

ORIGINAL PAPER

Influence of ethanol on the chain-ordering of carbonised polyaniline

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Polyaniline (PANI) was prepared by the oxidation of aniline hydrochloride with ammonium peroxydisulphate in water or in a water–ethanol mixture. In the presence of ethanol, PANI nanotubes and nanorods were observed. Both products were carbonised in a nitrogen atmosphere at 650 °C. Initial and carbonised products were characterised by scanning and transmission electron microscopies, thermogravimetric analysis and wide-angle X-ray scattering. Their molecular structure was studied by UV-VIS, infrared, and Raman spectroscopies. Carbonised sample obtained from the PANI salt prepared in the presence of ethanol exhibits Raman spectrum which corresponds to a more ordered carbon-like material than carbonised samples obtained from the PANI base and the PANI salt prepared in pure water. The influence of ethanol present in the reaction mixture on the molecular and supra-molecular structure of PANI and, consequently, on the enhancement of chain-ordering of carbonised PANI is discussed.

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Introduction

Polyaniline (PANI) is a conducting polymer which is the object of frequent studies due to its good environmental stability (MacDiarmid et al., 1987) and the variety of morphologies it forms (Konyushenko et al., 2010; Stejskal et al., 2010a; Tran et al., 2011). A fused granular structure is obtained by the precipitation polymerisation in acidic media (Stejskal & Gilbert, 2002). Nanotubes are produced in the presence of weak organic acids (Konyushenko et al., 2006; Stejskal et al., 2006; Park et al., 2007; Song et al., 2007), polymeric acids (Zhang et al., 2007a, 2007b) at low concentrations of strong inorganic acids (Zhang et al., 2002; Wu et al., 2008a), or in the absence of acids (Trchová et al., 2006a; Chiou et al., 2007; Huang & Lin, 2009), i.e. under the conditions of moderate acidity at the start of the oxidation process. Microspheres of several micrometre sizes have often been a product of aniline oxidation started under al-

kaline conditions (Wang et al., 2005, 2010; Jin et al., 2010; Stejskal et al., 2008; Stejskal & Trchová, 2012).

The literature has demonstrated that the addition of miscible organic solvents to aqueous media affects the morphology of the PANI produced. The transition from the granular morphology in favour of nanofibres or nanotubes was observed when the reaction mixture contained methanol (Zhou et al., 2007; Huang & Lin, 2009; Konyushenko et al., 2011a; Zhang et al., 2011), ethanol (Geng et al., 1998; Kan et al., 2004, 2006; Ghiurea et al., 2011; Yang et al., 2012), propan-1-ol (Huang & Lin, 2010a), phenol (Wu et al., 2008a), ethylene glycol and glycerol (Konyushenko et al., 2011b), 1,6-hexanediol (Huang & Lin, 2010b), or dimethylformamide (Sun et al., 2011). Aniline tetramer was observed to order to regular nanostructures after the addition of ethanol, due to hydrogen bonding between the aniline and ethanol molecules (Wang et al., 2010; Huang & Lin, 2010a).

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