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Synthesis of the hybrid porous rods and nanosheets composed of the nickel ions and poly(*p*-phenylenediamine) in aqueous solution

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Abstract

A new kind of metal-organic hybrid materials composed of the nickel ions and poly(*p*-phenylenediamine) have been synthesized in aqueous solution. Long hybrid rods and large nanosheets have been obtained by using the different ratios of the initial reactants. The synthesized rods and nanosheets have been characterized by SEM, TEM, AFM and XPS. The synthesized rods have been found to have porous polymeric structures. The nanosheets are made up of many small nanoparticles.

Keywords: Inorganic–organic hybrid nanomaterials; Porous rods; Nanosheets; Nickel ions; Poly(*p*-phenylenediamine)

1. Introduction

The syntheses of the different inorganic–organic hybrid materials have been paid considerable attention in recent years. Among the various inorganic–organic hybrid materials, metal-organic hybrid materials are the most interesting materials for many researchers. By using different metal ions, and selecting special organic ligands, a large number of metal-organic materials have been synthesized and reported. Recently, some metal-organic hybrid materials have been demonstrated for enantioselective separations, gas adsorption, ion exchange and catalysis [1–4]. Up to now, most researches of the metal-organic materials are focused on obtaining large crystal structures. When the single crystal of a hybrid material can be obtained, the detailed structure and its relationship with the property can be well studied and utilized. But in view of the practical applications, if the hybrid materials can be obtained in submicrometer-scale or nano-scale level, there will be much more surface areas of the materials, which will facilitate some physical and chemical process for their application. However, the syntheses of the different nanostructures of the hybrid metal-organic materials have not been paid enough attention according to their potential applications. In this paper, some submicrometer-scale and nano-scale structures of a new kind of metal-organic materials are reported.

2. Experimental

2.1. Chemical and synthesis

Ultra pure water was used throughout this study and its resistivity was >18 MΩ cm. *p*-phenylenediamine (PPD) was purchased from Sigma. $NiCl_2 6H_2O$ was of analytical grade and used without further purification. For synthesis of the hybrid rods, 16 mL of the 0.05 M $NiCl_2 \cdot 6H_2O$ aqueous solution was added into a 50 mL beaker, and then 4 mL of the 0.05 M *p*-phenylenediamine aqueous solution was added into the beaker under vigorous stir. The color of the mixed solution was gradually turned into navy blue. The mixed solution was vigorously stirred at least 5 h. Finally, the solution was centrifuged, a blue precipitate was obtained. The precipitate was washed three times with the absolute ethanol and then suspended in absolute ethanol for SEM, AFM, TEM, XPS characterization. For synthesis of the nanosheets, 4 mL of the 0.05 M $NiCl_2 \cdot 6H_2O$ aqueous solution and 16 mL of the 0.05 M *p*-phenylenediamine aqueous solution were used as the initial reactants. The following operations were the same as those used for the hybrid rods synthesis.

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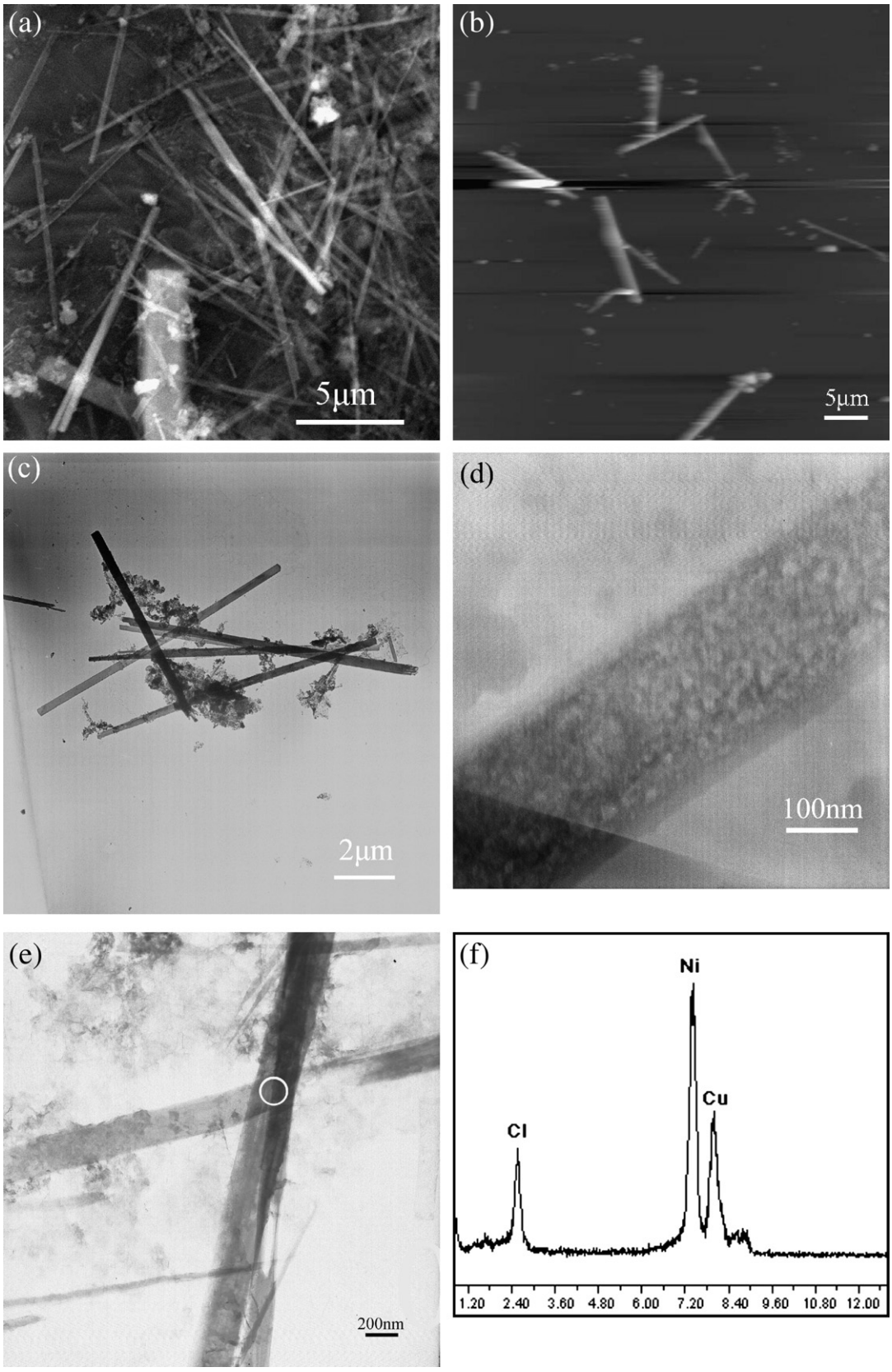

Fig. 1. (a),(b),(c) show the typical SEM,AFM and TEM images of the synthesized rods, respectively. (d) is the high magnification TEM images of the synthesized rods. (e) and (f) are the TEM images and corresponding energy dispersive analysis of X-rays (EDAX) of the synthesize rods, the white circle area in the (e) is the place for the EDAX data collection.