Ultra-fast efficient synthesis of one-dimensional nanostructures

Agnieszka Dąbrowska*,1, Andrzej Huczko1, Michał Soszyński1, Badis Bendjemil2, Federico Micciulla3, Immacolata Sacco3, Laura Coderoni3, and Stefano Bellucci3

1 Department of Chemistry, Warsaw University, 1 Pasteur str., 02-093 Warsaw, Poland
2 Department of Physics, University of Badji-Mokhtar, LEREC, BP. 12, 23000 Annaba, Algeria
3 Laboratori Nazionali di Frascati, Via E. Fermi 40, 00044 Frascati, Roma, Italy

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*Corresponding author: e-mail aggy-dab@wp.pl, Phone +48-22-8222375

1 Introduction

In a search for new methods to produce novel nanomaterials we propose the combustion synthesis [self-propagating high-temperature synthesis (SHS)], a thermal-explosion, autogenous mode of fast redox reaction between the strong reducing agent and oxidant. A careful selection of powdered reactants, which are very basic chemicals, can result in the efficient formation of novel nanostructures. The process takes place usually under far-from-equilibrium conditions so it may lead to products with a new morphology and stoichiometry. It is known that the one-dimensional (1-D) nanostructures (nanowires, nanotubes) often show distinct properties from their bulk counterparts because of the radial confinement. Here, we present a fast, simple, easy to operate and one-step chemical synthesis of branched 1-D SiC nanostructures, SiC nanofibres and 1-D nanocarbons from carbonates via an SHS route. The process can be easily escalated by using a bigger reactor chamber. Finally, a possible application of those nanomaterials in nanocomposites is proposed.

2 Experimental

The combustion was carried out in a high-pressure reactor, the modified calorimetric bomb provided with a polycarbonate window (Fig. 1) to perform in situ spectral registration of the emitted light. The details of the experimental procedure have been outlined elsewhere [1]. The effect of process parameters, such as: reactant composition (powdered Mg/carbonate, Si/PTFE or Si/PTFE/NaN3 mixture), initial combustion pressure (1–20 atm) and atmosphere (air, argon, nitrogen) was studied. The products were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and Raman spectroscopy [2]. The protocol for the chemical purification of sought products was proposed. The powder mixture of the reactants was placed in a quartz crucible (with the immersed carbon tape), the reaction was initiated by Ohmic heating and terminated usually within less than 2 s.

3 SHS process in carbonate systems

Different starting homogenous mixtures of Mg powder (Sigma–Aldrich, >99%) with various carbonates (Li2CO3, Na2CO3, CaCO3, FeCO3, (NH4)2CO3) were tried and the auto-thermal reactions were carried out under both reactive (air) and neutral atmosphere (argon) with an initial pressure of 1 or 10 atm to yield novel nanomaterials. Both SiC nanofibres and novel branched SiC nanostructures were also obtained from Si/polytetrafluoroethylene (PTFE) mixtures and their synthesis and purification have been optimized. The application of those one-dimensional (1-D) SiC nanostructures as a composite filler is presented.

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