high-pressure stable phases but also addressing these constraints. This report describes the synthesis of high-purity single crystals of Boron nitride (BN), alongside recent developments in quantum functionality. BN is consisting of boron and nitrogen, positioned on either side of carbon in the top row of Group IV in the periodic table. It possesses crystalline structural polymorphs similar to carbon. Its primary crystalline structures are hexagonal boron nitride (*h*BN), which shares the same stable, two-dimensional layered structure as graphite at atmospheric pressure, and cubic BN (*c*BN), a high-density phase stable under high pressure, which has the same zinc blende structure as diamond.

*h*BN, while a two-dimensional layered compound like graphite, has long been utilized industrially as an electrical insulator, a chemically stable heat-resistant material and a thermal insulator. *c*BN has a hardness second only to diamond, and exhibiting greater chemical stability than diamond towards iron-based metallic materials at high temperatures. Some progresses in the synthesis of high purity BN crystals were achieved by using Ba-BN as a growth solvent material at high pressure (HP) of 5.5GPa. Band-edge natures (cBN Eg=6.2eV and hBN Eg=6.4eV) were characterized by their optical properties. The key issue to obtain high purity crystals is to reduce oxygen and carbon contamination in the HP growth circumstances. Then an attractive potential of hBN as a deep ultraviolet (DUV) light emitter and also superior properties as substrate of 2-dimensional(2D) atomic layer devices such as graphene were realized. In recent years, h-BN has been applied not only as a 2D substrate material, but also as a low-loss dielectric, an infrared confinement device (phonon polariton), and a host material for quantum sensing such as post NV-diamond.

This report focuses on the crystal growth of *h*BN. hBN is a currently the only wide-bandgap semiconductor (bandgap = 6.4 eV) among two-dimensional layered compounds. We first introduce the high-pressure synthesis of cBN, which provided the background for synthesizing high-purity *h*BN single crystals. Subsequently, we also present the properties of the high-purity *h*BN crystals currently obtained, their growth under ambient pressure, and future prospects. Also, recent attempt to control of boron and nitrogen isotope ratio (10B,11B and 15N) in hBN and cBN crystals carried out by metatheses reaction under HPHT will be introduced.