AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
FUNDING CYCLE 2018 – 2020

TITLE: From Wastewater Materials to High-Energy-Density Lithium-Ion Batteries

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COOPERATORS:

EXECUTIVE SUMMARY: Chromium (Cr) produced from industrial water discharge is a major toxic element found in the environment. The improper handling of wastewater can significantly influence the water quality that is directly related to human health and agricultural products in Oregon and across the country. Using materials from nature we can obtain activated carbon that is a good adsorbent material to remove Cr contamination from wastewater. In addition, the Cr contained carbon, instead of being thrown away to generated secondary waster, can be used as the anode materials for lithium-ion battery to achieve high energy capacity. In this project, we demonstrate such sustainable method to improve the water-energy nexus.

OBJECTIVES: The goal of this proposal is to design an environmental benign process that can utilize cost-effective and highly porous carbon materials to effectively remove Cr(VI) in the wastewater, and subsequently the Cr-containing carbon can be easily separated from the wastewater to be engineered as the electrode for high-energy-density lithium-ion battery applications.

PROCEDURES: Last year we used Douglas fir leaves to produce activated carbon for wastewater treatment. Brunauer, Emmett and Teller (BET) test showed that the surface area of these activated carbon is 6.858 m^2/g, which is much lower than the average value of 200 m^2/g. These carbon materials exhibit limited Cr absorption capability. Therefore, we turned to different sources. Using Chitin from crab shell we produce highly porous activated carbon. In addition, these carbon materials are nitrogen-rich, suggesting pretty of nitrogen functional group that are important to reduce toxic Cr(VI) to non-toxic Cr(III) when absorbing them on activated carbon surfaces. As shown in **Figure 1**, when adding these activated carbon on Cr-containing solutions, the yellow color from high concentration of Cr(VI) disappear, indicating the successful absorption of Cr cations.

Figure 1. Procedures show how to generate activated for wastewater treatment.

We further performed UV-vis measurements, as shown in **Figure 2a**. The two peaks around 260 nm and 350 nm are features of the existence of Cr(VI) cations in the solution. When adding the same amount of activated carbon into solutions with different Cr(VI)

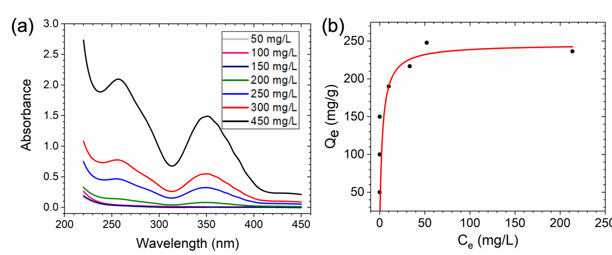

Figure 2. (a) UV-vis spectra showing the amount of Cr(VI) after carbon absorption for solution with different Cr(VI) concentration. (b) Langmuir isotherm analysis of the absorption powder of activated carbon.

concentration, solutions with low initial concentration (e.g., 50 mg/L and 100 mg/L) show almost no Cr(VI) peaks. In contrast, solutions with high initial concentrations (e.g., 450 mg/L) show slightly decrease of these peaks. These results strongly support the good absorption power of activated carbon made from crab shell. Using Langmuir isotherm equation:

$$C_e/q_e=1/q_mK_L+C_e/q_m, \qquad (1)$$

where C_e is the equilibrium concentration of the solution (mg/L), q_e is the amount of adsorbate adsorbed per unit mass of adsorbate (mg/g), and q_m and K_L are Langmuir constants that are related to the adsorption capacity and the rate of adsorption, respectively, we analyzed and obtained the maximum absorption capacity of our sample is 246 ± 68 mg/L with Langmuir adsorption constant of 0.338 (**Figure 2b**).

Our next step is to verify whether the absorbed Cr on carbon are Cr(VI) or Cr(III) using X-ray photoelectron spectroscopy (XPS) at Oregon State University. The latter will be critical for the anodes to achieve high capacity of lithium-ion battery. In the meantime, we have performed the electrochemical test of activated carbon without Cr, which shows reasonably good capacity. This is the controlled experiment to compare the carbon with Cr.

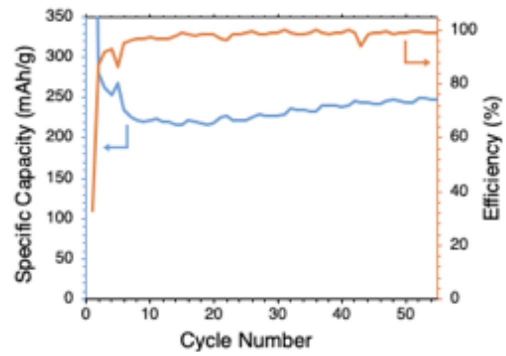

Figure 3. Electrochemical performance from activated carbon without Cr absorption as the anode for lithium-ion battery.

SIGNIFICANT ACCOMPLISHMENTS: As shown in above procedures, we are close to demonstrate the idea as proposed in our project. The results are promising. With additional characterizations (BET tests and XPS) and battery tests, we believe a manuscript can be developed.

The PI (Dr. Zhenxing Feng) is also invited to contribute a review article on Nanoscale Advances with a focus on carbon materials in lithium-ion and lithium-sulfur battery. Our results generated in this proposal will be included and the funding from ARF will be acknowledged in both manuscripts.

BENEFITS & IMPACT: The impact of results from this project is significant. It provides cost-effective strategy to develop materials that not only can be used for wastewater treatment but also can be subsequently used for energy storage applications. This is sustainable ways for enabling water-energy nexus.

ADDITIONAL FUNDING RECEIVED DURING PROJECT TERM:

FUTURE FUNDING POSSIBILITIES: With current preliminary results, we are planning to submit a full proposal to NSF Environmental Sustainability program.