Appendix of CSC 2020 PhD proposal

More detailed document

Synthesis and functional characterization of h-BN

Keywords:

Polymer Derived Ceramics process, Sintering processes, Boron Nitride, TEM, SEM, AFM, 2D-nanomaterial, microstructural/chemical/electrical/tribological characterization

Abstract:

2D-nanomaterials present a remarkable functional potential and that's why they have been intensively investigated in the past decade. For instance, graphene is probably one of the most studied compound to date, even if its real industrial applications are still unproved, owing to electrical limitations. In opposite, the hexagonal form of h-BN could combine the interesting behavior linked to its two-dimensional character with interesting versatile electrical properties. The problem is that such compound does not exist in the nature, and its synthesis remained a real issue.

Five years ago, two laboratories of Lyon devoted to materials science (Laboratoire des Multimatériaux et Interfaces (LMI) and MATEriaux, Ingénierie et Science (MATEIS)) have gathered their efforts to take up this challenge, and have proposed a dual-step synthesis involving a preceramic powder to be sintered. Two Chinese researchers (a post-doc, a CSC program PhD) were associated to this work, and the resulting product was pure and well-crystallized [2, 5-9]. Besides, the key-parameters susceptible to influence quality of the final product (sintering temperature and crystallization promoter content specially) are now well-identified, so that h-BN is now available in different forms: bulk, single-crystals or nanosheets.

Once available, the next step is now to find some outlets for such promising nanomaterial. In this sense, a whole characterization of the product is expected, what is the objective of the current PhD. Three different ways can be imagine from:

- A mechanical viewpoint,

h-BN is characterized by a 2-D structure. This structure consists in covalent strongly-bonded sheets associated each other by weak bonds. Such a structuration is often taken into profit in tribology to drastically reduce friction in the contact. A PhD part will then be devoted to evaluate the efficiency of h-BN as solid lubricant.

- An electrical viewpoint,

h-BN is characterized by an insulating electrical behavior. A promising way could be to test a multilayered architecture associating both conductive/resistive properties to modulate electrical characteristics of the formed heterostructure. Another way could be based on the nature of the precursor, including some carbon parts, intended to modify the electrical response of the B(C)N compound modified by Csp^2 groups.

- A chemical viewpoint.

Mainly composed by covalent B-N bounds, h-BN is characterized by a strong chemical stability. In this sense, collaborators of the PhD have already published some papers about advanced BN coatings susceptible to be used as protective layer for tools used at moderate temperature (360°C) [7]. Now

easily available in different forms, h-BN could be introduced in a "matrix-layer" (electroless nickel for instance) in order to improve its resistance.

The PhD candidate will be in charge of the synthesis of precursors, sintering of the resulting powder, and characterization of the products. The tribological, electrical and chemical characterization will be correlated with the synthesized h-BN in order to better understand the microstructure/properties relationships.

PhD Supervision

The PhD's program can be structured into three different parts: first, synthesis of preliminary solid polymer-like BN by the PDCs route, then, their sintering, followed by their characterization. Therefore, the PhD will be conducted in two laboratories of Lyon city (France):

- Laboratoire des Multimatériaux et Interface (LMI, Université Claude Bernard Lyon1, UMR CNRS 5615),
- Laboratoire MATEriaux Ingénierie et Science (Mateis, INSA de Lyon, UMR CNRS 5510).

Supervision of the Ph-D student will be ensured by one doctor of each laboratory: Bérangère TOURY, from LMI, will be more involved in the chemical synthesis aspects, while Philippe STEYER, from the MATEIS lab, will be more concerned by the deep characterization of the resulting materials.
Taking into account the high multi-disciplinary character of the study, supervision will also be shared with two other colleagues of both laboratories, specialists in C-based nanomaterials (Pr. Catherine JOURNET-GAUTIER) and in ceramics-shaping processes (Dr. Vincent GARNIER).

Some of their relevant papers appear below:

1. A. Etiemble, C. Lopes, G. Bouala, J. Borges, A. Malchère, C. Langlois, F. Vaz, P. Steyer, **Fracture resistance of Ti-Ag thin films deposited on polymeric substrates for biosignal acquisition applications**, Surface and Coatings Technology, Volume 358,2019, 646-653.
2. Y. Li, V. Garnier, C. Journet, J. Barjon, A. Loiseau, I. Stenger, A. Plaud, B. Toury, P. Steyer, **Advanced synthesis of highly crystallized hexagonal boron nitride by coupling polymer-derived ceramics and spark plasma sintering processes—influence of the crystallization promoter and sintering temperature**, *Nanotechnology*, Volume 30, 2018, 035604
3. M. Faustini, A. Cattoni, J. Peron, C. Boissière, P. Ebrard, A. Malchère, P. Steyer, D. Grosso, **Dynamic Shaping of Femtoliter Dew Droplets**, *ACS Nano, Volume 12, 2018, 3243-3252*
4. A. Etiemble, C. Der Loughian, M. Apreutesei, C. Langlois, S. Cardinal, J-M. Pelletier, J-F. Pierson, P. Steyer, **Innovative Zr-Cu-Ag thin film metallic glass deposed by magnetron PVD sputtering for antibacterial applications**, *Journal of Alloys and Compounds*, 707, 2017, 155-161.
5. S. Yuan, S. Linas, C. Journet, P. Steyer, V. Garnier, G. Bonnefont, A. Brioude, B. Toury**, Pure & crystallized 2D BN sheets synthesized via a novel process coupling both PDCs and SPS methods,** *Scientific reports*, Volume 6, 2016, 20388.
6. S. Yuan, C. Journet, S. Linas, V. Garnier, P. Steyer, S. Benayoun, A. Brioude, B. Toury, **How to Increase the h-BN Crystallinity of Microfilms and Self-Standing Nanosheets: A Review of the Different Strategies Using the PDCs Route,** *Crystals,* 6, 2016, 55.
7. S. Yuan, B. Toury, S. Benayoun, **Novel chemical process for preparing h-BN solid lubricant coatings on titanium-based substrates for high temperature tribological applications**, *Surface and Coatings Technology*, Volume 272, 2015, 366-372.
8. S. Yuan, B. Toury, C. Journet, A. Brioude, **Synthesis of hexagonal boron nitride graphene-like few layers,** *Nanoscale,* 2014, 6, 7838-7841.
9. S. Yuan, S. Benayoun, A. Brioude, O. Dezellus, B. Beaugiraud, B. Toury, **New potential for preparation of performing *h*-BN coatings via polymer pyrolysis in RTA furnace,** *Journal of the European Ceramic Society*, Volume 33, Issue 2, 2013, 393-402.

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