



## NANOPOROUS CARBON AS ENERGETIC NANOMATERIAL

Romuald Van Riet<sup>1,2</sup>, Peter Lodewyckx<sup>2</sup>, Michel H. Lefebvre<sup>2</sup>, Conchi O. Ania<sup>1</sup>

<sup>1</sup> *POR2E group, CEMHTI (UPR 3079), CNRS, Univ. Orléans, 45071 Orléans, France*

<sup>2</sup> *Department of Chemistry, Royal Military Academy, 1000 Brussels, Belgium*

\*Presenting author's e-mail: romuald.vanriet@rma.ac.be

### Introduction

Energetic materials (EM) are those capable of storing high amount of chemical energy, and rapidly convert it to thermal energy via external ignition. This has interesting perspectives in applications that require high energy conversion in a very short time (e.g., explosives, pyrotechnics, propellants) [1,2]. EM are typically composed of mixtures of oxidizer and fuel components either in one molecule (e.g., nitroglycerine) or in a composite (e.g. composite propellant). Recent research interests are directed towards the fabrication of energetic nanomaterials aiming to attain larger heat energy release rates, easily tuned by the size and distribution of the components.

This study investigates the use of nanoporous carbons as fuel matrix of novel energetic nanomaterials; combining an adequate porous structure (to be filled with an oxidizing agent) and an optimal oxygen balance (and surface chemistry), energetic nanomaterials based on nanoporous carbons offer a great potential for the fabrication of high-performance rocket propellants or explosives.

### Materials and Methods

Two commercial activated carbons (sample C manufactured by Cabot Norit, and sample F5001 manufactured by Blücher) were selected for this research. F5001 was used as-received and C was grinded and sieved and a particle size between 500 and 630  $\mu\text{m}$  was used. The carbons were characterized using various techniques included gas adsorption, mercury porosimetry, elemental analysis among most representatives. The energetic samples were prepared by immersing ca. 250 mg of nanoporous carbon in a saturated solution of oxidizing salt at room temperature for 24 hours. The suspension was filtered and the grains were carefully washed with n-hexane and dried at 120 °C under vacuum. The thermal properties of the nanoenergetic materials were measured by DSC experiments on a Q20 instrument (TA Instruments). The ignition temperature was measured according to the NATO STANAG 4491 [3] by loading 200 mg of the materials into glass tubes inserted into a heat sink, and controlling the temperature rise at a steady rate of 5 °C/minute, until an event occurs.

### Results and Discussion

Sodium perchlorate was chosen as an oxidizer for the fabrication of the energetic material based on the equilibrium adsorption capacity of the nanoporous carbons for this salt, its high density and its elevated oxygen balance. Assuming that sodium perchlorate is adsorbed at its bulk theoretical maximal density (TMD), and that the micropores and the mesopores are completely



filled by the salt, theoretical oxygen balances of -24 and +11 % could be achieved for C granular and F5001, respectively. The achieved experimental yield matched the sodium perchlorate quantity of 2.7 g per g of C, that corresponds to an oxygen balance equal to -16 %. It should be mentioned that no salt is visible on the surface of the carbon material. This indicates that a significant part of the micropores and the mesopores is filled by the oxidizing salt, probably at a density lower than the TMD, and confirms that the macropores play a role as well. As the obtained oxygen balance is in line with a potential use as an energetic material, the system carbon C granular / sodium perchlorate has been further investigated.

The DSC curves of sodium perchlorate, carbon C granular and the energetic material synthesized showed an onset of the decomposition peak of the latter around 320 °C; this is ca. 150 °C lower than the decomposition of pure sodium perchlorate. Such temperature difference may be explained due to the decomposition-point depression resulting from the sodium perchlorate confined in the pores of the carbon material. As expected, the pristine activated carbon did not show any reactivity in the same experimental conditions. An ignition temperature of 332 °C was measured for the composite prepared, in agreement with the DSC results. According to STANAG 4491 [3], the type of reaction can be described as an explosion. No flame or fume was observed and no solid residues were found after the experiment.

## Conclusions

An energetic nanomaterial has been synthesized by filling the nanoporous structure of a nanoporous carbon with an oxidizing salt. The filling method, i.e. an adsorption in liquid phase from a saturated aqueous solution followed by the crystallization of the salt during the subsequent evaporate on of the water, was successfully applied to the couples sodium perchlorate / C granular and sodium perchlorate / F5001. The results of DSC experiments and ignition temperature measurements have qualitatively confirmed the energetic character of the synthesized material, providing a proof of the proposed concept.

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## References

1. M. du Plessis, A Decade of Porous Silicon as Nano-Explosive Material, *Propellants Explos. Pyrotech.* 39 (2014) 348.
2. Q-L. Yan, M. Gozin, F-Q Zhao, A. Cohena, S.-P. Pang, Highly energetic compositions based on functionalized carbon nanomaterials, *Nanoscale* 8 (2016) 4799.
3. STANAG 4491 – Explosives, thermal sensitiveness and explosiveness tests. NATO Standardization Office. 2nd edition. 2015.