The Research Reports of the Faculty of Engineering, Kagoshima University, No.60 (2018)

Doctoral Dissertation, Graduate School of Science and Engineering, Kagoshima University, Doctorate No.455

Development of Flexible Ceramic Nanofiber Membranes for Energy and Environmental Applications

Muhammad Zobayer Bin MUKHLISH

1. Introduction

It is now well-known fact that energy production and environmental challenges constitute dominant issues for the 21st century. Consequently, limited fossil fuel resources and strict environmental regulations induce the search for sustainable, efficient and environmentally friendly energy sources. On the other hand, acute problems related to treatment of hazardous reactive dye contaminated water have emerged as an international priority.

This work is focused and aimed on the fabrication of flexible inorganic nanofiber (NF) membranes by electrospinning method, and their application to flexible and heat-resistive NF substrate in dye-sensitized solar cells (DSSCs) and adsorptive removal of dye contamination from water.

2. Results and Discussions

Two approaches were applied to make the ITO-silica NF mats: electrospun silica-NF mats drop coated by ITO and hybrid mats composed of ITO NF and silica NF fabricated by the dual-spinneret electrospinning technique. The self-standing ITO-silica NF mats with excellent flexibility and thermal durability (>400 ºC) was successfully fabricated with the sheet resistance of 15-113 Ω/sq. The ITO-silica NF mats were successfully applied to the as thermally stable light-weight substrates to produce working electrodes of DSSCs, and the problems in the existing application were highlighted.

The nonwoven membranes of ultrafine alumina-silica NFs were fabricated for the removal of Reactive Red-120 (RR-120) dye pollutant from aqueous solution. The NF membranes were successfully prepared by electrospinning, and also characterized by TG-DSC, FE-SEM, EDX, XRD and Raman spectroscopy. The membrane, consisting of continuous and randomly arranged NFs with an average diameter of ~ 95 nm, was self-standing, amorphous, and mechanically flexible.

Batch experiments for the removal of RR-120 dye from aqueous solution were carried out changing pH, adsorbent dosage and contact time. Adsorption equilibrium and kinetic studies were also carried out. The sorption process was pH dependent and followed the Langmuir isotherm model. The maximum adsorption capacity of the NF membrane for RR-120 dye was observed as high as 884.95 mg/g. After adsorption, the membrane could be separated from the liquid phase conveniently due to its flexible and self-standing nature. Moreover, most of the dye could be recovered from the dye-loaded membrane and the NF membrane could be reused as adsorbent.

For the next step, alumina-silica/α-Fe_3O_4 core-sheath nanofiber membranes were prepared for the enhancement of adsorption performance. The sorption characteristics of RR-120 dye from aqueous solution was investigated as the same manner. The equilibrium study revealed a maximum RR-120 dye sorption capacity of 1860.81 mg/g, and this was the highest adsorption capacity for RR-120 exhibited by an adsorbent ever reported in the literature. Thus, the alumina-silica/iron oxide NFs membrane is a practically applicable potential adsorbent for the removal of RR-120 dye.

3. Conclusions

The self-standing ITO-silica NF mats with excellent flexibility and thermal durability were found to be one candidate for the flexible electronics in the next generation. Furthermore, electrospun NF membrane can be a practically applicable promising adsorbent material for removal and recovery of dye from aqueous solution.

Date of Conferment of the Degree: March 23, 2018
Shahjalal Univ. of Science and Technology, Bangladesh