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Chapter

Significance of Boron Nitride in Composites and Its Applications

Sasikumar Rathinasabapathy, M.S. Santhosh and Manivannan Asokan

Abstract

Boron nitride (BN) exists in several polymorphic forms such as a-BN, h-BN, t-BN, r-BN, m-BN, o-BN, w-BN, and c-BN phases. Among them, c-BN and h-BN are the most common ceramic powders used in composites to ensure enhanced material properties. Cubic boron nitride (c-BN) has exceptional properties such as hardness, strength than relating with other ceramics so that are most commonly used as abrasives and in cutting tool applications. c-BN possesses the second highest thermal conductivity after diamond and relatively low dielectric constant. Hence pioneer preliminary research in AMCs proven substitute composites than virgin AA 6061 traditionally used for fins in heat sinks. Moreover, poly-crystalline c-BN (PCBN) tools are most suitable for various machining tasks due to their unmatchable mechanical properties. h-BN also finds its own unique applications where polymer composites for high temperature applications and sp^3 bonding in extreme temperature and compression conditions.

Keywords: cubic boron nitride, metal matrix composites, mechanical properties, thermal properties

1. Introduction

The boron nitride conglomerate was initiated by Balmain 1842 and achieved to form powders by GE scientist named Robert H. Wentorf in 1957 only. GE named the product commercially as Borazon. During the launch period, it was costlier than gold in the market [1]. As such carbon, boron nitride also can possibly be produced in amorphous and crystalline forms. In translucent form, boron nitride occurs or forms in three allotropes: hexagonal boron nitride (h-BN) similar to graphite (**Figure 1A**), sphalerite boron nitride (β-BN) similar to cubic diamond, and wurtzite boron nitride (ɣ-BN) similar to hexagonal diamond form [2].

Exceptional to the carbon fullerenes (C_{60} buckyballs), BN fullerenes have most common bonding nature of squares or octagons than pentagons to avoid adverse thermo-dynamical properties due to unfavorable B–B and N–N bonding (**Figure 1D**) [3]. Similar to one-dimensional carbon nano tubes (CNTs), BN nano tubes (BNNTs) (**Figure 1C**) are also isoelectric to CNTs with the correlation to tube diameters, chirality, and numerous numbers of walls [4]. Among different BN forms, h-BN is the steady and stable phase of BN and interest initiated succeeding the graphene sheets isolation in 2004 The structural texture of h-BN is layered structure and inside layer of each, the boron atoms and atoms of nitrogen are bound

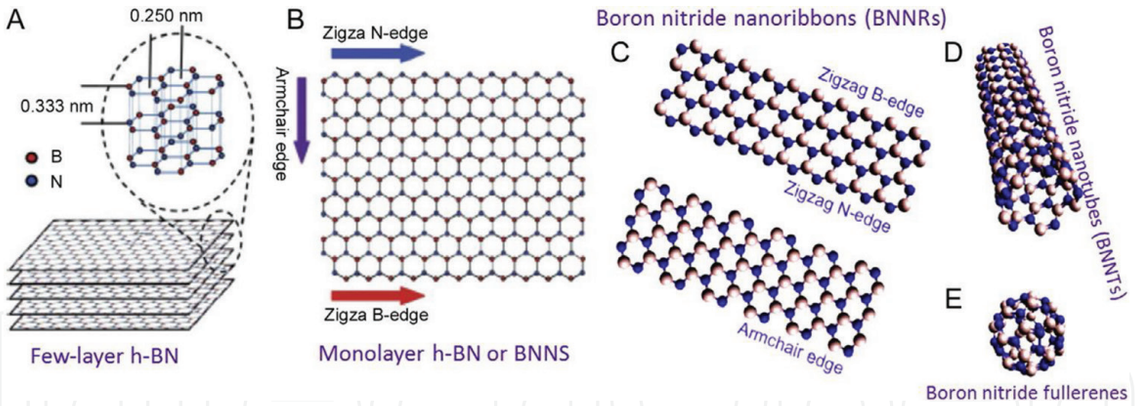


Figure 1.
Boron nitride allotropes: (A) few-layer hBN, (B) h-BN monolayer nanosheet or BNNS, (C) boron nitride nanoribbons (BNNRs) with various edge cessation leading to zigzag B-edge and structures of armchair edge, (D) boron nitride nanotubes (BNNT), and (E) BN fullerenes. Reproduced with the permission from "The Royal Society of Chemistry."

strongly due to covalent bonds nature in-plane and forces of van der Waals held together at each layer. A h-BN single layer is typically termed as BN nanosheet or BNNS. This formal structure is possible only for h-BN sheets since small aspect ratio [5]. For materials with higher aspect ratio their widths typical measurement will be <50 nm, they are known as BN nanoribbons or BNNR's. Even h-BN has similar graphene structure, yet material's bandgap is wide with 5.9 eV intrinsic band gap comparing more conductive graphene. Since its conductive thermally, h-BN is suitably fascinating for various electronic applications. h-BN possibly be used as filler material which insulates electricity for thermal radiators, polymer or ceramic composites, UV emitters and field emitters. Exceeding its properties of insulation, h-BN is inert chemically among wide variety of solvents, acids, and oxidizers. It is also insoluble in usual acids but soluble in nitrides (Li_3BN_2) and molten alkaline salts (LiOH, KOH). By high resistance nature chemically and thermal stability behavior, it finds as a fascinating material in hazardous environment [6].

2. Structural properties of h-BN

It is a powder (white in color and slippery nature) in physical form, in other way analogous to graphite. The size of the flake commercially available are h-BN varying from hundreds of nanometers to tens of microns. Thus, BNNS sheets developed through exfoliation process with these crystals are very frequently restricted to the maximum lateral sizes (few tens of microns) of the initial initiating material. Individual h-BN monolayers or BNNSs are structure with fluctuating atoms of boron and nitrogen combined to form a honeycomb. The bond length of B–N is 1.45 Å and B–N is covalent bond type. The neighboring borazine centers rings distance is 2.5 Å. The BNNS edge structure can be zigzag or armchair, alike graphene. The antecedent is a B or N-edged structure, in contrast hindmost is a BN pair-edged structure. The h-BN crystal structure is hexagonal with $P6_3/mmc$ space group (**Figure 1A**), lattice constants, a = b = 0.2504 nm, c = 6661 nm, bond angles, $\alpha = \beta = 90°$, $\gamma = 120°$. The BN is partially ionic structure in h-BN which reduces conductance capacity of electricity, covalence and dissimilar to graphite, it benefits the AÀ stacking sequence [7]. In most cases, this is the best energetically beneficiable stacking sequence noticed in BN, amongst them B atoms (electron-deficient) are directly above or below the N atoms (electron-rich) in the adjoining layer. The easiest possibility to calculate the number of h-BN layers by observing

from transmission electron microscopy (TEM) images of folded edges. **Figure 2A** and **B** depicts TEM images of high-resolution, which usually gives atomic lattice information more along with the layers in number. An additional simple proficiency to analyze/calculate h-BN thickness by atomic force microscopy (AFM).

The number of layers is possibly determined by observing the step height usually with respect to the surface (**Figure 2D** and **E**). Mostly sheets of monolayer h-BN formed by means of chemical vapor deposition process (CVD) and mechanical exfoliation process have a approximate height of 0.4 nm. In chemical exfoliation sheets, the height measured can vary as maximum to1 nm due to the solvent trapped in the middle of the substrate and h-BN flakes. Thus, HRTEM generally used to report number of layers, while recording the height by means of AFM and more characterization techniques needed to ensure the findings. Another convenient characterization technique and simple method, by means of an optical microscope aimed to locate the amount of layers in graphene sheets and it is also used for h-BN moreover. Normally, ~300 nm of a SiO_2 layer coated standard silicon wafer (**Figure 2C**) is benefited as a substrate for reference and the layers in number is determined depends on the noticed optical contrast using the respective microscope. In h-BN case, as absorption not takes place in visible region, the oxide layer's

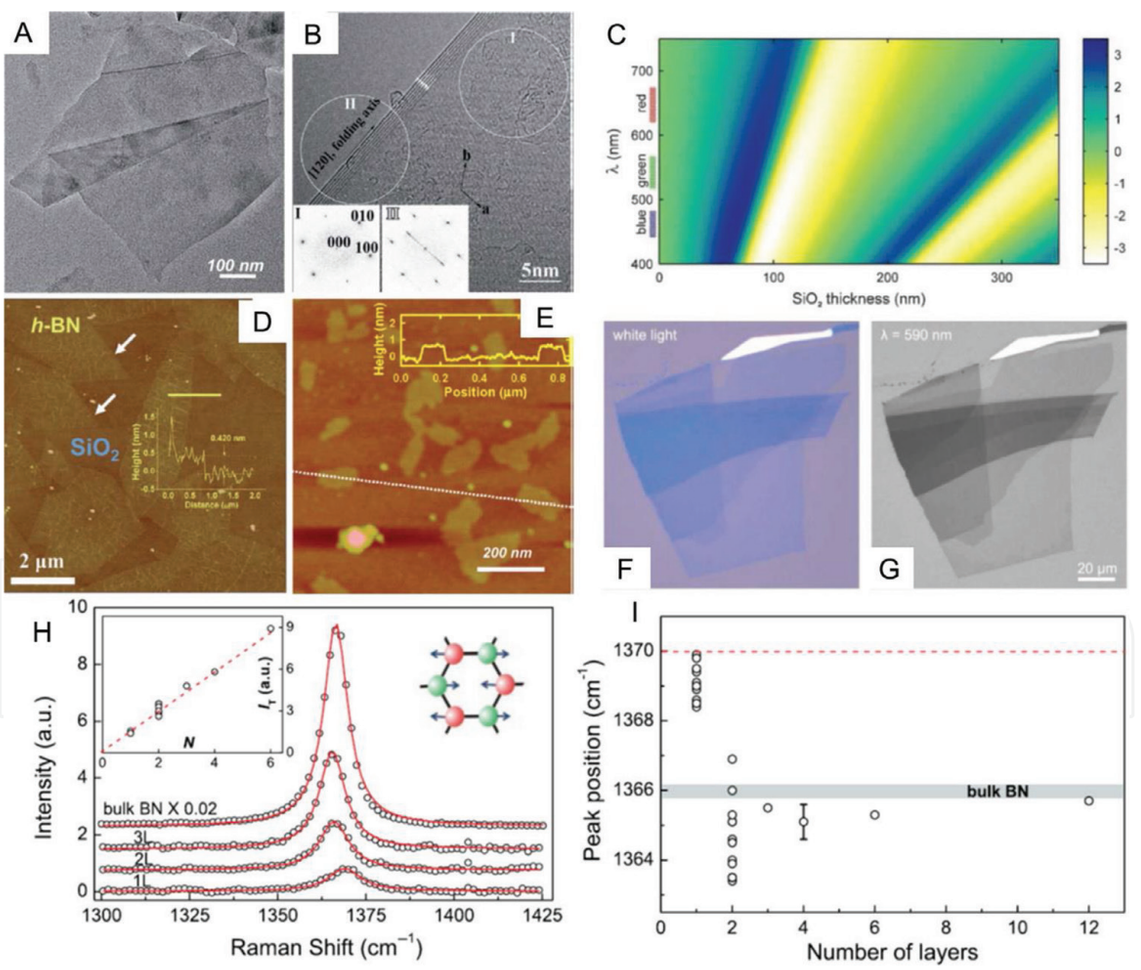


Figure 2.
(A) Low-exaggeration TEM image of an exfoliated BNNS. (B) HR-TEM image displaying the layers number at the overlap edges (Lin et al., 2010a). (C and D) Height map from AFM of CVD fatten BNNS displaying the single layer 0.4 nm thickness (E) chemically exfoliated BNNS displaying a 1 nm height (F) white light microscopy image of exfoliated h-BN flake displaying the optical contrast on 90 nm SiO_2/Si. (G) Enhanced h-BN optical image flake using a light source of 590 nm displaying the various contrast in-between layers. (H) BNNS in Raman spectra to a few-layer h-BN in relating the variance in the peak width to number of layers. (I) Top position difference as observed for single layer to BNNS bulk. Reproduced with the permission from corresponding author—Gorbachev (2011).

substrate need to be altered for 80 nm in spick and span to optically recognizing the single to few-layered materials. As flaunt in **Figure 2F**, a low value of 2.5% reaches the contrast white light in h-BN monolayer, that is, tetra times lesser than graphene, and the increases in contrast with the various number of layers increase in the same [8]. In other way, for identifying the amount of layers different wavelength light is being used, which can be seen in **Figure 2C**. By using ~590 nm wavelength light as flaunt in **Figure 2G**, the noticed contrast between numbers of layers was clearly obvious. This layer recognition study be further proceeded to Raman microscopy. Vibrational mode of boron nitride noticed at 1364–1371 cm^{-1}, which depends purely on the number of layers. **Figure 2H** and **I** flaunt the relative study by Gorbachev et al. relation to BNNS different layers. It is possible to be viewed in **Figure 2H** for monolayer, drifts to higher wave number of 1370 cm^{-1} noticed due to the Raman peak broadens and when it compared with the bulk, which is 1366 eV. This study evidently flaunts BNNS formation through the red shift, which could be used later as standard to ensure BNNS presence [9].

3. Thermal stability

Allotropes of BN, in-particular h-BN and c-BN exhibit high stability in terms of thermal and chemical nature. h-BN is more stable even without deteriorating at exceeding the temperatures 1000°C (air), 1400°C (vacuum), and up to 2850°C (inert atmosphere). The h-BN theoretically noticed thermal conductivity values are close to grapheme. It is the one among best materials which are thermally conductive that is available till date. Based on the structure of BNNR, at room temperature the arm chair edged ribbons are 20% smaller than the zigzag-edged BNNRs. In-plane thermal conductivity determined as high peak value of 390 W/m K even at room temperature, which is 280 times greater than that of the silicon dioxide, for electronic devices which generates heat deciding h-BN as an attractive material due to its dielectric nature. Alike graphite, because of its anisotropic strength bonding, h-BN also strongly exhibits coefficient of thermal expansion (CTE) anisotropically. The coefficient of thermal expansion (CTE) in the a-direction (in-plane) is ~2.90×10^{-6} K^{-1} during room temperature, in the c-direction, when the CTE is 10 times larger and over to value of 4.05×10^{-5} K^{-1} at room temperature. The greater thermal expansion in positive note along the c-direction is mainly because weak nature in van der Waals bonding in the middle of planes [10].

The popularly accepted boron nitride phase diagram explains various boron nitride phases was determined from thermodynamic properties. At ambient conditions, it is known that c-BN is thermodynamically stable rather than h-BN. But this is contrary to carbon phase diagram at ambient conditions; example is hexagonal phase (graphite) which is a more stable phase. The boron nitride phase diagram is shown in **Figure 3A** and **B**, where original calculations were indicated by the dashed lines and the refined diagram indicated by solid lines. The h-BN/c-BN/liquid triple point exists at 3480 ± 10 K and 5.9 ± 0.1 GPa, while the h-BN/liquid/vapor triple point exists at 3400 ± 20 K and 400 ± 20 Pa.

Based on the phase diagram above temperatures below 1600 K, it is obvious that c-BN is more favorable than h-BN. The general temperatures for growth in CVD are between 700 and 1100°C, which is 300°C at least cooler than that noticed in the above phase diagram. This odd behavior can be due to Gibbs free energy prevailing with the system. The temperature of transition travels in the middle range of h-BN and c-BN shifts as a Gibbs free energy function (Shift ± 10 meV/atom). The transition temperature varies between 1200 and 1800 K due to the change in free energy; mainly for the h-BN growth the typically lowest value used. There may be small

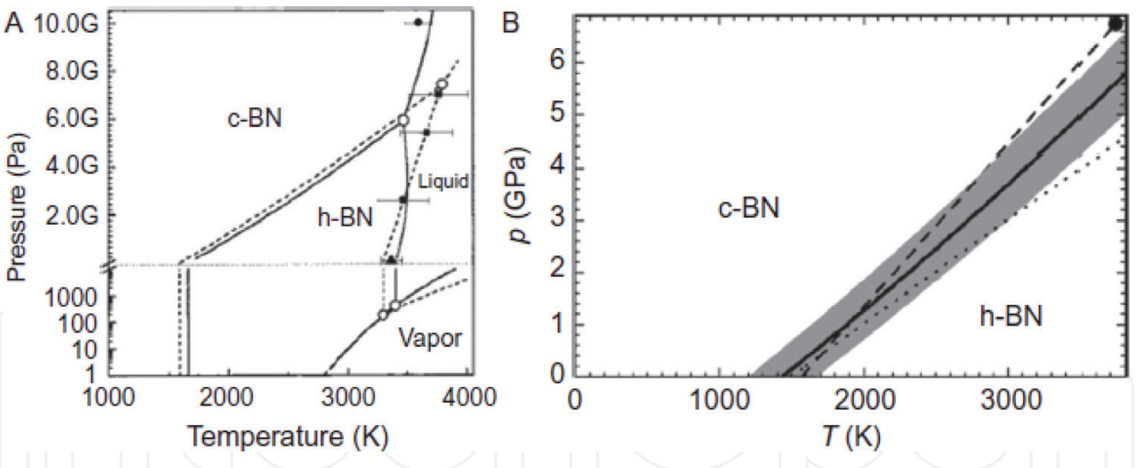


Figure 3.
(A) h-BN phase diagram displaying the stability nature of h-BN vs. c-BN at different temperatures and pressures. (B) Zoom image of the transition phase and Solozenko calculations (dotted line) (Solozhenko et al., 1999).

discrepancies casually caused by defects, grain size, contaminants, or sometimes interactions with the substrate transition metal itself [11].

4. Applications for h-BN

2D h-BN are considered greatly for use in various applications including substrate dielectrics for high-temperature resistive layers anticorrosive coatings, nanoelectronic devices, frictional layered coatings and also other 2D material systems and gate which are termed as advanced applications. The large bandgap (~6 eV), chemical resistivity and high temperature both the direct-grown h-BN and exfoliated h-BN materials are ideal for various hazardous applications like chemical and thermal industry.

4.1 Dielectrics for future generation nanoelectronic devices

Graphene is a well known for its highest electron and also whole mobility nature of any material till date, for future generation high-speed electronic gadgets and devices this 2D material a natural candidate. Initially graphene devices were transferred onto traditional substrates of SiO_2 and noticed a reduction in inherent transport properties because of its contrary reciprocal action with substrate (>120,000 cm^2/Vs compared to device performance on SiO_2 of ~2000 cm^2/Vs). The transporter potency in the devices was diminished because of the scattering from charged surface states and also due to impurities in SiO_2, the comparatively more roughness in surface of the substrate, and also the very low-frequency optical modes of phonon in surface of SiO_2. Dean et al. [12] was the team initiated study bulk h-BN's use as a substrate material to restrain these outcomes seen in SiO_2 devices. The h-BN's substrate strong in-plane bonding was suspected to permit for an atomically smooth, inert surface free from dangling bonds, or charge traps in the surface. This was trusted to be true, as the graphene's electronic properties increased including improved potency of transportation, decreased in transportation due to in-homogeneity, and decreased inherent intoxicating from the substrate were appreciably enhanced. The h-BN integrated first exfoliated GFET in the gate dielectric and also in the substrate, desired result obtained when manufacturing h-BN/graphene/h-BN sandwiched device. When related with a conventional GFET device produced along with SiO_2 and Al_2O_3, as dielectrics, a 70% enhance in the peak transconductance (gm) was

noticed with a higher operational frequency as well as appreciable than 5X enhance in graphene's potency of transportation from 1200 to 6500 cm^2/Vs. h-BN is a vital part in graphene and other 2D material-based electronic devices as a gate dielectric. In dielectric at a constant value of 6, voltage breakdown value of 8–10 MV/cm, and nearing bandgap value of 6 eV which are advantageous over typical SiO_2 dielectrics can be accomplished [13].

4.2 Vertical tunneling device and behavior

In inclusion to BN as a substrate material for graphene used electronics, few layer BN has been examined as a high-quality, low-dielectric constant railing material for 2D rampant electron tunneling devices where different compositions electrodes are divided by the dielectric layer thickness. These devices depend on the excavating via the ultrathin crystalline films layers and allow the smallest allowable gate lengths down to a single atom, and also permitting for exceptionally fast transport.

Excavating measurements via few-layer, device using exfoliated h-BN which constructs have been effectuated on a substrate which is conductive using conductive type atomic force microscopy (C-AFM). With beneficial tip areas normally on the 103 nm^2 order, fundamental characteristic merits of dielectric able to be examined and that are non dependent on general failure mechanisms of whether macro- or either microscopic dielectric including dust particles, grain edges and cross-plane defects.

4.3 h-BN in protective coatings

While h-BN research much concentrated on nanoelectronic applications, technologies of others use the ultrathin and impactful studies on layered materials also done. Thin h-BN used for corrosion resistance and antioxidation protective coatings, in particular, it is a applied science that got validated by chemical inertness and h-BN's stability even at high temperature to efficiently emblem the underlying material from revelation to a numerous elements. Due to inert nature and lack of swinging loosely bonds, h-BN possibly be an excellent antifriction coating, alike many other two dimensional materials which share same characteristics.

4.4 h-BN in gas sensing

h-BN also been used as a essential substance to sense gases such as ammonia and ethanol. h-BN atomic layers were used for manufacturing gas sensors and concentration of about very low (100 ppm) amount of gas was allowed to pass across the device. The technology in this mechanism is as follows: When sensor is air exposed, the absorbed oxygen molecule gets ionized through available free electrons of h-BN conduction band, the output is an enhance of the resistance. Identically, when ethanol gets introduced, it effects a resultant action on the surface, i.e., decreasing the resistance because of electrons releases back to the sensor. Thus, this mechanism proves the efficiency even at varied temperatures and concentrations of ethanol.

5. Synthesis of c-BN

In 2015, Caldwell et al. explored the utmost case of a-BN as initiating material. They concluded a-BN possibly be permuted into c-BN at above 7.0 GPa pressures and temperature of above 1070 K. On condition that portal pressure is bigger than the required in starting material which is of poorly crystalline

h-BN, in contrast the portal temperature is controlled beneath by about 400 K. A transformation accentuates the chances of two mechanisms relative to kinetic study. First is direct crystallization transformation process from a-BN to c-BN and the next is two step-process which forms h-BN in an in-between stage: a-BN--" h-BN ~ c-BN. When t-BN is dealt as the initiating material, in which (B, N) layers along the c axis are randomly distributed, c-BN's very small crystallites only present in operating conditions of temperature and pressure close to 6 GPa and 1250 K. In collateral to the investigation of eminent researchers it was concluded that, operating conditions of temperature and pressure given phase change figure for BN, it is feasible to balance c-BN at higher temperatures under the c-BN-h-BN equilibrium line provided by Wentorf. The transformation of h-BN--" c-BN stands on certain important factors such as structural excellence of starting material purity of used products etc. In many of the instances its importance's are not still defined significantly.

The professed catalysed process is the common method used for deriving c-BN at industrial scenario. Certain amalgams added to h-BN in the process of decreasing the higher activation energy barricade are mostly termed as catalysts or solvents. These terms are not exact to the required; because this initiating product does not act as a motivational element but preferably act as a flux antecedent, giving eutectic h-BN. In this eutectic, BN is partially dissolved. In this process, h-BN's starting material is either closely mixed or only stay in touch with flux antecedent. The impetus for formation of c-BN is the solubility difference between h-BN and c-BN varieties in the eutectic flux, beneath the fixed conditions of high pressure and temperature. In the (P, T) territory of c-BN balance, c-BN is impulsively nucleated and can grow faster. In spick and span to form p- or n-type semiconductors, doping of c-BN crystals possibly be done by impurities introduced into the lattice of zinc blende using high purity starting materials. After caring and curing process at high pressure and temperature, the c-BN particles recuperated are separated by particular chemical or physical methods (e.g., acids and/or molten alkalis—usually molten NaOH-Na_2CO_3 mixtures—are used) in spick and span to remove the flux antecedents and by-products as well as non-reacted h-BN residues [14].

6. Cubic boron nitride: synthesis methods

6.1 At static high pressure condition: crystal growth

The temperature variance method process includes the BN transport from hot area containing h-BN to a cold zone (where one or more c-BN seeds are placed) by using a solvent. The time needed for growth of crystal is higher than time handled for the synthesis as described early and it possibly reach several days. The flux antecedents used are generally those of group A materials. Yazu et al. patented a pressure cell in which the pattern of work consists of varied chambers splitted up by non-reactive layers. In conjunction to get good quality crystals, researchers selected flux antecedents as Li_3BN_2, $Mg_3B_2N_4$, $Ca_3B_2N_4$, $Sr_3B_2N_4$, $Ba_3B_2N_4$ or combinational constituents of these compounds. For example, good quality crystals can form after 60 hours, a 0.25 carat (50 mg) crystal at 5.5 GPa in-between a range of 1890–1540 K temperature gradient. The temperature variance can be changed by means of two main methods in the middle of nutrient and seed (i) by varying the position of a growth cell in a vertical furnace, minding the presence of a temperature gradient in-between the center and the top of the heater tube or (ii) by thrusting a thin molybdenum sheet with a drill hole, also as a baffle, in-between the flux and the h-BN source and changing the diameter of this hole. These two techniques allow

control of the super saturation which is responsible for the difference noticed in the crystal growth shape. The crystal shapes can change from polyhedral to dendritic geometries as the super saturation increases [15].

6.2 Dynamic high pressure process

This technique is mainly used for compacting c-BN powders. The emerging movement of a boron nitride impenetrable form produced under shock compression was studied by Sawaoka and Akashi. By single shock compression, they noticed only the transformation to w-BN with a greater decrement in the size of particle (by a factor of 10) in relation with the initiating material. A compression of type double-shock leading to form an amorphous material and a very little quantity (amount) of c-BN (certain per cent). These particles of c-BN are 2D seeds. The synthesis of c-BN requires shocks in multiple during compression. If w-BN is capitulated to a shock compression at above 10 GPa pressure, c-BN can be derived. Sawaoka and Akashi proposed the following sequence to achieve c-BN transformation. By single-shock treatment, a greater amount of lattice strains in numerical exists in the w-BN crystals and these flaws are enhanced with subsequent second shock during compression process. This is mainly because of the energy variance in-between wurtzite-type and zinc blende-type stacking sequence is very little quantity, yet the strains in lattice are enough to accomplish the w-BN-* c-BN conversion. Sato et al. process patented for producing c-BN from r-BN by shock wave compression. Dremin et al. studied the crack in the frail dominion region and the velocity of particle for trinitrotoluene-RDX blends with supplements of h-BN. They reviewed the works in which signs of the "weak detonation regime" have been found [16].

7. Cubic boron nitride: industrial and potential applications

7.1 Mechanical applications

c-BN, in relation to hardness correlating to diamond, is much more harder than the traditional abrasive materials like Al_2O_3, SiC and boron carbide. Hence, the output performance of grinding with c-BN wheels are enhance increased over the traditional abrasive material (SiC or Al_2O_3) wheels during grinding hardened high speed steels and cast irons of chilled mill grade. Tools made out of diamond cannot generally be used in above cases due to its chemical reactivity nature with ferrous metals, whereas c-BN is against to chemical attack in ferrous metals existence up to 1500–1600 K.

For cutting tools, c-BN is used as sintered c-BN. The c-BN sintering should be done in the region of thermodynamic stability with the pursuit to prevent retransformation into h-BN at higher temperatures while at the process of sintering. Alike diamond, c-BN is hard-to-sinter material typically, due to its bonding nature of strong covalence and its stableness at higher operating conditions of temperature and pressure. There are possibly two processes: the instantaneous sintering of c-BN while the conversion of h-BN or two-step sintering. During the previous case, the preliminary step is the transformation from h-BN to c-BN (utilizing a traditional higher temperature and pressure flux transformation method) exemplified by the isolation and purification of c-BN in powder form and the next step involves sintering during rest or movable during high pressure conditions.

Hirano et al. concluded work on the one-step process as follows; the concurrent sintering and transformation of c-BN from h-BN by means of adding A1N. The operating conditions of pressure and temperature are same as that of c-BN formation. It is observed that Fukunaga used additives to enhance transformation and sintering

which is 2 mol.% lesser than that of magnesium nitride (Mg_3N_2). He observed the complete change or an conversion during 5.0 GPa and 1770 K for 1 hour. Fukunaga and co-workers used Mg_3BN_3 as sintering agent and formed semi-transparent c-BN polycrystals, at the working conditions of 6 GPa pressure and 1770 K as temperature. The formed c-BN polycrystals are with 99% of the calculated density.

Akashi and Sawaoka studied shock compaction about the sintering of c-BN powder. The powders without any form of additives are directly handled using shock compression. The starting powders must be coarse. The density and micro hardness of the produced c-BN compacts are dependent in nature strongly based on the size of the starting powder. They obtained compacts with 98% of theoretical density and micro hardness of 51.3 GPa. Shintani et al. compared the microstructural metallographic study and the properties of mechanical associated with two sintered c-BN materials. Singh reviewed sintered materials of super hard nature such as diamond, w-BN and c-BN. By examining them through X-ray diffraction, scanning electron microscopy (SEM) and energy-dispersive X-ray analysis.

In most cases, the compacted c-BN powder is cemented on tungsten carbide or ceramic substrates. Sintered cutting tools allow ferrous metals, chilled cast irons and hardened steels to be machined. The cutting speed is augmented and life of the tool is increased influentially by the value of 7–50 (in comparison with tungsten carbide tools). The high quality of the surface finish dispenses with further grinding and polishing actions in many cases [17].

7.2 Applications in electronics

c-BN is an III-V semiconductor compound. Its very wide band gap makes it a very good insulator. Furthermore, c-BN has highest thermal conductivity, which allows it to be used as a heat sink for semiconductor lasers, microwave devices etc. In these applications, the surface of c-BN ceramics is coated with a group VIII metal or aluminium (or aluminium alloy) by CVD process. It is possible to metalize as innovated by Tanji and Kawasaki with nickel by CVD process or with gold or aluminium by sputtering.

c-BN is able to be mixed with silicon and also with beryllium in pursuance to get p-type or n-type semiconductors respectively. Mishima et al. patented a growing method semi conductable c-BN crystals. For example, when $LiCaBN_2$-Si mixture used as a flux antecedent to the h-BN-" and c-BN transformation at 5.5 GPa and at a temperature of 2070 K for 18 hours time period, researchers acquired n-type c-BN crystals size by 1.2 mm. These doped crystals of c-BN able to produce p-n junction diodes that even works at high temperatures due to c-BN's higher thermal stability. Injection scintillation in the ultra violet was noticed at a high pressure from a c-BN made p-n junction. This emission of light occurs near the certain region especially at junction only based on several conditions. Certain methods of producing p-n junctions from c-BN semiconductors formed through a high pressure, high temperature processes have been patented. Recently, Ahmad and Lichtman have studied c-BN thin films for UV sensor applications [18].

The c-BN electronic applications have only begun to be developed; their use should be increased significantly in the future. Because of the small size of the components required in electronics, compounds or thin films with a higher value of thermal conductivity and electrically insulating properties are needed [12].

8. Conclusion

The boron nitride amalgamation combination was noticed by Balmain in the year 1842 and synthesized to powders by Robert H. Wentorf a GE scientist at 1857. Boron

nitride occurs in various polymorphic forms like a-BN, h-BN, t-BN, r-BN, m-BN, o-BN, w-BN and c-BN phases. h-BN exists in three types of allotropes. BNNTs are isoelectric in nature to CNTs. h-BN is attractive for various electronic applications due to its thermal conductive behavior. It also can be used as filler materials in thermal radiators, UV emitters and field emitters. h-BN and c-BN shows high stableness both thermally and chemically. Direct grown h-BN and exfoliated h-BN materials are ideal for hazardous applications such as thermal and chemical industry. Exfoliated h-BN is favorably feasible with conductive type atomic force microscopy (C-AFM). h-BN can also be used as an excellent antifriction coating, corrosion resistance and also as antioxidation protective coatings. h-BN also used in gas sensing at any varied temperatures and concentration. There are two significant methods for cubic boron nitride synthesis; at static high pressure crystal growth observed and dynamic high pressure process. Sintered c-BN is necessary for mechanical applications to prevent conversion to h-BN at higher temperatures. c-BN powder is cemented on tungsten carbide tools and which allows ferrous metals, chilled cast irons and hardened steels to be machined. The doped crystals of c-BN are able to produce p-n junction diodes which can even works at higher temperatures due to its higher thermal stability. c-BN electronic applications have recently started to get developed; their significant usage will be developed in mere future. The future researchers can pay attention on the above area as well as on metal matrix composites in particular aluminium to produce better efficient and durable materials for modern era and requirements.

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References

[1] Alem N, Erni R, Kisiel Owski C, Rossell M, Gannett W, Zettl A. Atomically thin hexagonal boron nitride probed by ultrahigh-resolution transmission electron microscopy. Physical Review B. 2009;**80**:155425

[2] N. No. Manufacture of Boron Compounds, United States Patent Office; 1958. pp. 2-4

[3] Anota EC, Tlapale Y, Villanueva MS, Ma'rquez JAR. Non-covalent functionalization of hexagonal boron nitride nano sheets with guanine. Journal of Molecular Modeling. 2015;**21**:215

[4] Balmain WH. Bemer kungen uber die Bildung von. Verbindungen des Bors und Siliciums mit Stickstoff und gewissen Metallen. Journal für Praktische Chemie. 1842;**62**(1):422-430

[5] Barth JV, Costantini G, Kern K. Engineering atomic and molecular nanostructures at surfaces. Nature. 2005;**437**:671-679

[6] Bhaviripudi S, Jia X, Dresselhaus MS, Kong J. Role of kinetic factors in chemical vapor deposition synthesis of uniform large area graphene using copper catalyst. Nano Letters. 2010;**10**:4128-4133

[7] Constantinescu G, Kuc A, Heine T. Stacking in bulk and bilayer hexagonal boron nitride. Physical Review Letters. 2013;**111**:036104

[8] Bresnehan M, Hollander MJ, Wetherington MT, Wang K, Miyagi T, Pastor G, et al. Prospects of direct growth boron nitride films as substrates for graphene electronics. Journal of Materials Research. 2013;**29**:1-13

[9] Bresnehan MS, Bhimanapati GR, Wang K, Snyder DW, Robinson JA. Impact of copper overpressure on the synthesis of hexagonal boron nitride atomic layers. ACS Applied Materials & Interfaces. 2014;**6**:16755-16762

[10] Caldwell JD, Kretinin A, Chen Y, Giannini V, Fogler MM, Francescato Y, et al. Sub-diffraction, volume-confined polaritons in the natural hyperbolic material, hexagonal boron nitride. Nature Communications. 2014;**5**:1-9

[11] Caldwell JD, Vurgaftman I, Tischler JG. Probing hyperbolic polaritons. Nature Photonics. 2015;**9**:638-640

[12] Dean CR, Young AF, Meric I, Lee C, Wang L, Sorgenfrei S, et al. Boron nitride substrates for high quality graphene electronics. Nature Nanotechnology. 2010;**5**:722-726

[13] Coleman JN, Lotya M, O'Neill A, Bergin SD, King PJ, Khan U, et al. Two dimensional nano sheets produced by liquid exfoliation of layered materials. Science. 2011;**331**:568-571

[14] Corso M, Auw€arter W, Muntwiler M, Tamai A, Greber T, Osterwalder J. Boron nitride nanomesh. Science. 2004;**303**:217-220

[15] Cortes CL, Newman W, Molesky S, Jacob Z. Corrigendum: Quantum nano photonics using hyperbolic meta materials (2012 J. Opt. 14063001). Journal of Optics. 2014;**16**:129501

[16] Golberg D, Bando Y, Huang Y, Terao T, Mitome M, Tang C, et al. Boron nitride nanotubes and nanosheets. ACS Nano. 2010;**4**:2979-2993

[17] Cui Z, Oyer AJ, Glover AJ, Schniepp HC, Adamson DH. Large scale thermal exfoliation and functionalization of boron nitride. Small. 2014;**10**:2352-2355

[18] Dai S, Ma Q, Andersen T, Mcleod AS, Fei Z, Liu MK, et al. Sub diffractional focusing and guiding of polaritonic rays in a natural hyperbolic material. Nature Communications. 2015a;**6**:6963