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One-step Self-assembly for Producing Graphene and Carbon Nanocapsules

Jin-Wei Shi (石晉維) & Yeuh-Hui Lin* (林岳輝)

Abstract: The 2D graphene and 3D carbon nanocapsules (CNCs) structures of extreme strength may offer excellent protection to their encapsulated nanomaterials for applications. This interest has been driven by the potential applications of the filled nanocapsules, which lie in areas as diverse as optical, electronic, magnetic recording materials and nuclear medicine. Graphene and carbon encapsulated nanocapsules have been synthesized by a self-heating detonation process using an energetic explosive for providing the need of high temperatures, high shock waves, and parts of carbon sources in the presence of metallic-containing catalysts. The experimental results show that the metal compounds can be converted into metallic nanoparticles due to the fast decomposition with a reduction reaction after the detonation and this will play an important role for the growth of graphene related to different structures of carbon nanocapsules. The systematic of experiments indicate that the nanoparticles encapsulated in concentric layers of graphitic carbon. Additionally, these results experimentally used in this study show that it is possible for a cheaper process with simple one-step and can be as an alternative compared to these high energy and hardware intensive processes to prepare these nanomaterials.

Introduction: The synthesis of carbon-encapsulated metal nanoparticles has attracted much attention for their wide promising applications, especially in information technologies and biomedicines. The huge thermal energy transformed from the chemical energy of explosive compounds allows the reaction systems to reach high temperature and to support the detonation of metallic compound and the formation of the target structures and investigated the influence of transition metal surfaces and the degree of confinement of the explosive charge on the formation and morphology of the carbon nanostructures and other carbonaceous products

Experimental: Before the detonation experiments, the starting materials were mixed in desired ratios. When the detonation occurs, pressure and temperature were generated inside the vessel, varied with the loading density of RDX. After the detonation, the vessel was cooled in air to ambient temperature. High-resolution TEM images were performed operated at 200 kV, which is equipped with energy dispersive X-ray spectrometer (EDX) for elemental analysis.

Results and Discussion: In this process, the hot gases generated from the detonation collide with the gaseous metallic molecules and make latter quickly decompose into small carbon (Cn) and metal species, which subsequently condense into solid materials when cooling. In this work, the detonation reacting system shown in Figure 1 can provide a unique environment, which ensures a survival of the pre-fed catalyst and simultaneously a ready generation for the production of nano-structured materials. TEM images with EDX imagines for the as-synthesized products shown in Figure 2 analyses reveal that all of the simultaneous condensation of the metal clusters and the Cn species leads to the likely formation of an alloy. The feedstock can be mixed physically with the explosive compounds in solid state, and the detonation is carried out in a sealed vessel, so, any carrier gas is unnecessary. In this way, uniform iron nanoparticles well encapsulated within graphitic shells can be obtained. The content of carbon nanomaterials is estimated as the volume ratio of carbon nanostructures to the whole carbonaceous products based on systematic TEM investigations using the random sampling and repeated observations. Although it is difficult to completely rule out the presence of very small oxide and carbide particles from the XRD pattern obtained from Figure 3. In the present process, RDX not only serves as heat source by exothermic decomposition but also provides additional carbon source for the formation of core-shell structure or carbon nanocapsules although most of the carbon atoms involved in RDX molecular would be converted into volatile gases during the detonation. In addition, the as-synthesized products with carbon nanoparticles (L), carbon bamboo-like nanotubes (M) and the core-shell nanostructures for the catalytic detonation of metallic compounds (Figure 4).

Conclusion: This method represents a simple and low cost process towards carbon encapsulating structures, in which the needed high-temperature environment is self provided by the energy emitted from the detonation process. Results might can be used in the development of an efficient method for the production of graphitic carbon-encapsulated metallic nanoparticles, since understanding bottom-up self-assembly system uptake within metallic-catalyzed conversion of a carbon-rich explosive matrix into nanostructures is still as an important key aspect in developing suitable syntheses of the carbon-encapsulated metal nanoparticles and other related nanomaterials.

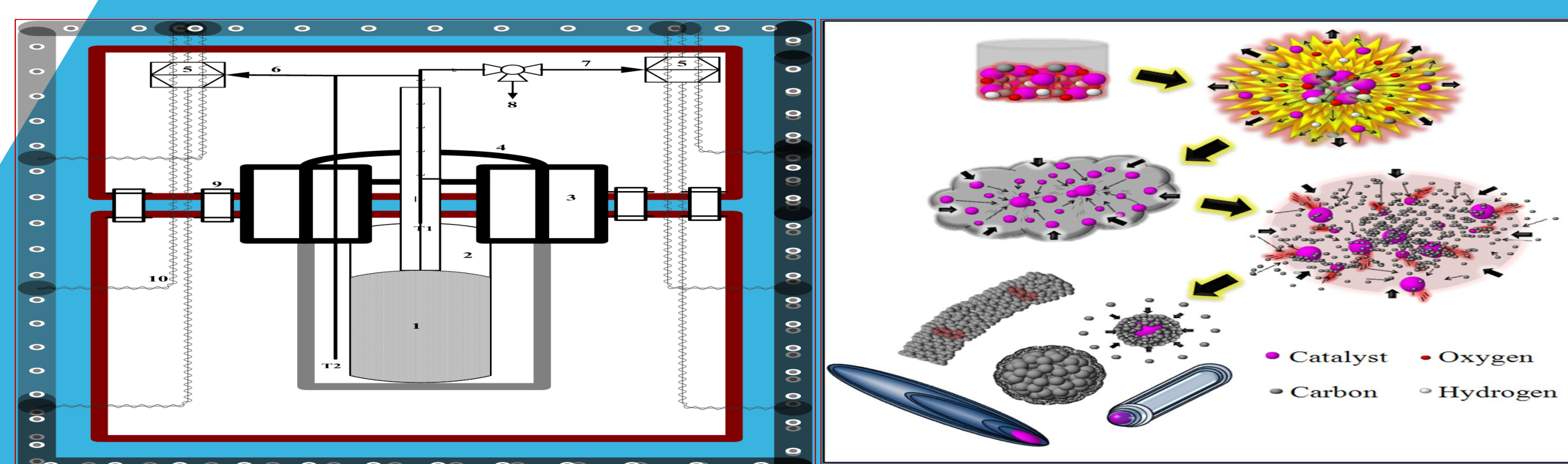


Figure 1. Schematic diagram (left) and reaction routes (right) of detonation reaction system for the assembly of various nanostructures.

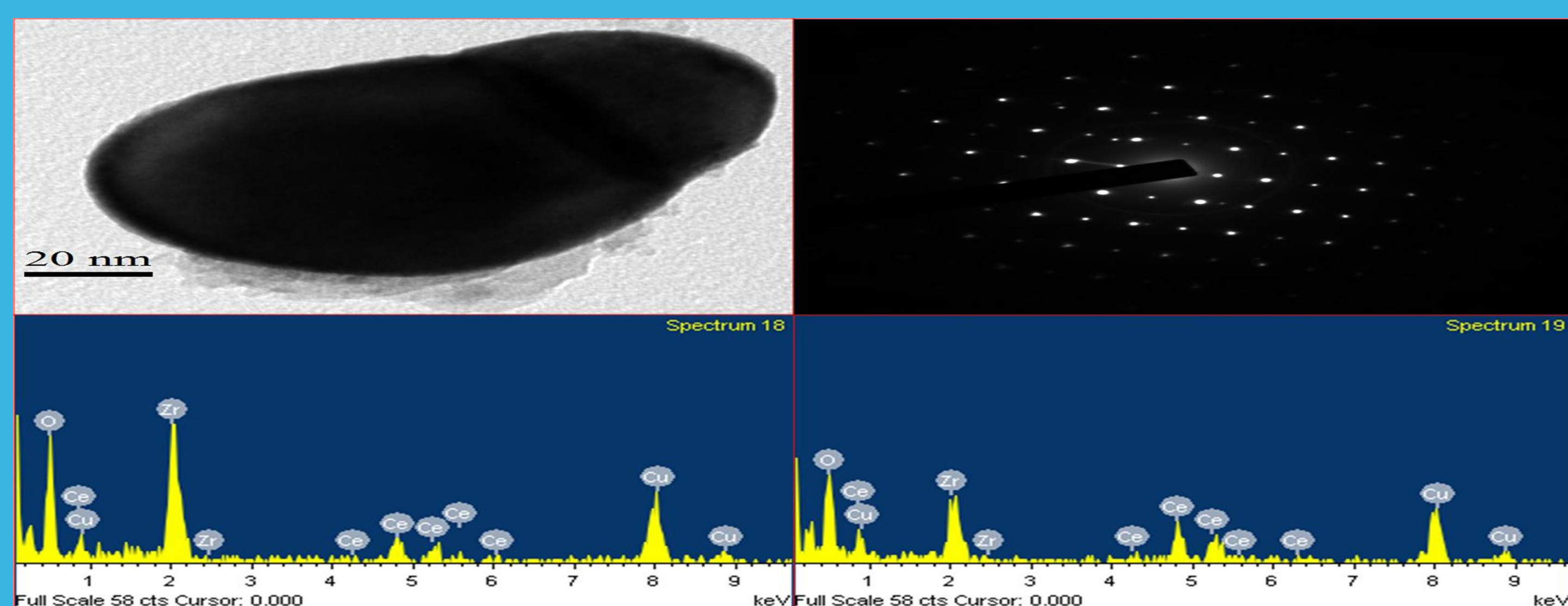


Figure 2. TEM images with EDX imagines for the as-synthesized products.

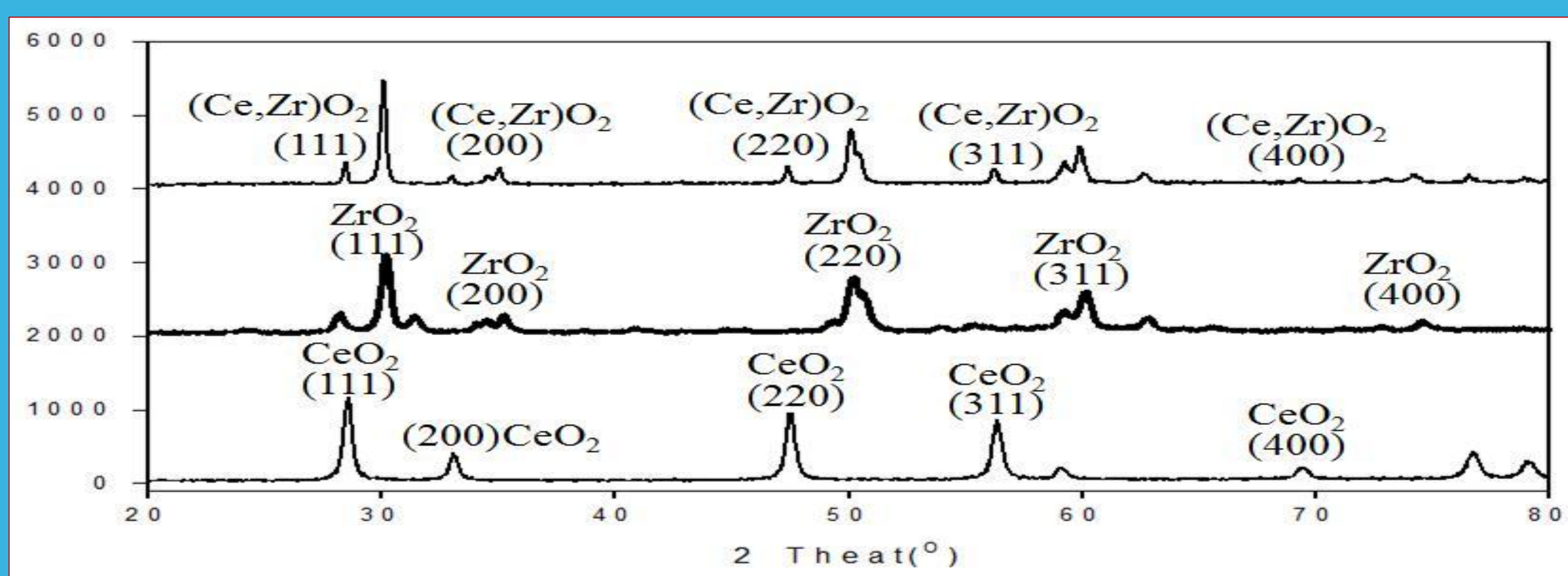


Figure 3. XRD spectrums of as-synthesized products

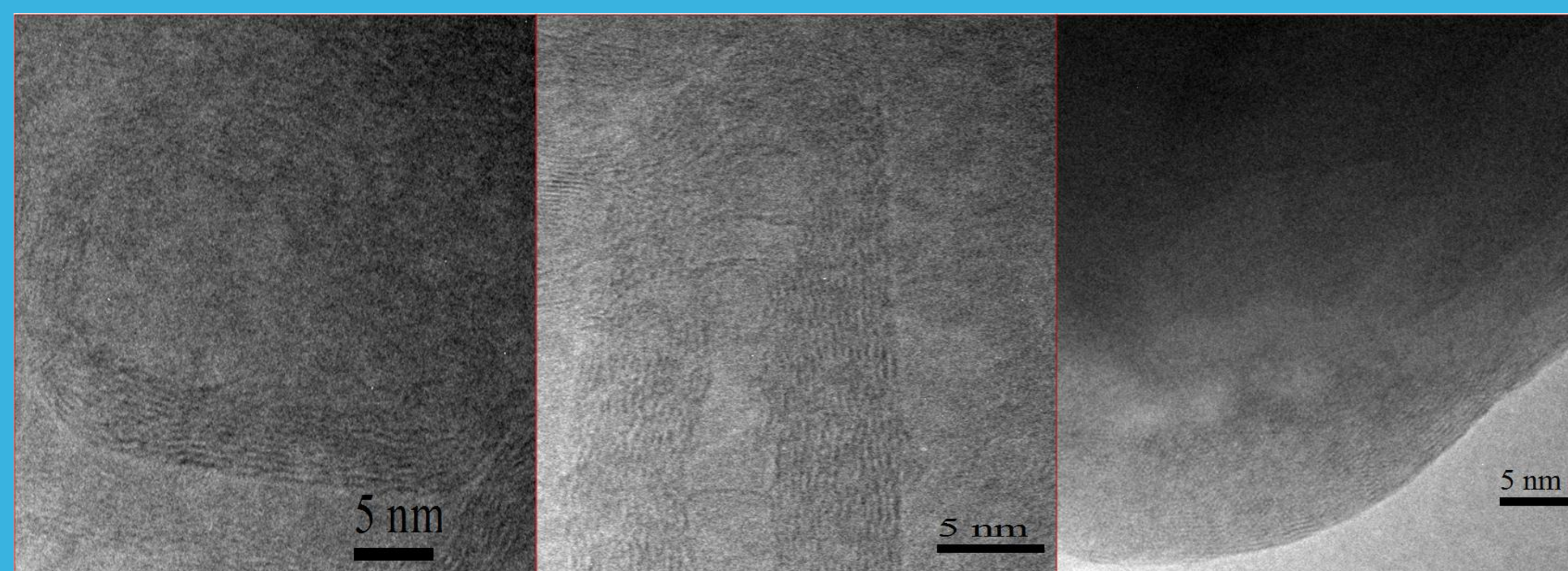


Figure 4. TEM images of as-synthesized products with carbon nanoparticles (L), carbon bamboo-like nanotubes (M) and the core-shell nanostructures

CONTACT PERSON

*Professor Y.-H. Lin
Department of Applied
Greenery, Kao Yuan
University, Kaohsiung 840
Taiwan, ROC.
E-Mail: t50027@cc.kyu.edu.tw

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