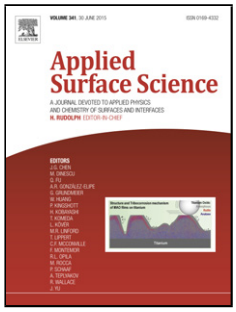


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# Synthesis and structural features of resorcinol–formaldehyde resin chars containing nickel nanoparticles

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## Abstract

A series of meso- and microporous carbons containing magnetic Ni nanoparticles (Ni/C) with a variety of Ni loadings were synthesized by a simple one-pot procedure through carbonization of resorcinol-formaldehyde polymers containing various amounts of nickel(II) acetate. Such composite materials were characterized by $N_2$ sorption, Raman spectroscopy, X-ray diffraction (XRD), scanning electron microscopy (SEM) and Transmission electron microscope (TEM). The XRD patterns reveal peaks corresponding to face centered cubic nickel with the average size of crystallites of 17-18 nm. SEM and TEM results reveal that the formation of the nanoparticles took place mainly in the carbon spheres (1-2 μm in size) and on the outer surface as well. The as-prepared composites are characterized by a core-shell structure with well-crystallized graphitic shells about 8-15 nm in thickness. The Raman spectra show that Ni content influences the structure of the carbon. It was also shown that the morphology (particle shape and sizes) and porosity (pore volume and pore size distribution) of the chars are strongly dependent on water and nickel contents in the blends. One of the applications of Ni/C was demonstrated as a magnetically separable adsorbent.

## Introduction

Porous carbon materials are of great interest due to their well-controlled pore architecture, high surface area, electrical conductivity, thermal stability, chemical inertness, biocompatibility, and specific surface properties. These features contribute to their high performance in various applications such as separation, catalyst supports, adsorption, energy storage/conversion, and biomedical engineering [1-3]. However, carbon powders dispersed in water can cause secondary pollution. The conventional separation approach normally involves a filtration or centrifugation procedure, which is rather complex and expensive. Because of easy separation and controlled placement of magneto-sensitive nanoparticles by means of an external magnetic field, the magnetic nanoparticles have been widely investigated [4, 5]. In addition, the mesoporous carbon materials with incorporated magnetic nanoparticles can also act as selective catalysts and adsorbents with further modification of the carbon surface.

Porous high-quality magnetic carbon nanocomposites have so far been prepared using several popular methods including template-based synthesis [6], chemical vapor deposition [7, 8], filling process [9], sol–gel process [10], hydrothermal/solvothermal method [11], pyrolysis procedure [12], detonation induced reaction [13] *etc*. Recently most frequently encountered methods are CVD and template-based synthesis because they allow obtaining high-quality products. However, the quality is much dependent on the structure of the template used, which is difficult to obtain according to the desired structures and properties. Besides, the removal of the template, without destruction of the product, is still one of the main challenges for the synthesis. The main merit of the CVD method is that it allows a precise control on the carbon nanostructure, but the main disadvantages of this method are the high cost, complex equipment and energy consummation. The pyrolysis procedure is based on the heat treatment of a mixture containing the soluble metal salt (magnetic metal source) and a type of organic compounds enriched with carbon. Pyrolysis provides an available way to fabricate nanostructured materials, due to its high efficiency and low cost.