Removal of Cs From Contaminated Aquatic Environments by Water-powered Janus Micromotor Adsorbent

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1. Introduction

The accidental release of radioactive substances from nuclear facilities can induce contamination of the aquatic environment. Among various radionuclides, cesium is considered as one of most hazardous substances because of its long half-life and high gamma radiation energy. Nevertheless, it has been difficult to remediate large aquatic environments on site using the conventional Cs adsorbent. In this presentation, we report the self-propelled micromotor that can move under self-generated propulsion in an aqueous environment using a force generated by water-metal reaction. The Cs selective half-shell of the Janus micromotor enabled removal of Cs from the contaminated water.

2. Experimental

Mg particles (38~45 μm) were deposited on the poly(vinylpyrrolidine)-coated glass substrate, and the humidity was raised until the polymer layer became adhesive to fix Mg particles in the polymer layer. Top surfaces of the Mg particles were coated with Ni and Au layers to prepare half-coated Janus microspheres. The Au layer was cationically modified by reaction of the particles with thiolated polyethyleneimine (PEI). The Cs-selective layer-by-layer film was formed on the half-surface of the particle by sequential treatment of the particles with anionic ferric ferrocyanide particles and cationic PEI.

Self-propulsion of the Mg/ferric ferrocyanide micromotor was observed in aqueous solutions using a stereomicroscope (Leica M250C, Germany) equipped with a high-speed CMOS camera (Lt225, Aegis Electronic, USA).

The radioactivity of ^{137}Cs solution before and after treatment with the micromotor adsorbent was measured using high-resolution gamma spectrometry (CANBERRA Ind.) with a high-purity germanium detector equipped with a multi-channel analyzer.

3. Result & Discussion

The Cs-selective ferric ferrocyanide functionalized Janus micromotor particles were prepared by modifying the surfaces of the Au half-shell on the Mg microspheres with layer-by-layer film of ferric ferrocyanide and PEI. SEM analysis of the particles demonstrated that half of the Mg microsphere surface was coated with cubic ferric ferrocyanide particles.

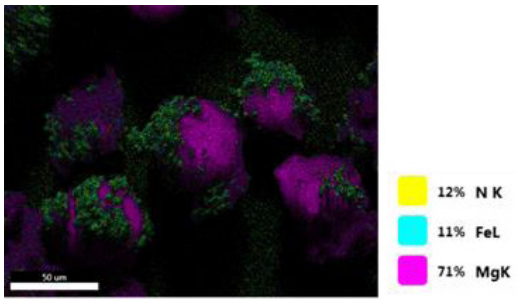

Fig. 1. Janus micromotor adsorbents observed using scanning electron microscopy with elemental mapping using energy dispersive spectroscopy.

The propulsive motions of the Janus micromotors were analyzed in an aqueous solution containing Cl^- or HCO_3^- anions. The reaction between Mg metal and water generated hydrogen gas bubbles. Asymmetrical bubble evolution from the Janus particle produced a net propulsive force on the particle.

Finally, we demonstrated the removal of radioactive ^{137}Cs by the self-propelled Mg/ferric ferrocyanide micromotor. The self-propelled micromotors were able to remove over 99.7% of Cs from ~85 Bq/mL of ^{137}Cs concentrations.

4. Conclusions

We successfully demonstrated the preparation of Mg/ferric-ferrocyanide micromotors by a layer-by-layer technique. The synthesized micromotor could be self-propelled in aqueous solutions via the water-metal reaction. Adsorption of Cs by the micromotor adsorbent enabled the successful removal of radioactive ^{137}Cs from aqueous solutions

REFERENCES

[1] Hwang J, Yang H-M, Lee K-W, Jung Y-I, Lee K J, Park C. W. A remotely steerable Janus micromotor adsorbent for the active remediation of Cs contaminated water, 2019. J Hazard Mater, 2019;369.