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Research Article

SYNTHESIS, CHARACTERIZATION AND EVALUATION OF ELECTRICAL STIMULUS SENSITIVE BEHAVIOR OF Gt-cl-poly(AA) SUPERABSORBENT HYDROGEL

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ABSTRACT

In this research paper, synthesis of *Gum tragacanth*-acrylic acid based hydrogels using KPS-ascorbic acid and glutaraldehyde as an initiator-crosslinker via free radical polymerization technique was carried out. Morphological difference was observed using Scanning Electron Microscopy (SEM). Electrical stimulus studies on the swelling of candidate polymer using distilled water and artificial biological electrolytic system were carried out using 10V AC/DC source at 37^{0}C.

Keywords: *Gum tragacanth,* SEM, Superabsorbent, Electrical stimulus sensitive

INTRODUCTION

Superabsorbent polymers have the property to absorb and retain extremely large amounts of a liquid relative to their own mass[1]. Cross-linked hydrogels[2] undergoes hydrogen bonding with water molecules. This gives rise to swelling and holding of large amount of water while maintaining the physical dimension and structure[3]. Superabsorbent polymers can absorb 500 times its weight, when immersed in deionised /distilled water, but its absorbency decreases to 50 times when immersed in 0.9% saline solution. Some unique physical, chemical and biological properties of natural based polymers like non-toxicity, biocompatibility, renewability, equilibrium swelling and biodegradability give it an edge over the synthetic polymers. Dextrin, starch, psyllium and guar gum[4-7] are among the natural polysaccharides being modified by various researchers. Biocompatible polymeric hydrogels are extensively used for biomedical and pharmaceutical applications such as sustained drug delivery[8-9], pulsatile drug delivery[10-11], for controlling cell adhesion in tissue engineering[12-13], as components of extracellular matrix[14], for reconstruction or repair of soft tissues[15], as biosensors[16] and muscle actuators[17].

Physiological stimulus such as pH, ionic strength, temperature and electric field resulted in the phase transition of stimuli-responsive hydrogels. Yuk and Lee[18] demonstrated the reversible bending of crosslinked acrylamide gel induced by electric current in aqueous NaCl and proposed the mechanism for the bending phenomenon. Kim et al.[19] reported the bending behaviors of poly(acrylic acid)/poly acrylonitrile semi IPN hydrogels under various voltage conditions. They reported that as the applied voltage increases, the bending speed increases and further the deformation of the IPN hydrogels was reversible when the applied voltage was turned on and off. Osada and Hasebe[20] reported the electrically activated artificial muscle system which contracted by the electrical stimulus under isothermal conditions. They reported that addition of NaCl increased the rate of water release whereas, addition of organic solvents such as ethanol, acetone reduces the rate of water release and the contraction resulted from the electrostatic interaction between charged macromolecules and the electrodes lead extensive dehydration of the gel. Uhl[21] studied the use of electricity in bone healing and to treat scaphoid fractures. Sumano and Mateos[22] reported forty-four patients were treated with electrical stimulation of the skin. Following electro-stimulation in all patients healing proceeded in a thoroughly organized manner, almost regardless of the severity of the type of wound or burn treated. Large volume change was observed in hydrogels under the influence of external stimuli[23].

In this research paper, *Gum tragacanth*-acrylic acid based hydrogels was studied for electrical stimulus under AC/DC influence and its impact on swelling deswelling behavior.

MATERIAL AND METHODS

Gum tragacanth (SD Fine Chemicals Pvt. Ltd.), ascorbic acid-potassium persulphate (SD Fine Chemicals Pvt. Ltd.), glutaraldehyde (MERCK), acrylic acid (MERCK) and electrolytic powder (Cipla Pharmaceutical Ltd.) were used as received.

Instrumental Analysis

Scanning Electron Micrographs of the candidate polymers were taken on LEO-435VF, LEO Electron Microscopy Ltd. Thermal studies were carried-out on TGA/DTA 6300, SLL EXSTAR 6000 at a heating rate of 10 °C/min in air.

Synthesis of superabsorbent

25ml of distilled water and 1.0 g of *Gum Tragacanth* were taken in a reaction flask and 0.5 mol L^{-1} of acrylic acid was added with constant stirring. This was followed by the addition of ascorbic acid-KPS in 1:1.25 molar ratios and 0.42 mol L^{-1} of glutaraldehyde. The reaction was carried out at pH 7.0 for 90 min at 40 °C. The homopolymer was removed on completion of reaction by washing with hot water and gel was allowed to stand for about 10-12 hours undisturbed for gelling process to take place. The product obtained was dried in oven at 60 °C till a constant weight was obtained. The percentage grafting (%G) and percentage swelling (%S) were calculated as per the following equation (1):

$$\%S \text{ or } \%G = \frac{F_W - I_W}{I_W} \times 100 \quad (1)$$

Where Iw = initial weight, F_w = final weight

Preparation of artificial biological fluid

Artificial biological fluid was prepared in the laboratory using electrolytic powder and distilled water (DW). 25gms of electrolytic powder was dissolved in 1000ml of distilled water to obtain the artificial biological fluid of 25000ppm.

Electrical stimulus sensitive studies using DC / AC source

Apparatus used for the electrical stimulus sensitive studies is shown in the Fig. 1. The system consists of an inner compartment [20.5cm(l)×15cm(b)×10cm(h)], two copper electrodes [8cm(l)×5.3cm(b)×0.2cm(h)], a thermostat, thermometer and an outer compartment [24.5cm(l)×19cm(b)×12cm(h)] acting as a closed system. Distance between two copper electrodes was about 15.5cm. Preoptimised and weighed dried hydrogel was immersed in artificial biological fluid at 37^{o}C and 10V AC/DC source was applied. The polymer was found to show swelling behavior and was weighed after a regular time interval. Percentage swelling (Ps) was calculated by the formula:

$$Ps = \frac{W_s - W_d}{W_d} \times 100$$

Where W_s and W_d are weights of swollen polymer and dry polymer, respectively

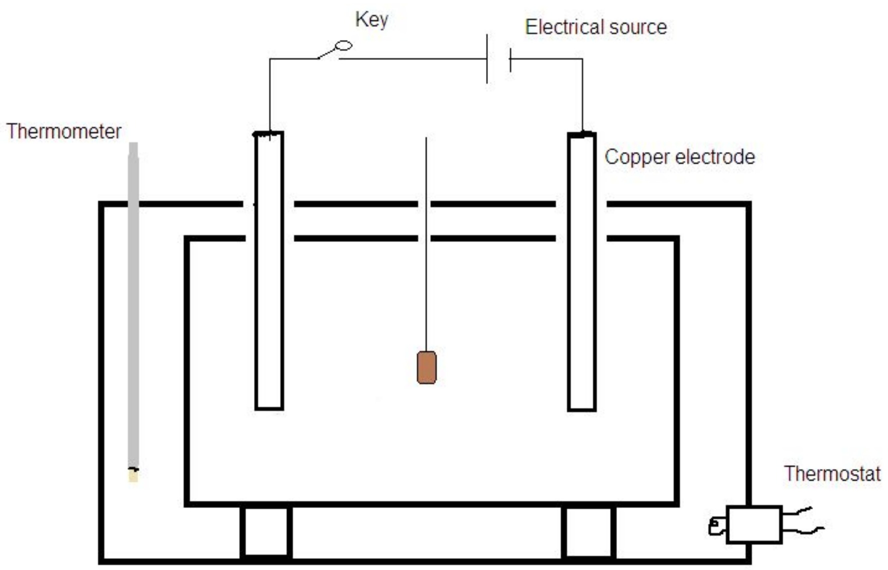
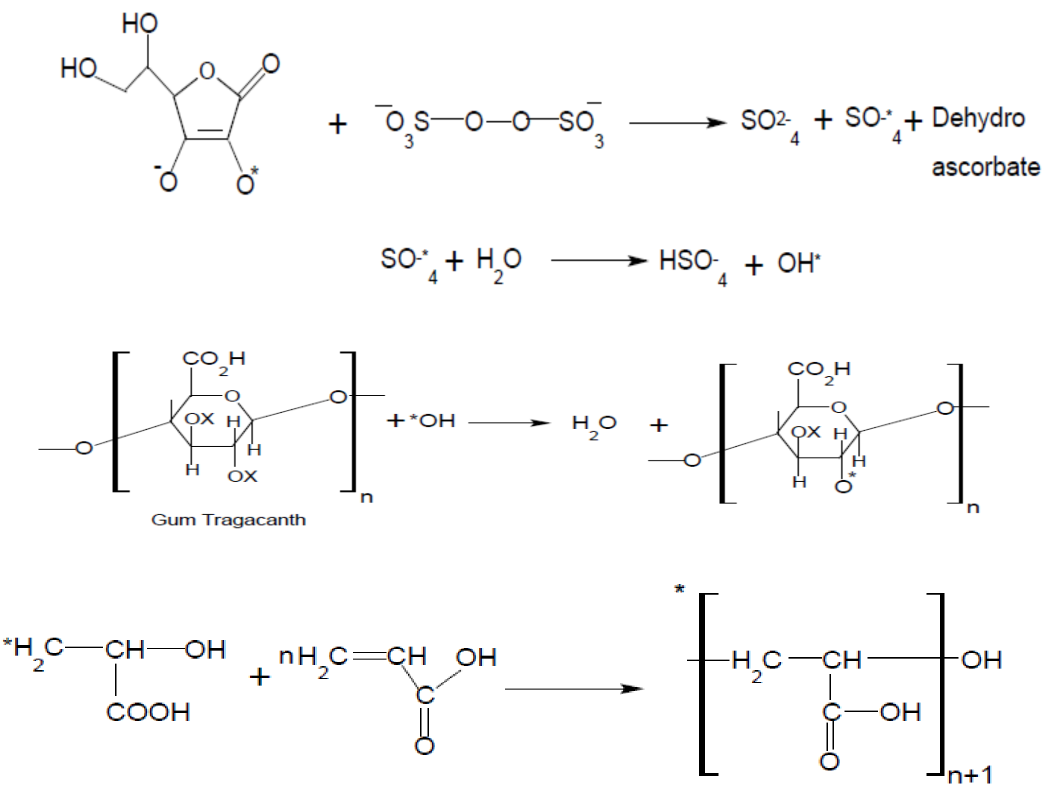


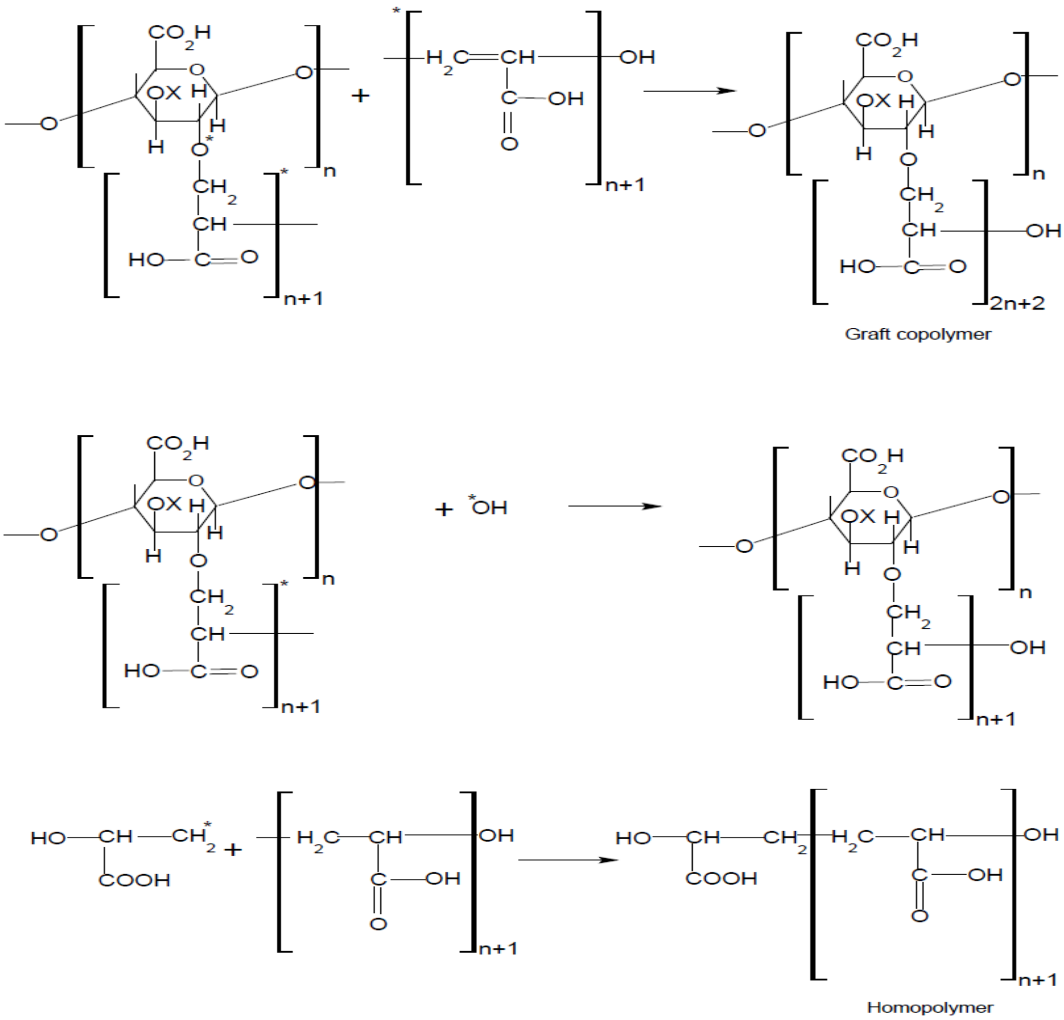
Fig. 1: Apparatus for AC/DC stimuli studies

RESULTS AND DISCUSSION

Mechanism

Graft copolymerization of vinyl monomer onto the backbone takes place through –OH and -CH_2 groups. Reaction mechanism for the grafting to take place can be summarized as below:





OH^* and SO_4^{-*} radicals are produced which create the active sites both on backbone and monomer. Reaction between monomer and backbone propagate the chain further resulting in the formation of graft copolymer along with homopolymer. Reaction termination takes place on collision of two live chains or reaction of OH^* with the propagating chain.

Scanning Electron Microscopy (SEM)

A distinct morphological difference has been observed in case of SEMs of backbone and its graft copolymer with vinyl monomer. (Fig. 2)

FTIR

Broad peaks were obtained in the FTIR spectrum of *Gum tragacanth* at 3427.08 cm^{-1} (O-H stretching bonded absorption of carbohydrates), 2934.78 cm^{-1} (CH_2 asymmetric stretching), 1039.07 cm^{-1} (C-O stretching region as complex bands, resulting from C-O and C-O-C stretching vibrations), 638 cm^{-1} (Pyranose ring). On the other hand, FTIR spectrum of Gt-cl-poly(AA) showed peaks at 2854.31 cm^{-1}, 2659.42 cm^{-1} and 2521.73 cm^{-1} (O-H stretching of carboxylic acid). 1750.23 cm^{-1} and 1613.40 cm^{-1} (C=O stretching in carboxylic acid) was observed.

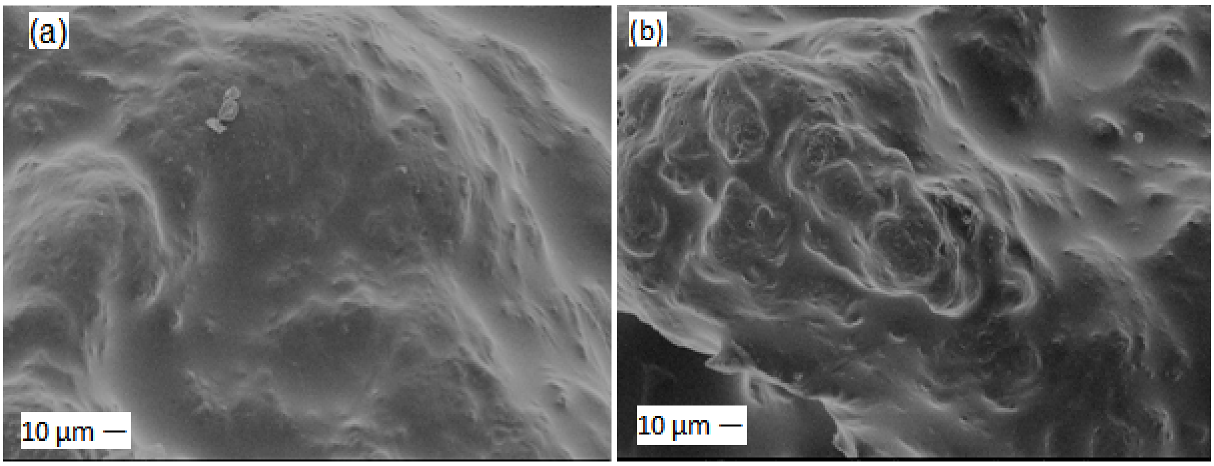


Fig. 2: SEM (a) *Gum tragacanth*; (b) Gt-cl-poly(AA)

Electrical stimulus sensitive studies using DC / AC source

Effect of AC source

From the Fig. 3 (a) it is evident that in both the media percentage swelling increases with time interval under the influence of AC source. In case of distilled water percentage swelling was found to increase for 24 hrs and attained maxima afterwards. However, in case of artificial biological fluid percentage swelling was found to increase until 19 hrs and became constant with further increase in time interval. Maximum swelling found in artificial biological fluid and distilled water was 344% and 361%, respectively. Under the influence of AC source, electrolysis takes place with the generation of H^+ and OH^- ions, which exerted ion screening effect. Due to electrostatic repulsions, the candidate polymer was found to exhibit swelling. Moreover, under the influence of AC source, lesser swelling was found in artificial biological fluid in comparison to distilled water. It is because of the fact that artificial biological fluid is a hypertonic solutions and the polymer showed shrinking behavior in higher concentration solutions due to reverse osmosis[24].

Effect of DC source

Percentage swelling was observed to increase with time interval under the influence of DC source (Fig. 3b). Maximum swelling in artificial biological fluid and distilled water was found to be 323% and 350%, respectively. It can be due to the fact that under the influence of DC source electrolysis takes place with the generation of H^+ and OH^- ions, which exerted ion screening effect and electrostatic repulsions took place. This resulted in increased swelling rate of crosslinked system. Moreover, under the influence of DC source, maximum swelling in artificial biological fluid was found to be lower in comparison to distilled water. This can be due to the fact that artificial biological fluid is a hypertonic solution and due to reverse osmosis polymer showed shrinking behavior under higher concentrations[24].

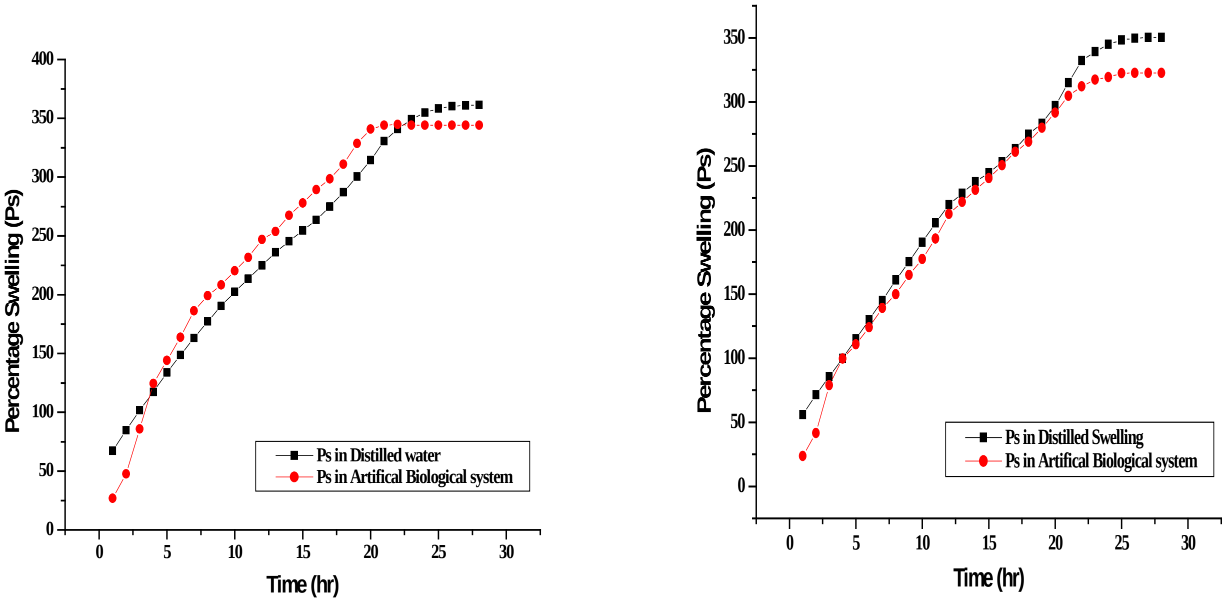


Fig. 3(a): Effect of AC source on percentage swelling of Gt-cl-poly(AA) in distilled water and artificial biological fluid; (b) Effect of DC source on percentage swelling of Gt-cl-poly(AA) in distilled water and artificial biological fluid

CONCLUSION

The candidate polymer synthesized was found to show superabsorbent behavior both in distilled water and artificial biological fluid. Moreover, the product obtained showed AC/DC stimulus sensitive behavior which could be compared with the tissues in response to electrical stimulus in the body. Such smart electrical stimulus sensitive material could be used for the replacement of body organs like kidney, lung, muscles and heart valves and have got a great significance in tissue engineering.

REFERENCES

1. Bajapi SK, Johnson S Superabsorbent hydrogels for removal of divalent toxic ions. Part I: Synthesis and swelling characterization. React Funct Polym 2005; 62: 271-283.
2. Kabiri K Synthesis of fast-swelling superabsorbent hydrogels: effect of crosslinker type and concentration on porosity and absorption rate. Eur Polym J 2003; 39: 1341–1348.
3. Mahdavinia GR, Pourjavadi A, Hosseinzadeh H, Zohuriaan MJ Modified chitosan 4. Superabsorbent hydrogels from poly(acrylic acid-co-acrylamide) grafted chitosan with salt- and pH-responsiveness properties. Eur Polym J 2004; 40: 1399-1407.
4. Hangargekar SR, Shyale SS, Shafi S, Nagoba SN Formulation and evaluation of guar gum based colon targeted tablets of secnidazole and its β-cyclodextrin complex to treat amoebiasis. Int J Pharm Pharm Sci 2011; 3 Suppl 4: 294-298
5. Singh V, Tripathi DN, Tiwari A, Sanghi R Microwave synthesized chitosan-*graft*-poly(methylmethacrylate): An efficient Zn^{2+} ion binder. Carbohydr Polym 2006; 65: 35-41.
6. Jain S, Biswal I, Dinda A, Moitra SK, Kohli S Modified sustained release chitosan-coated zidovudine microspheres. Int J Pharm Pharm Sci 2011; 3 Suppl 4: 95-97.
7. Pandey PK, Srivastava A, Tripathy J, Behari K Graft copolymerization of acrylic acid onto guar gum initiated by vanadium (V)–mercaptosuccinic acid redox pair. Carbohydr Polym 2006; 65: 414-420.
8. Mishra A, Bajpai M Flocculation behavior of model textile wastewater treated with a food grade polysaccharide. J Hazard Mater 2005; 118: 213-217.
9. Kwon IC, Bae YH, Kim SW Electrically credible polymer gel for controlled release of drugs. Nature 1991; 354: 291.
10. Kikuchi A, Okano T Pulsatile drug release control using hydrogels. Adv Drug Del Rev 2002; 54(1): 53–77.
11. Hu SH, Liu TY, Liu DM, Chen SY Controlled Pulsatile Drug Release from a Ferrogel by a High-Frequency Magnetic Field. Macromol 2007; 40(19): 6786–6788.
12. Yamato M, Konno C, Utsumi M, Kikuci A, Okano T Thermally responsive polymer-grafted surfaces facilitate patterned cell seeding and co-culture. Biomater 2002; 23: 561–567.

13. Yeo Y, Kohane DS Polymers in the prevention of peritoneal adhesions. Eur J Pharm Biopharm 2008; 68(1): 57–66.
14. Fedorowich NE, Alblas J, deWijn JR, Hennink WE, Werbout ABJ, Wouter JA, Dhert WJA Hydrogels as Extracellular Matrices for Skeletal Tissue Engineering: State-of-the-Art and Novel Application in Organ Printing. Tissue Eng 2007; 13(8): 1905–1925.
15. Ho E, Lowman A, Marcolongo M Synthesis and Characterization of an Injectable Hydrogel with Tunable Mechanical Properties for Soft Tissue Repair. Biomacromol 2006; 7(11): 3223–3228.
16. Lee W, Choi D, Lee Y, Kim DN, Park J, Koh WG Preparation of micropatterned hydrogel substrate via surface graft polymerization combined with photolithography for biosensor application. Sens Actuators B Chem 2008; 129: 841–849.
17. Hoffmann J, Plotner M, Kucling D, Fischer WJ Photopatterning of thermally sensitive hydrogels useful for microactuators. Sens Actuators 1999; 77: 139–144.
18. Yuk SH, Lee HB Electric-current-sensitive polymers: Reversible bending of rod-shaped acrylamide gel in NaCl solution. J Polym Sci Polym Phys 1993; 31: 487-489.
19. Kim SJ, Lee KJ, Kim SI Electrostimulus responsive behavior of poly(acrylic acid)/polyacrylonitrile semi-interpenetrating polymer network hydrogels. J Appl Polym Sci 2004; 92: 1473-1477.
20. Osada Y, Hasebe M Electrically activated mechano-chemical devices using polyelectrolyte gels. Chem Lett 1985; 165: 1285-1288.
21. Uhl RL The use of electricity in bone healing. Orthop Rev 1989; 18: 1045-1050.
22. Sumano H, Mateos G The Use of Acupuncture-Like Electrical Stimulation for Wound Healing of Lesions Unresponsive to Conventional Treatment. Am J Acupunct 1999; 27: 5-14.
23. Mukae K, Bae YH, Okano T, Kim SW A new thermosensitive hydrogel: Poly(ethylene oxide-dimethylsiloxane-ethylene oxide)/poly(N-isopropylacrylamide) interpenetrating polymer networks. I. Synthesis and Characterization. Polym J 1990; 22: 206-217.
24. Kim SJ, Shin SR, Lee SH, Lee JH, Kim SI Electrical response characterization of chitosan/polyacrylonitrile hydrogel in NaCl solutions. J Appl Polym Sci 2003; 90: 91-96.