Electrospun zeolite composite nanofibers for the adsorption of uremic toxins

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Abstract

Purpose: End stage of renal failure (ESRD) is a debilitating condition in which the kidneys are no longer able to remove enough wastes and excess fluids from the body. Although recently, hemodialysis can be performed at home which saves patients some time, it is still an inconvenient, time consuming, and expensive process, especially in resource-limited environments such as disaster areas and the developing world. Here we report we develop a zeolite-polymer composite nanofiber mesh to remove uremic toxins for blood purification without the requirement of specialized equipment. The nanofiber is composed of blood compatible poly(ethylene-co-vinylalcohol) (EVOH) as the primary matrix polymer and zeolites which are capable of selectively adsorbing uremic toxins such as creatinine (Fig.1a). We investigated the creatinine adsorption capability of the EVOH-zeolite nanofiber composites.

Methods: The composite nanofibers were successfully developed by EVOH blended with beta-type zeolites. The fiber morphologies and incorporation of the zeolites were observed by EDX-SEM. The content of zeolites in the fibers was measured by TG-DTA analyses. Creatinine adsorption capacity of the zeolite and nanofibers were also determined by UV spectroscopy.

Results: Fig.1b shows SEM images of the EVOH fibers blended with beta-type zeolites. Because the average particle size of zeolites (approximately 2-3 µm) was significantly larger than the fiber diameter, bead-like formations were observed. To determine the successful incorporation of zeolites within the fibers, EDX mapping images of the fibers were obtained (Fig. 1c). The elemental mapping images of Si atom, which correspond to zeolites components, show that zeolites are successfully incorporated within the fibers. The amounts of the incorporated zeolites were also determined by TG-DTA analyses. It was determined that over 90% of zeolites were successfully incorporated into nanofibers Fig.1d plots the zeolite content against feed concentration. There is a good correlation between incorporated amounts and feeding amounts. These results indicated that a nanofiber composite composed of adsorbent particles and a blood compatible polymer was successfully fabricated using electrospinning techniques. Fig. 1e shows the creatinine adsorption capacity of the composite fibers with various zeolite contents. The adsorption capacity by fiber mass was proportionally increased with increasing zeolite content in nanofiber. Although the barrier properties of the EVOH matrix lowered the creatinine adsorption capacity of the zeolites in the fiber when compared with adsorption to free zeolites, their adsorption capacity of the composite fiber was still 67% of the free zeolites. In the rough calculation, around 170 g of the zeolite/EVOH nanofiber composite would be needed to adsorb a daily production of creatinine. Future works will explore these various possibilities of zeolite-polymer composite fibers for their practical uses in the human body.

Conclusions: The composite fibers have the potential to be utilized as a new wearable blood purification system especially in low infrastructure areas such as disaster sites and the developing world.

References

[1] K. Namekawa, M.T. Schreiber, T. Aoyagi, M. Ebara, **Biomaterials Science** *(submitted)*

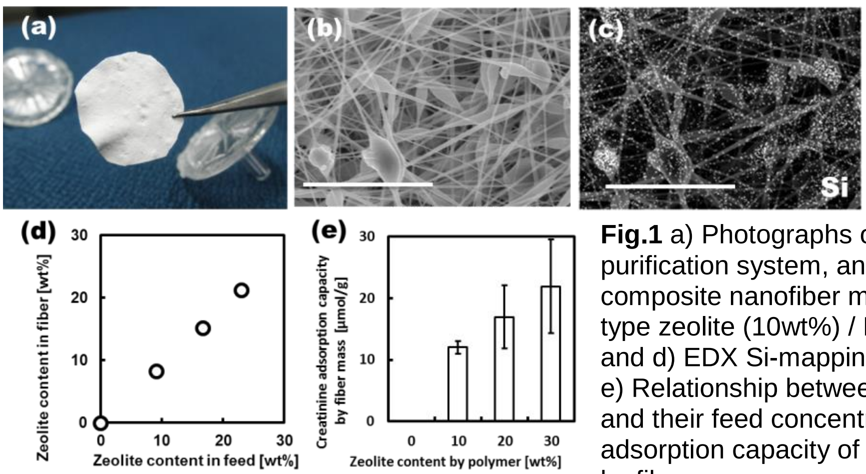

Fig.1 a) Photographs of a wearable blood purification system, and b) a zeolite-polymer composite nanofiber mesh. c) SEM images of beta-type zeolite (10wt%) / EVOH nanofiber composite, and d) EDX Si-mapping images (scale bar: 8 µm). e) Relationship between zeolite contents in the fiber and their feed concentrations. f) Creatinine adsorption capacity of beta-type zeolite nanofibers by fiber mass.