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Swelling behavior of poly(*N*-cyclohexylacrylamide-*co*-acrylamide/AMPSNa) gold nanocomposite hydrogels

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ABSTRACT

In this study, poly(*N*-cyclohexylacrylamide-*co*-acrylamide/sodium 2-acrylamido-2-methyl propanesulfonate) gold nanocomposite hydrogels were synthesized by free-radical copolymerization in methanol/water at 60 °C. The gold nanocomposites hydrogels were prepared *via in situ* polymerization using gold nanoparticle. The weight percentage of *N*-cyclohexylacrylamide (NCA) and acrylamide (AM) monomers was fixed 50:50 and the weight of sodium 2-acrylamido-2-methylpropanesulfonate (AMPSNa) was varied from 0.1 to 0.5 g. The swelling behavior of gold nanocomposite hydrogels was studied by gravimetric method and it was found that swelling increases as the amount of sodium 2-acrylamido-2-methylpropanesulfonate increases. The surface morphology study indicates the formation of spherical shaped gold nanoparticle in the polymer matrix.

1. Introduction

Hydrogels are three-dimensional polymeric networks which are capable of absorbing large quantities of water, but remain insoluble due to chemical or physical crosslink between individual polymeric chains [1]. Recently, there is a great deal of interest concerning the production of nanoparticles in the hydrogel networks since they have valuable applications in bio-related fields [2]. Hydrogels can swell to profitable rates when placed into an appropriate environment, which means a specific pH, temperature, electric field, light, pressure or specific molecule [3–6]. N-substituted acrylamides are temperature sensitive monomers and are producing thermosensitive polymers that can be used in drug delivery and dewatering of protein solution [7,8]. The hydrophilic/hydrophobic interaction (balance) of the hydrogels, the degree of cross-linking, and especially, the degree of ionization and its interaction with counter ions are the important parameters which control the equilibrium swelling. The hydrophilicity of the network is due to the presence of certain groups like hydroxylic (—OH), carboxylic (—COOH), amidic (—CONH—), primary amidic (—$CONH_2$), sulphonic (—SO_3H), and others that can be found within the polymer backbone or as lateral chains [9]. Brundha and Pazhanisamy prepared a novel nanocomposite hydrogels based on *N-tert*-amylacrylamide. Terpolymerization of hydrophobic (NTA) and hydrophilic monomer (AM) to make hydrophobic and hydrophilic interaction followed by the addition of ionic monomer sodium 2-acrylamido-2-methyl-1-propanesulphonate (AMPSNa) via free radical polymerization at 60 °C. The incorporation of nano clay enhances the swelling rate to a greater extent [10]. Jayaramudu et al., developed a novel biodegradable gold nanocomposites hydrogels as antibacterial agent using acrylamide and wheat protein isolate. The result reveals that the biodegradable gold nanoparticle composite hydrogels can be used as potential candidates for antibacterial applications [11].

In this work, we have synthesized gold nanocomposite hydrogel by *in situ* polymerization of *N*-cyclohexylacrylamide, acrylamide and sodium 2-acrylamido-2-methyl propanesulfonate using ammonium persulphate as free radical initiator and *N*,*N*′-methylenebisacrylamide (MBA) as cross linker. Swelling behavior and swelling kinetics of the obtained hydrogels were evaluated. Distribution of gold nanoparticles within the polymer matrix was studied by SEM analysis.

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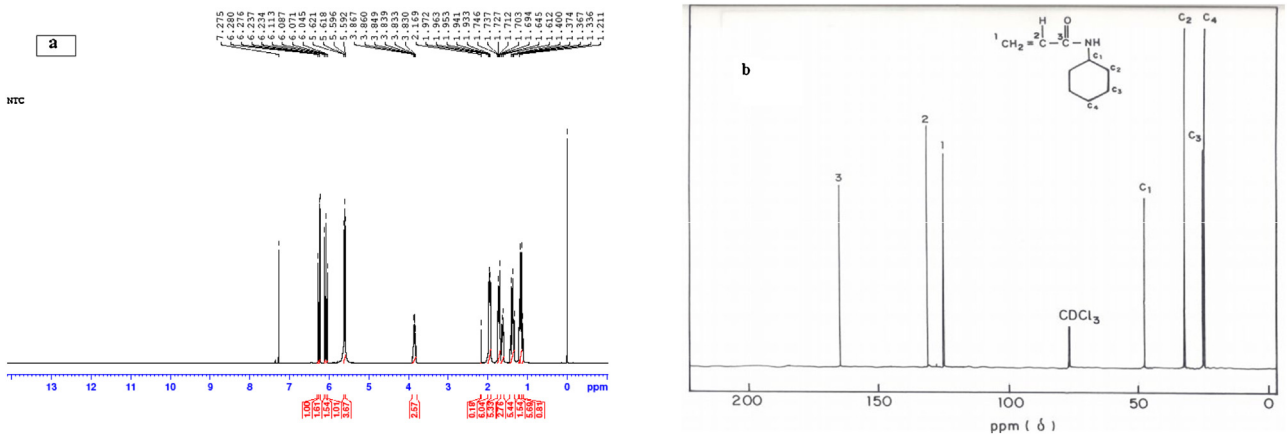

Fig. 1. ^{1}H NMR (a) and ^{13}C NMR (b) spectra of *N*-cyclohexylacrylamide.

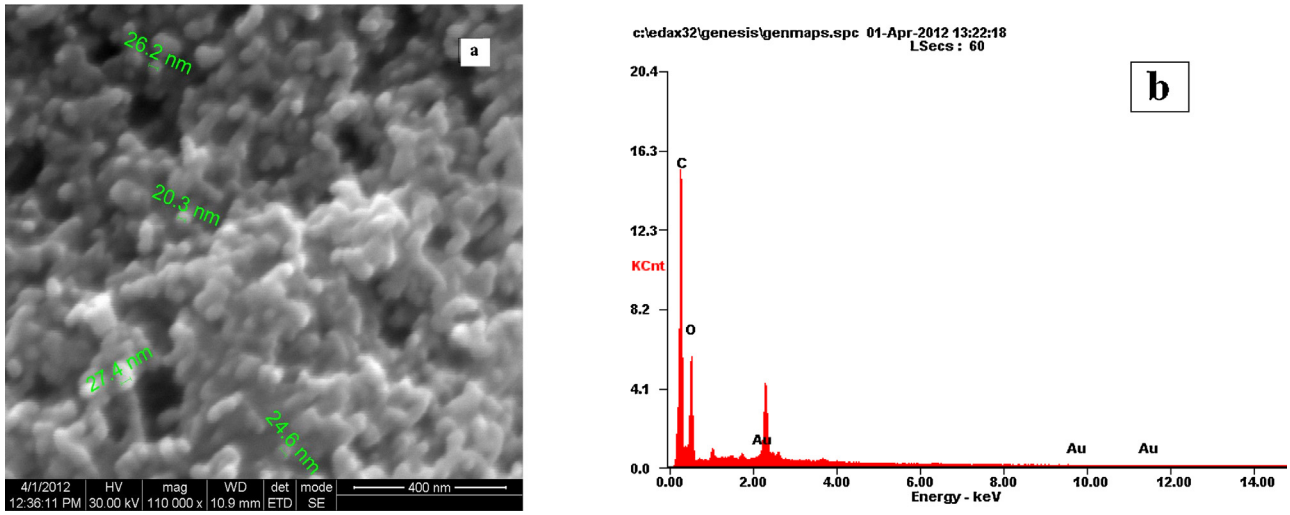

Fig. 2. SEM image (a) and EDAX (b) of gold nanoparticle.

2. Experimental

2.1. Materials

Acrylamide (AM, Merck) was recrystalized from acetone/ethanol mixture. Ammonium persulphate (APS) and Sodium hydroxide were supplied from Aldrich. The crosslinker *N*,*N*′-methylene-bis-acrylamide (MBA) was used as received.

2.2. Preparation of monomers

The monomer *N*-cyclohexylacrylamide was synthesized by the reaction of cyclohexanol with acrylonitrile. The product was recrystalized in warm dry benzene [12]. The ionic monomer AMPSNa was prepared by neutralizing the 2-acrylamido-2-methyl-1-propanesulfonic acid using Sodium hydroxide.

2.3. Preparation of gold nanoparticles

100 ml of 1.0 mM $HAuCl_4$ is boiled with vigorous stirring and then 10 ml of 38.8 mM sodium citrate is added rapidly. The pale yellow color of the solution is turned into wine red color. Boiling is continued for 10 min and stirred for 30 min. The synthesized gold nanoparticle containing solution is stored in refrigerator [13].

2.4. Synthesis of poly (N-cyclohexylacrylamide-co-acrylamide/AMPSNa) gold nanocomposite hydrogels

The hydrogels were prepared by free radical copolymerization using NCA, AM and AMPSNa in the presence of MBA as crosslinker and APS for initiating system (shown in Table 1). A solution containing a weighed amount of NCA, AM, MBA, APS and certain amounts of AMPSNa (0.10, 0.30, 0.50 g) were dissolved in methanol/water (3:1) mixture and final volume was made 10 ml in a polymerization tube. A solution containing 10 mg (mg/ml) of gold nanoparticle was added with constant stirring. The content of the solution placed in thermostatic water bath at for 24 h. The resulting hydrogel is washed with (methanol/water) mixed solvent to remove the unreacted monomers and dried at 50 °C.

2.5. Characterization

The swelling behavior of dried hydrogels were carried out by immersion in doubly distilled water at 30 ± 0.1 °C in a water bath. The water absorbed was determined by weighing the samples, after wiping, at various time intervals. The swelling behavior and the diffusion mechanism of hydrogels are determined by Eqs. (1) and (2) respectively. FTIR spectral analysis of the gold nanocomposite hydrogels were recorded using Schimadzu. Images for the gold nanoparticle and gold nanocomposite hydrogels were recorded