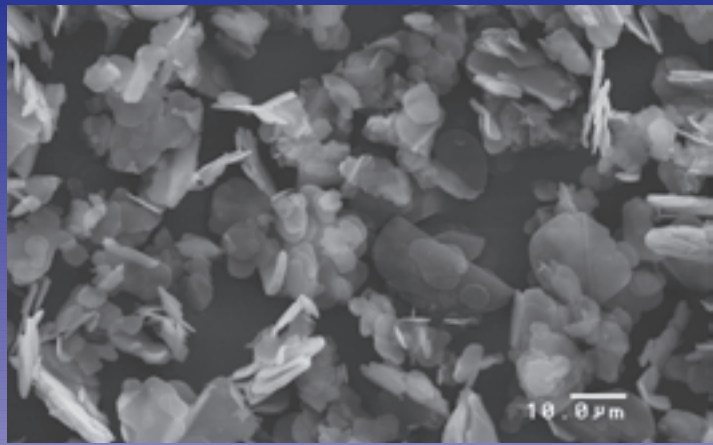




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**Boron Nitride –  
The Active »Inert« with a Velvety Feel**



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## Boron Nitride – The Active »Inert« with a Velvety Feel

Keywords: Boron Nitride Powder, colour cosmetic formulations, active filler, skin care

### Introduction

**N**ot so many solid raw materials are used in cosmetics and those few mainly in make-up products:

- Talc
- Pigments
- Sericite
- Kaolin
- Mica
- Precipitated Calcium Carbonate
- Light Magnesium Carbonate
- Pyrogenic silica
- Di-calcium and Mono-calcium phosphate
- Calcium stearate
- Alumina
- Pearls (Titanium dioxide and other pigments on Mica)
- Bismute oxychloride
- Nylon
- Polymethylmethacrylate
- Zinc oxide
- Calamine

Reasons are very simple: the solid materials behavior strictly depends on the combination of its surface properties, its crystalline lattice characteristics (bulk properties) and of the chemical na-

ture of such a substance, while for traditional non-solid cosmetic raw materials only the last one is important.

Solids often pass a milling treatment as confinement, a sometimes sophisticated operation, which has typically a hard to control outcome, as the dimensions of particles of these micro-milled powders scatter statistically around an targeted, average value. Their surface activity is consequently variable. Moreover, it is influenced by its zeta potential, by absorbed gas or humidity. Finally the surface of such solid particles can show a selective absorption for the wetting liquids. This can become a problem in formulation development, when cosmetic blends of several ingredients are used in combination.

Nevertheless, solids are intriguing materials. Beside just acting as an inert, passive filler, they provide eventually additional functionality. Onto the skin, they transform sliding friction during spreading and massage into

rolling friction. They fill small skin imperfections and wrinkles, help adhesion and slipperiness, interfere with incident light, hiding skin spots and blemishes.

They help water and sweat resistance, while modifying interactions of the skin with sun rays and influencing heat dispersion. Their active surface can absorb irritating materials, contribute to a healing effect, like e.g. solid Zinc derivatives can do. Last but not least, they help processing characteristics of finished products and can act as carriers for active ingredients (1).

Among the historical uses of minerals, cosmetics are now facing the availability of 'new' solids. Their existence has been made possible by modern technology of ceramics, using industrial synthesis processes, reaching temperatures as high as 2000 °C and sometimes hundreds of atmospheres of pressure for creating new solids. Boron Nitride is one of these synthetic solid materials born from extreme conditions.

## BORON NITRIDE

## ■ Boron Nitride

Boron Nitride (BN) is a manmade, synthetic substance, which exists in several modifications. In its cubic form (cBN), Boron Nitride is the second hardest material after diamond. It requires 5000 atmospheres to be produced, its melting point is 2967 °C (2) and its micro-hardness is estimated around 4000 kg/mm<sup>2</sup>. It was first prepared in 1842, but its real industrial production started in the 1950s.

BN exists also in a hexagonal crystalline modification, forming thin platelets, which is then in contrary a very soft material. Indeed, there are many similarities between the chemistry of Carbon and Boron Nitride: they are isoelectronic. The cubic forms of both substances are very hard, as in the case of diamond, while the hexagonal forms (graphite and hexagonal BN) are soft and lubricant. Boron Nitride can give rise to fullerenes-analogue compounds.

In the graphitic form (hBN), the crystalline structure is hexagonal, with Nitrogen and Boron sp<sup>2</sup> bonded, in alternating sequence forming stacks of 2-dimensional layers. In literature, it is often called graphitic Boron Nitride or «white graphite». hBN has a «white» colour, does not adsorb visible light (whiteness as measured by colorimetry parallels that of Titanium dioxide), contrary to graphite, as in BN electrons are not delocalised as in graphite, but permanently resident around the more electronegative Nitrogen atom, outside the conductivity band. hBN is considered as one of the most promising fine ceramics due to its high electrical resistivity, excellent thermal conductivity (heat transmission is mediated by phonons and not by electrons), chemical resistance and extremely low dielectric constant. Its different, modern synthesis can start from organo-boron compounds, boranes with nitrogen, or nitrogen-containing compounds like urea or melamine with boric acid in Nitrogen atmosphere, even Boron trioxide reacting with ammonia. Very fine powders can be produced by reacting elemental Boron with Nitrogen in a plasma at 5000 °C (3).

Synthesis conditions, temperature, reagents, inert gas, concentration can strongly influence the outcome (yield, purity,

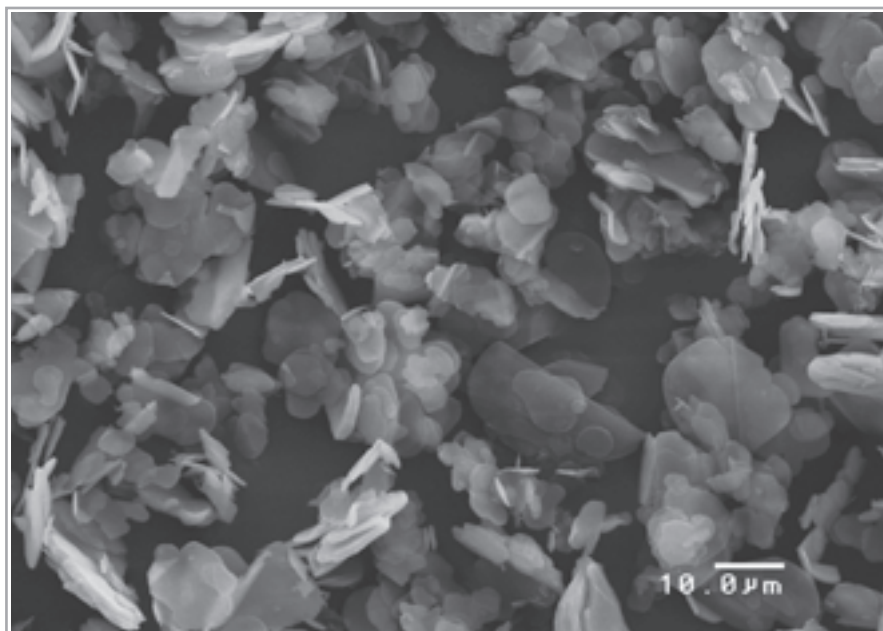


Fig. 1 Typical SEM picture of a Boron Nitride powder

crystallinity) of the high temperature reaction of the formation of hexagonal Boron Nitride. Typical, industrial synthesis temperatures range from 900 °C to 1600 °C, but even higher temperatures are used for highest quality grades. Resistant to oxidation up to 850 °C to 1000 °C, in its purest grades, BN purity is higher than 99.5%, the other impurities being mainly B<sub>2</sub>O<sub>3</sub> (~ 0.03%) and Oxygen (~ 0.3%), some Carbon (0.1%) or metallic impurities (0.01%) like Na, Ca, Si, Fe (4). A standard quality can show a

mean primary particle size around 3 microns, and a corresponding average surface area of approximately 15 m<sup>2</sup>/g (Fig. 1).

## ■ Cosmetic Applications

15 years ago, when (hexagonal) BN was first introduced to the cosmetic market in the western world, after several decades of technical industrial applications in protective surface coatings,

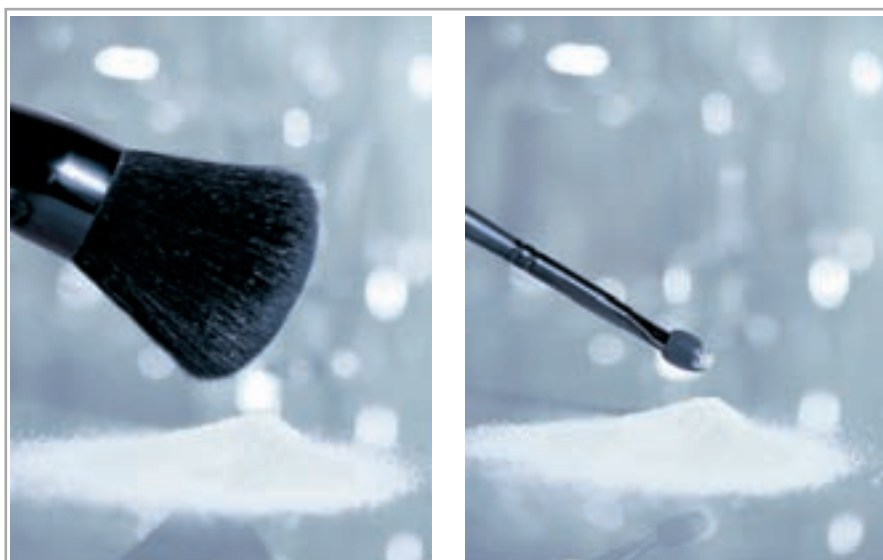


Fig. 2 Boron Nitride in cosmetic applications

like handling corrosive chemicals, metallurgy, glass forming etc., the acceptance was quite high. The initially offered grades had »just« a normal powdery feel, the substance name was very 'synthetic' and they were very costly. Successively, the producers developed many different grades, with variable granulometry, transparency and skin feel, customized powder qualities. Today, Boron Nitride finds very many different interesting application fields in cosmetics. The main characteristics of the modern grades are: lubrication, ease of spreading, good coverage, velvety and silky touch (Fig. 2).

Its ability to dissipate heat at a rapid rate provides formulations with the ability to produce cooling effect upon application to the skin (5). Indeed, its thermal conductivity is comparable or even higher than of pure metals (400 W/mK) due to Boron Nitride crystalline structure and to the good adhesion of the large surfaces of BN platelets. Just to make an example mineral rocks are from 1000 to 10 times less conductive. This nice set of characteristics, together with the high chemical inertness, finds important applications not only in the field of fillers for make-up, but also in the sun-screens formulae. In w/o emulsions, BN has been reported to exert a stabilizing effect, together with an increase of product spreadability and skin smoothness (6). In o/w emulsions, it is easy to verify that even small additions (around 1%) accelerate apparent skin absorption and reduce the greasiness and tackiness of the residual film.

In sunscreens, the additional key characteristic of BN resides in its IR-absorbing properties. This reduces the acute and chronic negative effect of hyperaemia induced by sun exposure both under the sun and after irradiation. Therefore, use in broad-spectrum sunscreens and in after-sun emulsions has been successfully experimented. Its association with micronized titanium dioxide provides synergistic effect in sun radiation absorption.

### ■ Colour Cosmetic Uses

Hiding power, ease of spreading, white colour, lubrication, skin adhesion, long-

lasting effect have been instrumentally quantified in an early work (7) together with the high absorbing power toward oils, which can reach the double of that of talc. Use of BN grades has been proposed in foundations, liquid make ups, concealers, mascara, pressed powders, lipsticks and all kind of pencils. An enhancement of haptics has been demonstrated for some grades of BN.

In recent times, sensory evaluations have been applied to the comparison of perceived sensory characteristics, the only measurements that allow a direct communication between the formulator and the consumer. No objectively sound sensory evaluation has been ever applied to the evaluation of BN properties. In a series of experiments (8) the 'Boron Nitride powder' – BORONEIGE® – was evaluated in comparison with five different fillers, in order to compare their performances related to the following sensory features:

- **spreadability:** ease of moving product over the skin;
- **skin coverage degree:** product's ability to cover the skin;
- **skin coverage homogeneity:** homogeneity level in the skin coverage;

- **skin softness:** intensity of velvety skin-feel perceived by gently touching the treated forearm area with the fingers.

16 trained panellists evaluated the samples according to a standard protocol and ranked them with regard to the intensity degree of each selected parameters. This test (9-12) was repeated twice in order to insure accuracy and reproducibility. Then, rank sums are calculated and analyzed by means of statistical analysis. The assessment was performed on the forearms' skin according to a balanced and randomized order of presentation (Fig. 3).

Firstly, the technician delivered a standard quantity of each sample in a marked site of the fore-arms, than the panellists spread the powder by a constant and elliptic movement of their index finger. Finally they evaluated individually the listed four sensory parameters. For each sample and each parameter under test, the **Rank position** given by each panellist and the **Rank Sum** obtained by adding all individual rank positions of each panellist are calculated. Successively, the Rank Sums are analyzed by means of *Friedman* statistical test and finally the critical value of LSD (Least Significant Difference) is calculated, to

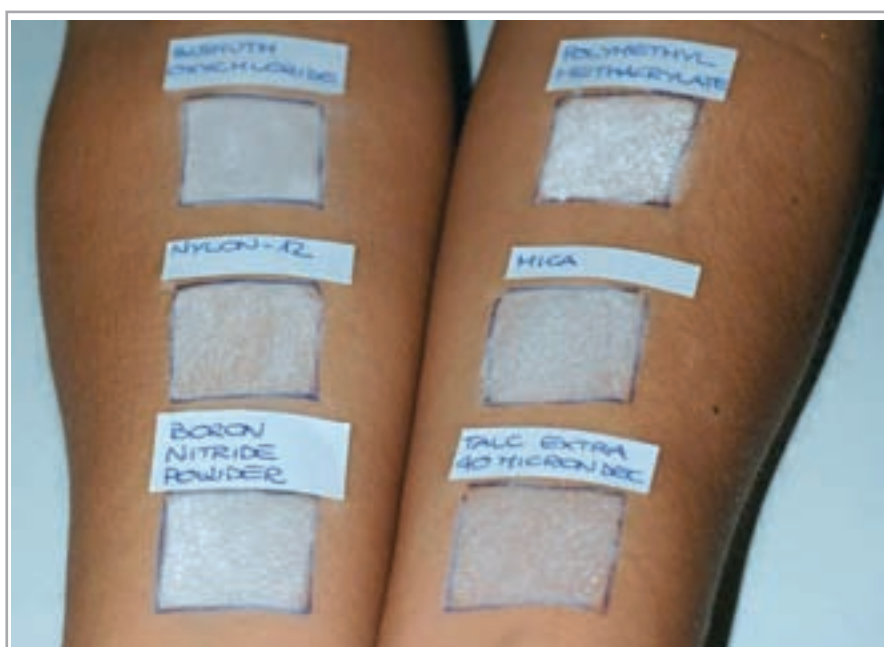


Fig. 3 Raw materials applied on forearms

BORON NITRIDE

| Samples                   | Polymethyl Methacrylate | Mica | Talc extra 40 micron dec. | Bismuth Oxychloride | Nylon-12 | BORONEIGE® (Boron Nitride) |
|---------------------------|-------------------------|------|---------------------------|---------------------|----------|----------------------------|
| Spreadability             | 35.0                    | 47.5 | 53.5                      | 74.5                | 56.5     | 68.5                       |
| Skin coverage degree      | 20.5                    | 60.5 | 45.0                      | 81.0                | 51.0     | 77.0                       |
| Skin coverage homogeneity | 21.5                    | 60.0 | 49.0                      | 84.5                | 51.0     | 70.0                       |
| Skin softness             | 35.0                    | 59.0 | 48.0                      | 75.5                | 48.5     | 68.5                       |

Table 1 Rank sum for each tested sample

identify the pairs of rank sums that differ from each other. LSD value is the smallest difference between rank sums of any pair of samples that is necessary in order to state that products are significantly different, in relation to the selected attribute.

In this study, the LSD value is equal to 20.7. Consequently the pairs of samples,

whose »rank sum« differs by a value greater than 20.7, can be considered significantly different in the evaluated sensory features. In Table 1 the »rank sum« obtained for each tested sample: the higher the value, the better the performance.

The *Friedman* test, applied to the rank sum obtained, evidences that there are

significant differences between products:  $p < 0.05$ . On the basis of LSD value, a multiple comparison test between the rank sums of samples is performed. The results are reported in Tables 2–5, where (s) means that the two products are significantly different in the investigated attribute ( $p < 0.05$ ).

| Spreadability (LSD)       | Polymethyl Methacrylate | Mica | Talc extra 40 micron dec. | Bismuth Oxychloride | Nylon-12 | BORONEIGE® (Boron Nitride) |
|---------------------------|-------------------------|------|---------------------------|---------------------|----------|----------------------------|
| Polymethyl Methacrylate   | -                       | N.S  | N.S                       | s                   | s        | s                          |
| Mica                      | N.S                     | -    | N.S                       | s                   | N.S      | s                          |
| Talc extra 40 micron dec. | N.S                     | N.S  | -                         | s                   | N.S      | N.S                        |
| Bismuth Oxychloride       | s                       | s    | s                         | -                   | N.S      | N.S                        |
| Nylon-12                  | s                       | N.S  | N.S                       | N.S                 | -        | N.S                        |
| Boron Nitride Powder      | s                       | s    | N.S                       | N.S                 | N.S      | -                          |

Table 2 Rank sum of samples

| Skin coverage Degree (LSD) | Polymethyl Methacrylate | Mica | Talc extra 40 micron dec. | Bismuth Oxychloride | Nylon-12 | BORONEIGE® (Boron Nitride) |
|----------------------------|-------------------------|------|---------------------------|---------------------|----------|----------------------------|
| Polymethyl Methacrylate    | -                       | s    | s                         | s                   | s        | s                          |
| Mica                       | s                       | -    | N.S                       | N.S                 | N.S      | N.S                        |
| Talc extra 40 micron dec.  | s                       | N.S  | -                         | s                   | N.S      | s                          |
| Bismuth Oxychloride        | s                       | N.S  | s                         | -                   | s        | N.S                        |
| Nylon-12                   | s                       | N.S  | N.S                       | s                   | -        | s                          |
| Boron Nitride Powder       | s                       | N.S  | s                         | N.S                 | s        | -                          |

Table 3 Rank sum of samples

| Skin coverage<br><u>Homogeneity</u><br>(LSD) | Polymethyl<br>Methacrylate | Mica | Talc extra<br>40 micron<br>dec. | Bismuth<br>Oxychloride | Nylon-12 | BORONEIGE®<br>(Boron Nitride) |
|--|----------------------------|------|---------------------------------|------------------------|----------|-------------------------------|
| Polymethyl Methacrylate                      | -                          | s    | s                               | s                      | s        | s                             |
| Mica   | s                          | -    | N.S                             | s                      | N.S      | N.S                           |
| Talc extra 40 micron dec.                    | s                          | N.S  | -                               | s                      | N.S      | s                             |
| Bismuth Oxychloride                          | s                          | s    | s                               | -                      | s        | N.S                           |
| Nylon-12                                     | s                          | N.S  | N.S                             | s                      | -        | N.S                           |
| Boron Nitride Powder                         | s                          | N.S  | s                               | N.S                    | N.S      | -                             |

Table 4 Rank sum of samples

| Skin softness<br><u>(LSD)</u> | Polymethyl<br>Methacrylate | Mica | Talc extra<br>40 micron<br>dec. | Bismuth<br>Oxychloride | Nylon-12 | BORONEIGE®<br>(Boron Nitride) |
|-------------------------------|----------------------------|------|---------------------------------|------------------------|----------|-------------------------------|
| Polymethyl Methacrylate       | -                          | s    | N.S                             | s                      | N.S      | s                             |
| Mica                          | s                          | -    | N.S                             | N.S                    | N.S      | N.S                           |
| Talc extra 40 micron dec.     | N.S                        | N.S  | -                               | s                      | N.S      | N.S                           |
| Bismuth Oxychloride           | s                          | N.S  | s                               | -                      | s        | N.S                           |
| Nylon-12                      | N.S                        | N.S  | N.S                             | s                      | -        | N.S                           |
| Boron Nitride Powder          | s                          | N.S  | N.S                             | N.S                    | N.S      | -                             |

Table 5 Rank sum of samples

### ■ Conclusions

Analyzing the 4 sensory features of these typical cosmetic fillers and Boron Nitride resulted in an interesting ranking.

- **Spreadability**, from the easiest to spread to the least easy to spread:  
Boron Nitride Powder = Bismuth Oxychloride > Nylon-12 > Talc Extra 40 Micron Dec > Mica > Polymethyl Methacrylate.
- **Skin coverage degree**, in order of the performance level from high to low:  
Boron Nitride Powder = Bismuth Oxychloride > Mica > Nylon-12 > Talc Extra 40 Micron Dec > Polymethyl Methacrylate.
- **Skin coverage homogeneity**, in order of the performance level from high to low:

Boron Nitride Powder = Bismuth Oxychloride > Mica > Nylon-12 > Talc Extra 40 Micron Dec > Polymethyl Methacrylate.

- **Skin softness**, in order of the performance level from high to low:  
Boron Nitride Powder = Bismuth Oxychloride > Mica > Nylon-12 > Talc Extra 40 Micron Dec > Polymethyl Methacrylate.

In general, BORONEIGE® Boron Nitride Powder and Bismuth Oxychloride gave the best performances in all evaluated sensory characteristics. They were perceived similar without any statistically significant difference.

Following conclusion can be drawn with regard to these test results:  
BORONEIGE® Boron Nitride is a high potential active filler, as it not only contributes to formulations in terms of lu-

brication, high oil absorbing power, stabilization of emulsions, skin adhesion, hiding power and coverage degree, etc., but also provides additionally very homogeneous and easy spreadability and giving the skin a soft and silky feeling. As a »synthetic« solid Boron Nitride, BORONEIGE® is the perfect additive with the »velvety touch« to all colour cosmetic formulations. Availability in large volumes at attractive prices enables formulators to use BORONEIGE® Boron Nitride as a raw material for the latest state of the art formulations.

BORONEIGE® is a registered and protected trademark by ESK Ceramics GmbH & Co. KG, Kempten, Germany.

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