

*Boron nitride thin films can be deposited on different substrates using techniques such as plasma deposition, ion beam deposition and reactive sputter deposition.*

This is an open access article distributed under the Creative Commons Attribution License , which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The effects of temperature, time, and the possible mechanism of the growth of the BN nanotubes were also discussed. They also exhibit some attracting properties, including a stable insulator, a superresistance to oxidation at high temperatures, an excellent thermal conductivity, uniform electronic properties, interesting piezoelectricity, and optical properties [ 1 ]. Moreover, in addition to these characteristics, BN nanotubes also can be used as a perfect insulating tubular shield to encapsulate some materials within and demonstrated distinctive features [ 2 – 4 ]. Obviously, the unique properties of BN nanotubes will be the prerequisite of the important applications in the fields of optoelectronics, nanosemiconductor devices, electronics, energy storage, and biomedical medicine [ 5 ]. In recent years, various synthetic methods have been used to grow BN nanotubes. The high-temperature methods usually need special sophisticated instruments or complex processes to meet the high-temperature requirements and only obtain single morphology BN nanotubes, which was unaffordable. In contrast to the high-temperature methods, the low-temperature methods can operate at a mild condition and normal pressure. Importantly, different types of BN nanotubes could also be prepared by changing annealing conditions, which may be suitable for popularization and application. And the catalytic chemical vapor deposition CVD method is one of the most popular techniques for the low-temperature synthesis of BN nanotubes. Various kinds of boron-containing precursors can be used to prepare BN nanotubes. In addition, for the CVD method, precursors with uniform dispersion of metal catalyst and boron source are especially significant. Many efforts have been made to deal with the problem, such as ball-milling process [ 22 – 27 ], which is very consumptive of energy and time. Herein, we introduce a convenient way so-called SHS-annealing method to synthesize BN nanotubes using an effective porous precursor. The porous precursor can be readily produced by self-propagation high-temperature synthesis SHS , which plays an important role in synthesis of large quantities of BN nanotubes. The effects of temperature, time, and possible mechanism of the growth of the BN nanotubes were also discussed. Calcium hexaboride  $\text{CaB}_6$  was made by ourselves having the particle size of 0.  $\mu\text{m}$ . YAG laser at excitation of  $1064\text{ nm}$ . Fourier transform infrared FTIR spectra were recorded on a Nicolet Fourier transform infrared spectrometer in transmission mode using a KBr wafer. The scanning electron microscopy SEM was studied using a Hitachi SN scanning electron microscope and energy-dispersive X-ray EDX spectroscopy attached to it was employed to determine chemical contents. Samples were observed by directly spreading the samples on conductive tapes and sputtering Au or Pt on the surface. For HRTEM and TEM observations, samples were prepared by ultrasonically dispersing the product in ethanol and depositing on copper grids coated with carbon film. After the SHS reaction, After cooled to room temperature naturally, the furnace was opened, and the crude product shown in Figure 1 was collected and washed with 5 M hydrochloric acid, ethanol, and distilled water. The yields of BN nanotubes based on boron were about 10%. Photo of the crude product in an alumina boat. Results and Discussion 3. Results The typical SEM image of as-synthesized BN nanotubes is shown in Figure 2 a , which indicates the products possess a high density of one-dimensional structures with diameters in the range of 30–100 nm and an average of about 60 nm. Few BN flakes and particles were observed. The thin BN nanotube reveals a diameter of 60 nm with the wall thickness of 20 nm Figure 2 b. However, the thick BN nanotube presents a diameter of 100 nm with the wall thickness of 60 nm, as seen in Figure 2 c. The boron nitride nanotube has multiple walls with thickness of about 60 nm and clearly exhibit fringes with an average interlayer distance about 0.34 nm. The EDX spectrum presented in Figure 2 e demonstrates corresponding signals of boron and nitrogen, and quantitative analysis indicates that the molar ratio of B: N is about 1:1. The O peak can be ascribed to the slight surface oxidation of BN

nanotubes. It is worth noting that the Ca signal also was revealed in the EDX spectrum, while no signal of Mg was observed. Probably, the Ca particles were encapsulated at the root of BN nanotubes as the metallic catalyst during the BN nanotubes growth process. A small amount of metal Ca particles still remained after the annealed precursor was washed with 5 M hydrochloric acid. On the contrary, the MgO particles only acted as a supporter during the BN nanotubes growth process and were removed after the purification processes mentioned above. Four peaks at  $\lambda$ -spacings of 3. No noticeable peaks of other impurities, such as MgO and B<sub>2</sub>O<sub>3</sub>, were detected in this pattern. Figure 4 a shows the typical wide-scan FTIR spectrum in the range of  $\nu$  to  $\nu$ -cm<sup>-1</sup> of the as-synthesized BN nanotubes sample. Two strong peaks located at  $\nu$  and  $\nu$ -cm<sup>-1</sup> can be ascribed to the out-of-plane B-N TO models of the sp<sup>2</sup>-bonded h-BN and the B-N-B in-plane bonding vibrations, respectively. The broad absorption band near  $\nu$ -cm<sup>-1</sup> can be resulted from the O-H bonds due to the absorbed of water. As shown in Figure 4 b , a peak at  $\nu$ -cm<sup>-1</sup> in the deconvolution spectrum should be assigned to the unique stretching of the h-BN network around the circumference of BN nanotubes [ 28 ], while the other peak at  $\nu$ -cm<sup>-1</sup> in the deconvolution spectrum may be attributed to the abnormal vibrations like those of wurtzite BN, which may exist due to structure defects in the as-synthesized cylindrical BN nanotubes. Figure 5 is the typical Raman spectrum of the as-synthesized BN nanotubes. A sharp Raman peak was showed at around  $\nu$ -cm<sup>-1</sup>, which corresponded to the in-plane model of the h-BN networks [ 29 ], while the other weak peak at about  $\nu$ -cm<sup>-1</sup> may be due to the glass holder used during the analysis. Typical Raman spectrum of the as-synthesized BN nanotubes. Reaction Mechanism In this experiment, the possible reactions are likely to occur as follows: According to the VLS growth mechanism [ 30 ], boron nitride nanotubes began to grow on the surface of metal catalyst liquid supported on MgO, as in 3. Growth Mechanism of Boron Nitride Nanotubes According to the catalytic VLS growth mechanism [ 30 ], the diameters of nanotubes depend on the particle sizes of catalyst liquid drops. Small droplets could lead to BN nanotubes with small diameters, while large droplets could render large diameters. Therefore, the distribution of catalyst drop sizes leads to a certain diameter range of BN nanotubes. Moreover, to grow a cylindrical BN nanotube by the base growth mechanism, there is at least one initial open tip. The growth rate can be either approximately a constant or smoothly changing due to the change of microcircumstance such as the vapor constitution, temperature, and catalyst. The proposed growth model agrees well with the observed morphology of the as-synthesized BN nanotubes. It can be observed that there were many BN nanotube embryos of small pointed by an arrow and large in a frame sizes. Interestingly, all of these embryos revealed open tips. Therefore, we suggest a base growth scenario as schematically illustrated in Figures 6 b - 6 e. Typical SEM image of the porous SHS precursor at the initial annealing stage a and schematic illustration of base growth model of BN nanotubes with small b and large c diameters. Secondly, when the concentrations of B and N species are supersaturated, BN nuclei begin to precipitate on the surface of Ca-B liquid drop and form a top-opened BN cap Figures 6 b and 6 c. Thirdly, with the continuous supply of B and N atoms, the cap grows gradually up into a cylindrical BN nanotube with an open tip Figures 6 d and 6 e. The growth of BN nanotube will not be terminated unless the B or N atoms are consumed. In this base growth process, BN nanotube grows from the liquid-solid interface in order to give the lowest liquid-solid interfacial energy [ 31 ]. Contrast Experiments A collection of experiments were carried out to investigate the influence of the reaction temperature, time, and starting materials on the growth of BN nanotubes. The crystallinity of BN nanotubes will become better with the rise of temperature in this range. The reaction time had an essential influence on the yield of BN nanotubes. In the optimum temperature range, if annealing time is less than 3 h, the reaction will become very incomplete, and as a result, the yield will be approximately less than 30 percent. It is likely that the porous precursor has an optimum porous structure and highly dispersion state of metal catalyst and the reactant. A base growth mechanism was proposed. The existence of metal liquid drop played an important role during the growth process of BN nanotubes. The present work demonstrates that the SHS-annealing method is effective to synthesize quantities of BN nanotubes. Acknowledgment The authors acknowledge the financial support from the government of Hubei province of the China for this research work. Lamy de la Chapelle, P. View at Google Scholar S.

## 2: Synthesis and Properties of Boron Nitride

*Synthesis and Properties of Boron Nitride by Pouch, J. J.; Alterovitz, S. A, Editors. and a great selection of similar Used, New and Collectible Books available now at [www.enganchecubano.com](http://www.enganchecubano.com) - Synthesis and Properties of Boron Nitride Materials Science Forum by John J Pouch - AbeBooks.*

This is an open access article distributed under the Creative Commons Attribution License , which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. Abstract One-dimensional 1D nanomaterials with novel photoelectric, magnetic, mechanical, and electronic transport properties have long been the research focus throughout the world. Herein, the recent achievements in preparation of 1D boron nitride nanomaterials, including nanotubes, nanowires, nanoribbons, nanorods, and nanofibres are reviewed. As the most intriguing and researched polymorph, boron nitride nanotubes BNNTs are introduced thoroughly involving their functionalization and doping. The electronics and engineering applications of 1D boron nitride nanomaterials are illustrated in nanoscale devices, hydrogen storage, polymer composites, and newly developed biomedical fields in detail. Introduction A nanoscience and nanotechnology revolution initiated by the observation of carbon nanotubes CNTs [ 1 ] has rapidly swept the world over the last couples of decades. A number of peculiar phenomena were found at the nanoscale. Of the epoch-making revolution, nanomaterials lie in the central position and construct a bridge between nanoscience and nanotechnology. Synthesis and characterization of new types of nanomaterials have attracted enormous concentration of scientists in chemistry, physics and materials. Of all, 1D nanomaterials such as tubes, wires, ribbons, fibers, and rods with exceptional electronic, mechanical, optical and magnetic properties have been widely researched and used as building blocks in nanoscale devices [ 2 ]. It is generally suggested that quantum confinement in 1D nanostructures leads to novel electronic and transport properties, which provides a good model to investigate the effect of dimensionality and reduced size on the above properties of 1D nanomaterials [ 3 ]. Light-weight 1D nanomaterials with large elastic modulus can be promising candidate in engineering field and used as reinforcement agent into composite materials [ 4 ]. Stimulated by rapid development of carbon nanomaterials, a series of boron nitride nanostructures have been synthesized, especially 1D nanomaterials such as nanotubes, nanowires, nanoribbons, nanofibers, and nanorods Figure 1 [ 5 - 9 ]. One-dimensional boron nitride nanomaterials exhibit not only excellent thermal conductivity and high elastic modulus comparable to these of carbon materials but better thermal and chemical stability. Contrary to carbon with good electrical conductivity, boron nitride is a nearly electrical insulator with a large band gap of 5. Consequently, BNNT can be used as insulating protective shields encapsulating semiconducting nanowires to form nanocables [ 11 - 16 ]. BN nanowires and nanoribbons could play key roles in nanoscale devices [ 6 , 7 ]. And BN fibers may substitute for carbon fibers under electrical insulating and rigorous environment at high temperature [ 8 ]. Family of 1D boron nitride nanomaterials. Copyright Elsevier Ltd. Copyright Institute of Physics. Copyright American Chemical Society. In this paper, the latest advances in synthesis and applications of 1D boron nitride nanomaterials in device and engineering are comprehensively introduced. Of all, BNNTs and their functionalization and doping are systematically reviewed as well as their various applications particularly in newly developed biomedical field. Other 1D BN nanomaterials are illustrated in detail as well. Boron Nitride Nanotubes 2. Following research improved this method by using HfB<sub>2</sub> [ 18 , 19 ] or ZrB<sub>2</sub> [ 20 ] electrodes in a nitrogen atmosphere. Most of the tube ends were closed by flat layers or encapsulated metal particles or amorphous BN material. When nitrogen-free, boron-rich electrodes incorporating minority of nickel and cobalt were arced in a nitrogen atmosphere, double-walled BNNTs self-assembled into bundles or ropes were mass-produced [ 21 , 22 ]. Reprinted with permission of [ 18 ]. Copyright American Physical Society. BNNTs, especially single-layer ones, can be prepared by laser ablation. BNNTs of only 1 to 3 layers with flat or polyhedral caps were synthesized by using excimer laser ablating BN target with nanosized Ni and Co powder at [ 23 , 24 ]. Low-energy electron-cyclotron resonance ECR plasma

was also used to deposit single-walled BNNTs with fourfold and eightfold ring structures on tungsten substrate [ 25 ]. In the absence of metal catalysts, single-walled nanotubes could also be synthesized in gram quantities using CO<sub>2</sub> laser ablation [ 26 ], which indicated different growth mechanism from carbon single-walled nanotubes. A root-growth model was proposed based on the observation of boron particles at the tube ends. Noticeably, Laude et al. However, this method was the unique route known to the massive preparation of single-layer BNNTs. Besides, Wang et al. However, laser ablation, combined with arc-discharge, was limited owing to the expensive and complex apparatus. Ball milling and annealing method with facile operation and mass production was successfully introduced to the synthesis of BN nanomaterials by Chen et al. Originally, h-BN powder was used as the starting material which was ball milled and annealing at under nitrogen gas flow [ 31 ]. The product was composed of both cylindrical and bamboo-like nanotubes. However, when the annealing process was conducted under ammonia gas flow keeping other conditions unvaried, pure cylindrical BNNTs were obtained which was attributed to two-dimensional growth of the BN phase without metal catalysis [ 35 ]. According to this model, selective synthesis of BNNTs, bamboos and nanowires was achieved through tuning the reaction parameters [ 38 ]. BNNTs obtained by this method were generally catalyzed by metal catalysts from the reaction vessel [ 39 ]. Overall, this method provides an effective mechanochemical route for the growth of BNNTs from solid phase, which is suitable for mass production of BNNTs. Precise structure investigations showed many changes from CNTs to BNNTs, for example, decreased numbers of shells, increased orderliness of nanotube shells along the tube axis, flat tip-end terminations, and so forth [ 43 ]. Novel conical nanotubes with their cone axis parallel to the tube axis were regularly found in the product [ 44 ]. The growth mechanism was considered to be oxidation-induced defect growth model. Aligned BNNTs were of great importance in the fabrication of nanoscale device which can be made interestingly via substitution reaction using aligned multiwalled CNTs [ 53 ]. Novel hollow conical-helix BNNTs were found through additional high-temperature treatment on the basis of above method and its structure was studied in detail [ 54 , 55 ]. On the whole, although this route is easily subject to carbon contamination, carbon doped BNNTs with tuned band gap which is promising candidate in diverse photoelectrical device could be produced by carefully controlling the reaction parameters. In the carbon nanotube substitution reaction, CNTs acted as both templates and reducing agent. Borazine or related materials such as 2,4,6-trichloroborazine, polymeric borazine, borazine oligomer and BH<sub>3</sub>NH<sub>3</sub> or B<sub>2</sub>H<sub>6</sub> was generally selected as the starting materials [ 56 – 60 ]. The synthesis procedure was divided into three steps, that is, pyrolysis of the precursors at relatively low temperature below to produce amorphous or turbostratic or poor crystalline BNNTs, removal of AAO template by immersing in 0. The key factor of this route is to choose a compatible precursor with the AAO templates. Recently, a mixture of smooth boron nanowires and branched boron nanofeather nanojunctions was employed as precursor to react with nitrogen gas forming novel boron nitride nanotube branched nanojunctions which can act as functional units in nanoelectronic and nanomechanical devices [ 61 ]. The results demonstrated the template role of boron nanowires as well as reactant. Moreover, other hard templates may be attempted for the synthesis of BNNTs. Actually, both the above-mentioned template methods are performed in chemical vapor deposition CVD equipment. However, available boron source suitable for CVD synthesis is severely restricted. Frequently used gaseous boron-contained compounds in the synthesis of boron nitride films, most notably BCl<sub>3</sub> [ 62 ] and B<sub>2</sub>H<sub>6</sub>, can also be beneficial to the growth of BNNTs. Recently, two groups reported the massive production of BNNTs by using B<sub>2</sub>H<sub>6</sub>-based gas precursors catalyzed by Ni or Fe nanoparticles on similar substrate at low temperature below [ 63 – 65 ]. Recently, double-walled BNNTs with 2 nm diameters were obtained from borazine with a floating nickelocene catalyst at [ 67 ]. Later on, they improved this method by adding FeO to the starting mixtures aiming to promote the formation of highly reactive B<sub>2</sub>O<sub>2</sub> intermediate Figure 3 [ 5 ]. Up to now, this route remains one of the most effective carbon-free routes to BNNTs in large scale, which advanced further functionalization and performance research of BNNTs. The results showed that the combined promoters of MgO and FeO apparently presented the predominant efficiency. Besides, some

homemade precursors were employed to effectively synthesize BNNTs [ 73 ]. Structure analysis showed that the obtained BNNTs exhibited zigzag arrangement and rhombohedral stacking order. The nanotubes growth was suggested to be promoted by boron oxynitride nanoclusters at the tips involving Si, Al and Ca. Subsequently, controlled synthesis of BN nanotubes, nanobamboos, and nanocables was implemented using the B-N-O precursor under different conditions [ 76 ]. The as-produced nanotubes were found to grow in a layer-by-layer fashion. In view of its successful application in the mass production of CNTs, CVD technique may play a similar key role in the mass production of pure BNNTs in the future by selecting proper precursors and optimizing the reaction parameters. Reprinted with permission of [ 5 ]. One facile and easy-controlled method based on confined reactions in a sealed autoclave developed by our groups has been successfully utilized to preparation of various nanostructures including carbon, carbide, and nitride nanomaterials from 1D to 3D at low temperature [ 78 – 83 ]. The confined environment allows full diffusion and homogeneous distribution of reactive species leading to more efficient production and high anisotropic growth. Diverse tips like acute and obtuse conical and square tips were observed in the product and many BN nanocages were found to coexist with BNNTs. The conical nanotubes with unique geometry may possess specific properties and promising applications. The BNNTs were closed at one ends or both ends and presented cone-like tips as well as the traditional tip-ends. More recently, well crystalline BNNTs were synthesized as a side product together with hollow spheres [ 86 ]. The control experiments showed that crystalline BNNTs could be formed at quite low temperature of. Therefore, low temperature copyrolysis method in stainless steel autoclaves has been proved to be an effective way for the high yield production of crystalline BNNTs. Other methods towards BNNTs were exploited. Arc plasma jet can generate high-temperature K resulting in evaporating exposed BN sintered disk to grow multiwalled BNNTs with square tips [ 87 ]. The innermost tube with diameter of 0. Based on the above discussion, synthesis of pure multiwalled BNNTs have been achieved, although single-walled and aligned BNNTs which is of significance in device applications still remain a challenge. For industrial production, current methods developed in labs cannot meet the requirement yet. Moreover, precisely controlled synthesis of BNNTs with pure hexagonal or rhombohedral stacking and zig-zag or armchair arrangement needs further research. Although the price is still very high now, this suggests huge application future of BNNTs undoubtedly. In the last few years, following the successful massive production of pure BNNTs, many reports about surface modification of BNNTs towards solubility in aqueous or organic media sprung out [ 88 ]. Functionalization could modulate the band gap of BNNTs in some cases. Covalent functionalization was achieved through forming acylamino bond between chemical reaction of COCl group of stearoyl chloride or chloroacetyl chloride and amino groups on the BNNTs [ 89 , 90 ]. It was noteworthy that long alkyl chains introduced by stearoyl chloride induced changes in band structure of BNNTs with reduced band gap. Another method for covalent functionalization based on boron site at the surface of BNNTs was established via introducing amine groups by using ammonia plasma irradiation or amine-terminated oligomeric poly ethyleneglycol [ 91 , 92 ]. Introduced alien groups at the BNNTs surface enabled facile development of composite structure on this scaffold [ 93 ]. Very recently, hydroxyl groups –OH were successfully introduced onto the surface of BNNTs via solvothermal treatment in hydrogen peroxide Figure 5 [ 95 ]. Hydroxylated BNNTs enabled a series of further chemical reactions based on hydroxyl bonding. Hydroxylated BNNTs [ 95 ].

### 3: Boron Nitride Nanostructured: Synthesis, Characterization and Potential Use in Cosmetics

*Synthesis of boron nitride films prepared by photon- and ion-assisted deposition eds.), Synthesis and Properties of Boron Nitride, Materials Science Forum, Vols.*

Its layered structure is similar to that of graphite. In the manufacture of cosmetics, this structure is intended to improve the appearance, sensory aspect and makes it easy to mix excipients contained in the formulation in the mixture process. In cosmetology, the efficiency and the penetration of active substances into skin are known to be directly related to the particle size. However, only recently their nanostructured properties have been explored. In this work, the synthesis of hexagonal boron nitride in the nanoscale, its composition, structure, morphology and potential for future application in sunscreens are being investigated. Results have shown that boron nitride may be synthesized in the nanoscale and that this material has the potential to be incorporated into cosmetics.

**Introduction** The cosmetic industry currently has researched materials that offer advantages and which are attractive to customers. Ceramic materials are widely used in cosmetics and are manufactured by ceramic powder processing, sol-gel technology and precipitation solutions. The boron nitride is a ceramic material with a chemical formula BN. The hexagonal structure allows the molecules to be arranged in layers so they slide one over the other and their use becomes interesting in cosmetic formulation to confer better lubricity mixtures. Regarding the new researches in parameters used for the h-BN nanostructure synthesis aim to improve productivity, quality and control the size of synthesized particles. Recently, many studies have reported the preparation of nanostructures of the boron nitride with special morphologies, such as nanotubes [3,4], nanocapsules [5], nanocages [6] porous structures [7], hollow spheres [8], and nanofibers [9].

On the other hand, for special BN nanostructures synthesis, laser ablation, chemical vapor-phase, carbothermal reduction of B<sub>2</sub>O<sub>3</sub> and B<sub>4</sub>C and other methods have been developed [11]. Most of these methods cannot meet the needs of high yields, and therefore, the understanding on its synthesis is still a challenging subject. Moreover, BN nanotube obtained from different synthetic methods has different physical properties. Quality, quantity, and type of nanotubes synthesized depend on the synthetic method used. In the cosmetics field, the particle size is important because smaller diameters may enable an increase in the surface area and the possibility of encapsulating cosmetics actives. The h-BN may offer advantages for use in cosmetics, particularly in sunscreens, since it allows manipulation of the structure during different phases of formation and, consequently, control of the size and the specific surface area; nevertheless, it has an excellent performance in the dispersion, it is non-toxic, transparent, and chemically inert. Solar radiation is known to damage skin health and the cosmetic industry has invested in the research and manufacture of effective sunscreens. The range of the solar spectrum that normally reaches the surface of the Earth and has a special interest for photomedicine is that of ultraviolet B UVB and the Infrared IR [12]. The effect of ultraviolet rays is harmful to the health of the skin and can result in an increased cancer incidence, aging and other undesirable skin changes. Ultraviolet B is responsible for sunburn, erythema and inflammation. The effects of infrared rays are less described in the scientific literature, but these rays are known to increase the damages on the skin induced by ultraviolet rays [13], premature aging [14,15] and infrared radiation may have a photocarcinogenic potential [16]. Sunscreens have been researched for a long time and currently they have been developed using the nanoscience and nanotechnology knowledge, as titanium dioxide, an important cosmetic used as sunscreen against ultraviolet radiations. However, for the protection against infrared radiation little has been researched. In the market, there are several inorganic actives such as titanium dioxide TiO<sub>2</sub> and zinc oxide ZnO, which are able to block effects of ultraviolet radiation. These materials currently have smaller sizes and have advantages over the conventional product, as the phenomenon of radiation spread and therefore a white color under the skin [17]. With this regard, there is a great need to create formulations of sunscreens which can offer protection against ultraviolet rays as well as infrared rays. The boron nitride nanostructure is a potential material for this purpose as it is possible to manipulate its size, an important factor to use in sunscreens, thus

reducing shine from oily skin as it has a high thermal conductivity. Indeed, it has absorption in the infrared ray region and special formulation containing titanium dioxide particles with nanostructured boron nitride would be a perfect combination to be applied as a cosmetic for protection against solar radiations in a broad spectrum. Synthesis BN nanostructured samples were prepared using We observed the formation of a precipitate early in the reaction. The material was allowed to stand for 48 hours at room temperature. Results and Discussion The synthesis begins with the formation of the melamine diborate precursor [18]. It was prepared from boric acid and melanin reaction as below. They can be described in Equation 1 see below. For this synthesis, an initial 2-hour purge was carried out in order to minimize the presence of contaminants. This was crucial to the proposed result. The sample has characteristic peaks in the hexagonal boron nitride formation. The spectrum has to be free of impurities, which are related to other crystalline forms of boron nitride. It is noteworthy that this technique generates important data to characterize the h-BN phase, since it is possible to distinguish  $sp^2$  bonds of hexagonal h-BN phase samples and  $sp^3$  of cubic c-BN phase. According to Hao and colleagues [19]  $sp^2$ - type bonds h-BN are thermodynamically stable under the synthesis conditions of this work, whereas for the formation of  $sp^3$  bonds typical of c-BN, there is a kinetics barrier to formation. This sample is more crystalline compared to other temperatures tested. The turbostratic structure imperfect structure with no three-tridimensional order has been produced at a low temperature. From the diffraction data, we measured the particle size according to the Scherrer equation: The average size of the particle found was 15 nm. This value is important for the objective of the study since it shows that the material is in the nanoscale. Figure 3 shows nitrogen isotherm and pore distribution of the sample. This material also has the potential to be used as a matrix for embedding drugs due to area surface. The isotherm is similar to type IV mesoporous material with micropores contribution and display type H3 hysteresis loop according to the IUPAC classification, which is often observed with aggregates of plate-like particles that give rise to slit-shaped pores. The adsorption of the gas first starts with micropores and then continues with mesopores. The adsorption and desorption mechanism occurs at the same time in micropores. While adsorption occurs by the condensation towards the walls of pores, desorption occurs by evaporation from the walls of pores. In mesopores, adsorption and desorption follow different ways. The filling of the mesopores occurs by the condensation on the wall of pores with formation of layers. On the other hand, desorption occurs by moving away from pore opening with the evaporation. This experiment revealed that the final material possess a narrow pore size distribution with an average pore size of about 3. The pore size distribution Figure 3 a for the produced nanostructured boron nitride was plotted using desorption data of BJH Barrett-JoynerHalenda method at 0. The material presents a total pore volume of 0. Table 1 shows the main results obtained from the  $N_2$  adsorption. The formation of an agglomerate of fine grain of hexagonal boron nitride with diameter around 0. This image is important to demonstrate the application of the material studied in the field of cosme- a b Figure 3. Figure 5 shows a typical EDS boron nitride. This figure illustrates the general analysis of the material surface. There are only boron and nitrogen atoms. The results allow us to verify the homogeneity of the sample containing the boron and nitrogen. This result was obtained due to the purge of the sample before conducting the synthesis with nitrogen gas flow for two hours. This procedure was important to minimize the presence of contaminants in the sample. The image confirms nanoscale of the synthesized samples and the formation of primary particles of fine grains. The microstructure has approximately 0. The high-resolution transmission electron microscopy image shows a spacing layer of about 0. This finding is in agreement with values reported for interplanar distance of h-BN presented in the literature [18]. Two different absorptions have been observed, near eV and eV as described in the literature [18] being assigned to the hexagonal boron nitride. These figures refer to boron and nitrogen, respectively. The quantification of this analysis shows a ratio close to 1: Interestingly, no other element has been detected in this sample. These rings can be indexed as , , and reflections, which are typical of hexagonal boron nitride. The spectrum of infrared radiation may be divided according to three sub-regions: The absorption of infrared radiation is different in various layers of the skin and infrared radiation penetrates more deeply into the skin when compared to the ultraviolet radiation

[16]. Depending on the penetration into the skin, it is possible occur damage in cellular responses, a heating sensation and burning takes place. Thus, it is of great importance to consider this characteristic, since these materials have the ability to block effects of hard radiation and, consequently, to minimize such reactive effects in the human health. Titanium dioxide has an absorption band different from that of boron nitride. The region of the spectrum boron nitride is wider than the titanium dioxide which indicates an additional photoprotection when it is associated with a cosmetic formulation. As previously mentioned, this photoprotection is important to minimize the damage in the skin. The boron nitride has a high reflectivity in the visible spectrum and thus, its properties in this wavelength are insignificant. Titanium dioxide is more effective than boron nitride hexagonal in this range Figure 8. Depending on the particle size, the protection of the titanium dioxide may occur not only through reflection but also through absorption. Conclusion The material developed in this synthesis provides chemical and structural features similar to those described in the literature for the formation of hexagonal boron nitride. The particle size is found in the order of nanometers, being important result for the proposed theme. The ability to absorb in the infrared range makes these materials a powerful adjuvants together titanium dioxide for application in sunscreens. E Costa and E.

**4: mp BN (cubic, Fm, )**

*Cubic boron nitride (c-BN) thin films are of significant interest because of their diamond like structure and properties. c-BN shows high thermal conductivity, chemical inertness against ferrous metals even at high temperatures, wide band gap, and good transmittance over a wide spectral range from UV to visible.*

On the other hand, for special BN nanostructures synthesis, laser ablation, chemical vapor-phase, carbothermal reduction of B<sub>2</sub>O<sub>3</sub> and B<sub>4</sub>C and other methods have been developed [ 11 ]. Most of these methods cannot meet the needs of high yields, and therefore, the understanding on its synthesis is still a challenging subject. Moreover, BN nanotube obtained from different synthetic methods has different physical properties. Quality, quantity, and type of nanotubes synthesized depend on the synthetic method used. In the cosmetics field, the particle size is important because smaller diameters may enable an increase in the surface area and the possibility of encapsulating cosmetics actives. The h-BN may offer advantages for use in cosmetics, particularly in sunscreens, since it allows manipulation of the structure during different phases of formation and, consequently, control of the size and the specific surface area; nevertheless, it has an excellent performance in the dispersion, it is non-toxic, transparent, and chemically inert. Solar radiation is known to damage skin health and the cosmetic industry has invested in the research and manufacture of effective sunscreens. The range of the solar spectrum that normally reaches the surface of the Earth and has a special interest for photomedicine is that of ultraviolet B UVB and the Infrared IR [ 12 ]. The effect of ultraviolet rays is harmful to the health of the skin and can result in an increased cancer incidence, aging and other undesirable skin changes. Ultraviolet B is responsible for sunburn, erythema and inflammation. The effects of infrared rays are less described in the scientific literature, but these rays are known to increase the damages on the skin induced by ultraviolet rays [ 13 ], premature aging [14,15] and infrared radiation may have a photocarcinogenic potential [ 16 ]. Sunscreens have been researched for a long time and currently they have been developed using the nanoscience and nanotechnology knowledge, as titanium dioxide, an important cosmetic used as sunscreen against ultraviolet radiations. However, for the protection against infrared radiation little has been researched. In the market, there are several inorganic actives such as titanium dioxide TiO<sub>2</sub> and zinc oxide ZnO , which are able to block effects of ultraviolet radiation. These materials currently have smaller sizes and have advantages over the conventional product, as the phenomenon of radiation spread and therefore a white color under the skin [ 17 ]. With this regard, there is a great need to create formulations of sunscreens which can offer protection against ultraviolet rays as well as infrared rays. The boron nitride nanostructure is a potential material for this purpose as it is possible to manipulate its size, an important factor to use in sunscreens, thus reducing shine from oily skin as it has a high thermal conductivity. Indeed, it has absorption in the infrared ray region and special formulation containing titanium dioxide particles with nanostructured boron nitride would be a perfect combination to be applied as a cosmetic for protection against solar radiations in a broad spectrum. Synthesis BN nanostructured samples were prepared using We observed the formation of a precipitate early in the reaction. The material was allowed to stand for 48 hours at room temperature. Results and Discussion The synthesis begins with the formation of the melamine diborate precursor [ 18 ]. It was prepared from boric acid and melamin reaction as below. They can be described in Equation 1 see below. For this synthesis, an initial 2-hour purge was carried out in order to minimize the presence of contaminants. This was crucial to the proposed result. The sample has characteristic peaks in the hexagonal boron nitride formation. The spectrum has to be free of impurities, which are related to other crystalline forms of boron nitride. It is noteworthy that this technique generates important data to characterize the h-BN phase, since it is possible to distinguish sp<sup>2</sup> bonds of hexagonal h-BN phase samples and sp<sup>3</sup> of cubic c-BN phase. According to Hao and colleagues [ 19 ] sp<sup>2</sup>- type bonds h-BN are thermodynamically stable under the synthesis conditions of this work, whereas for the formation of sp<sup>3</sup> bonds typical of c-BN, there is a kinetics barrier to formation. This sample is more crystalline compared to other temperatures tested.

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The turbostratic structure imperfect structure with no three-tridimensional order has been produced at a low temperature. The average size of the particle found was 15 nm. This value is important for the objective of the study since it shows that the material is in the nanoscale. Figure 3 shows nitrogen isotherm and pore distribution of the sample. This material also has the potential to be used as a matrix for embedding drugs due to area surface. The isotherm is similar to type IV mesoporous material with micropores contribution and display type H3 hysteresis loop according to the IUPAC classification, which is often observed with aggregates of plate-like particles that give rise to slit-shaped pores. The adsorption of the gas first starts with micropores and then continues with mesopores. The adsorption and desorption mechanism occurs at the same time in micropores. While adsorption occurs by the condensation towards the walls of pores, desorption occurs by evaporation from the walls of pores. In mesopores, adsorption and desorption follow different ways. The filling of the mesopores occurs by the condensation on the wall of pores with formation of layers. On the other hand, desorption occurs by moving away from pore opening with the evaporation. This experiment revealed that the final material possess a narrow pore size distribution with an average pore size of about 3. The pore size distribution Figure 3 a for the produced nanostructured boron nitride was plotted using desorption data of BJH Barrett-JoynerHalenda method at 0. The material presents a total pore volume of 0. Table 1 shows the main results obtained from the N<sub>2</sub> adsorption. The formation of an agglomerate of fine grain of hexagonal boron nitride with diameter around 0. This image is important to demonstrate the application of the material studied in the field of cosme-.

5: John J. Pouch | Open Library

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