Phosphonic Acid Functionalized Electrospun Nanofibers for Uranium (VI) Uptake

Allison Peroutka[a], Jiajie Quian[a], David Cwiertny[a], and Tori Forbes[b]

[a] *University of Iowa, College of Engineering*

[b] *University of Iowa, Department of Chemistry*

Abstract

In the Four Corners region of the United States, Native American communities are threatened with exposure to high concentrations of uranium in the drinking water due to leakage from local abandoned uranium mines. Increased levels of uranium exposure pose health concerns as uranium is considered a nephrotoxin, which has many harmful consequences including the potential increased risk for cancer. The most prevalent form of uranium in aqueous solution is U(VI) in the form of the uranyl cation. The goal of this project is detection of U(VI) in groundwater and eventually extraction, which we target through the coupling of engineering concepts with chemical techniques to develop new material and understand binding preferences of U. Initial efforts use polyacrylonitrile (PAN) electrospun nanofibers, which are combined with various phosphonic acid surfactants for selective uptake of U. Changing the surfactants chemistry via adjustment of the carbon chain (resulting in increased hydrophobic nature of the tail), total uptake of uranium is observed with the longer chains, confirmed by both LSC and ICP-MS results. In addition, stability of the surfactants were assessed and washing experiments indicated variable incorporation of the phosphonate groups that are dependent on chain length.

Objective

Previous research determined that hexadecyl phosphonic acid (HDPA) is useful for uranium detection because of its high uranium sorption concentration. Elongating the chain on the phosphonic acids changes the hydrophobicity of the mat, which in turn affects uranium uptake.

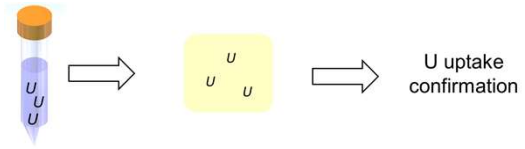

Figure 1. An initial uranium solution (1 M) is used in a batch experiment with nanofiber mats. Functionalization of the mats allow for the surface binding of the uranium. The remaining solution and mats are then separately analyzed to confirm uranium uptake.

Instrumentation

A B C

A rotator (A) is used so the nanofiber mats are mixed with uranium solution. Uranium uptake on nanofiber mats were calculated by using LSC as shown above (B) which detects the counts of beta radiation emission. The remaining solution is acidified in HNO_3 and analyzed on ICP-MS (C) which detects the concentration of uranium.

Binding Agents

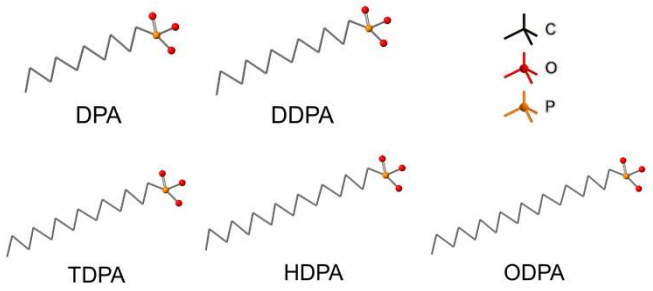

Figure 2. Different chain lengths of phosphonic acids were used to test how the nanofiber mat's uranium uptake changed with altering hydrophobicities when integrated into polyacrylonitrile (PAN).

Characterization of Nanofiber Mats

Nanofiber mats were characterized with scanning electron microscopy (SEM) and x-ray photoelectron spectroscopy (XPS).

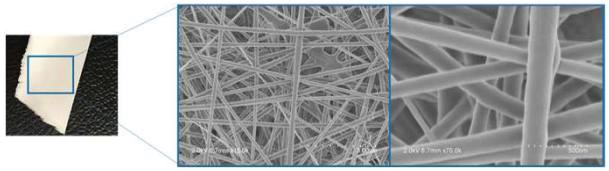

Figure 3. SEM images of ODPA illustrate that electrospun mats are made of amorphous nanofibers that have a high surface area to volume ratio.

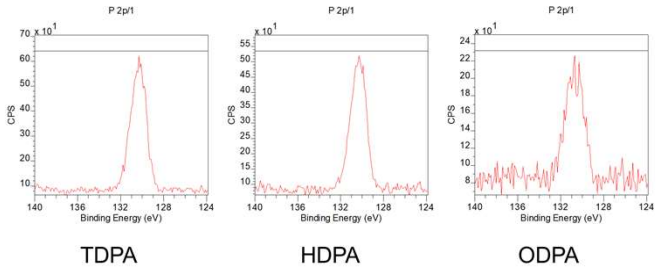

Figure 4. Above, XPS data confirms that the phosphonate surfactants are present on the surface of the nanofiber mat.

Performance

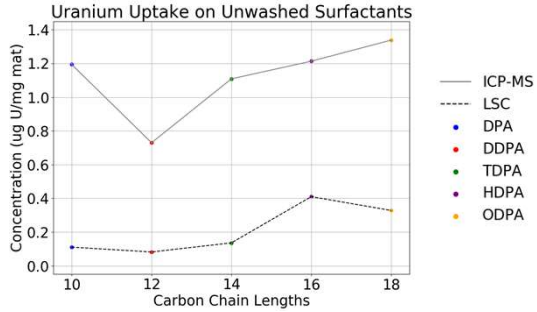

Figure 5. Sorbed concentration verse varying carbon chain lengths of unwashed nanofiber mats in a clean water system. An initial uranium concentration of 1 μM was at pH 2 was prepared in deionized water. Adjustment to pH was performed with HNO_3.

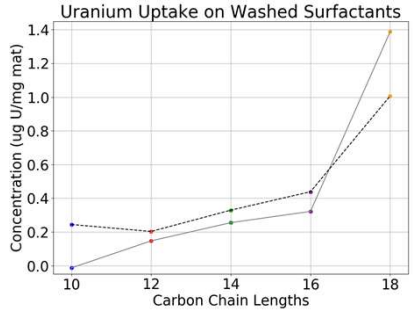

Figure 6. Sorbed concentration verse varying carbon chain lengths of washed nanofiber mats. An initial uranium concentration of 1 μM was at pH of 2. The phosphonic acid functionalized mats were tested in a clean deionized water system. For pH adjustment, HNO_3 was used.

Future Studies and Conclusion

Future work will involve synthesizing nanofiber mats with PAN and various functionalized acids for testing for uranium uptake. The nanofiber mats uranium uptake will be analyzed and compared to the corresponding hydrophobicities.

Acknowledgements

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