Development of a Phosphate Biosensor for Soil & Groundwater

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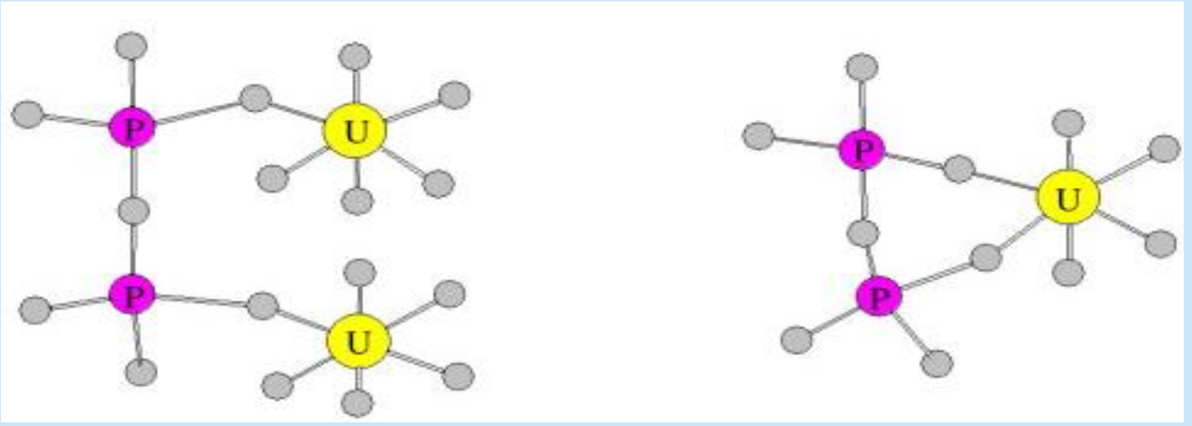
Abstract

Uranium contamination in soil and groundwater sediments is a monumental problem in Hanford, WA. Since phosphate(PO_4^{3-}) plays an important role by binding and precipitating uranium in the field, a limited amount of this compound should be injected. In contrast, excess amount of (PO_4^{3-}) causes eutrophication (increase in the concentration of chemical nutrients) in the environment. In order to provide the optimum phosphate concentration in the field, continuous field-deployable and reliable (sensitive, accurate) monitoring techniques are crucial. Therefore, an enzyme-linked phosphate sensor is being developed by employing advanced materials for enhancing the sensitivity of the existing sensors.

Introduction

Uranium-Phosphate Interaction

Uranium in the environment usually exists in +6 and +4 states. Studies have shown that uranium in the presence inorganic phosphate (PO_4^{3-}) reduces to the +4 state (precipitation), which immobilizes the uranium [1]. The figure below shows the uranium-phosphate interaction.



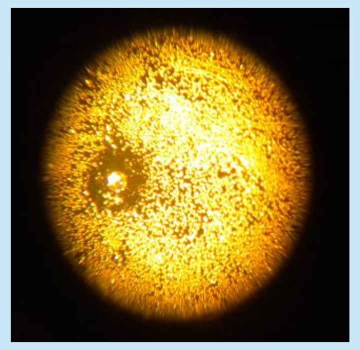
Materials

For this experiment three different advanced materials were employed:

1. Silica polymer coated with gold (Au).
2. Highly conductive Carbon Nano Tubes with Silver (Ag) and Nickel (Ni) (Ag, Ni, CNT).
3. Highly conductive Multi Wall Carbon Nano Tube (MWCNT).

Enzyme Linkage to the Surface

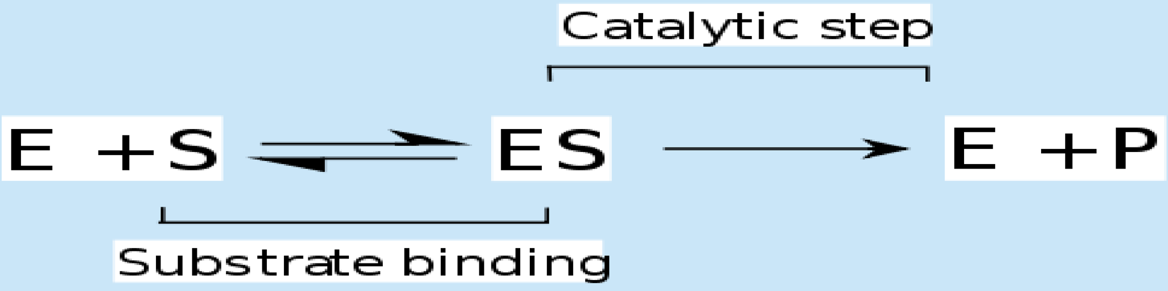
Pyruvate Oxidase (POX) was immobilized on the advanced materials prepared at FIU and ORNL, then via covalent attachment techniques, it was linked to the surfaces of the materials.



Method

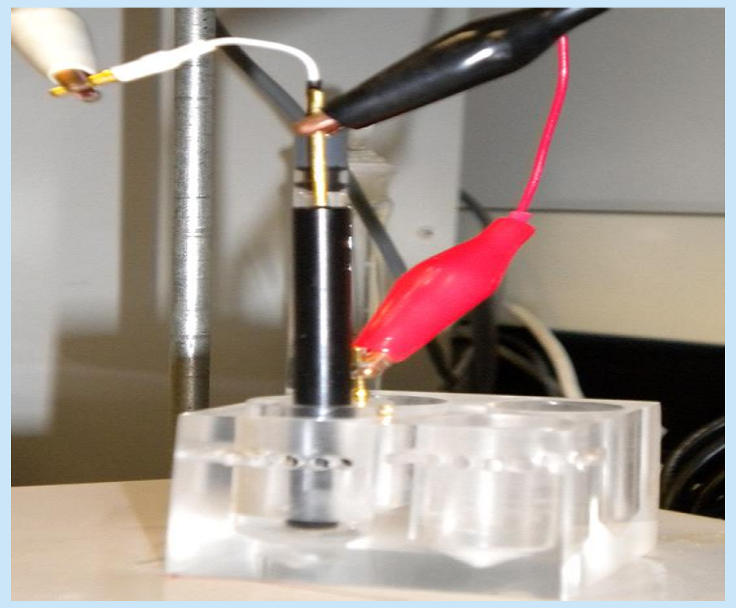
In order to develop the sensor, Pyruvate Oxidase (POX) was immobilized on gold-coated polymers and nano-structured advanced materials. The final product of the enzyme-substrate (POX-pyruvate) reaction, hydrogen peroxide (H_2O_2), was measured via electrochemical techniques. As the phosphate solution was added to the reaction cell, the obtained output signal was recorded via amperometry.

The enzyme-substrate reaction is demonstrated below.

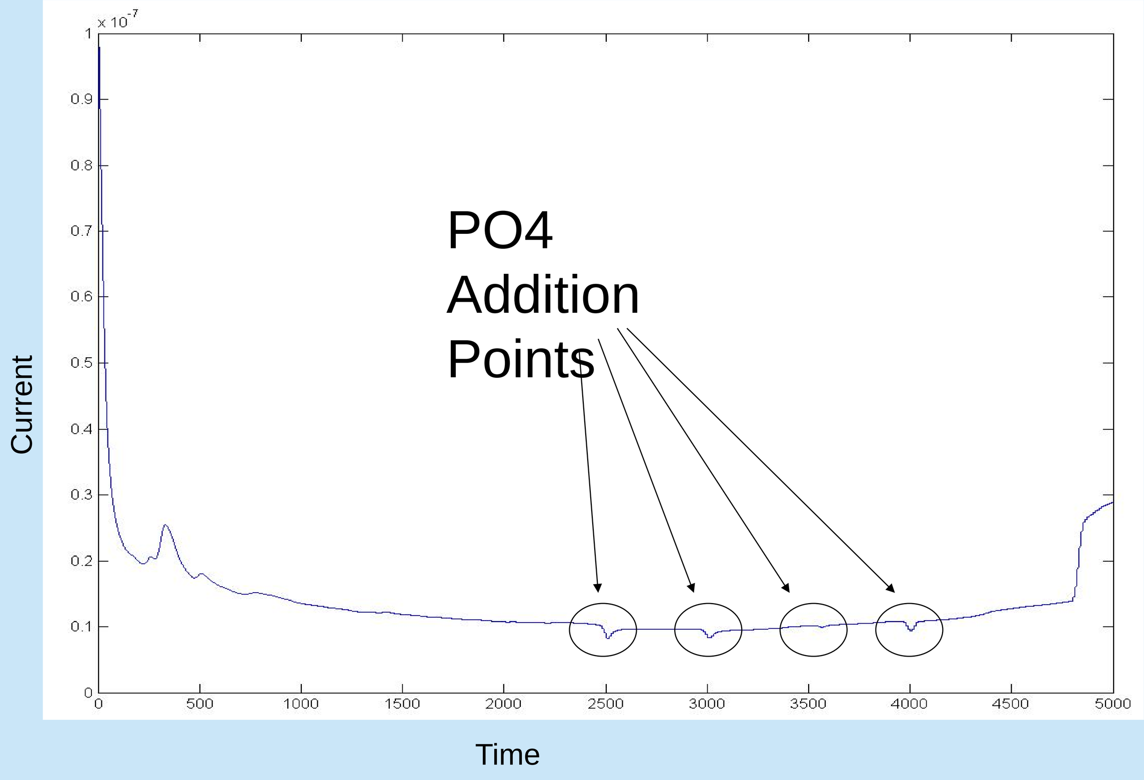


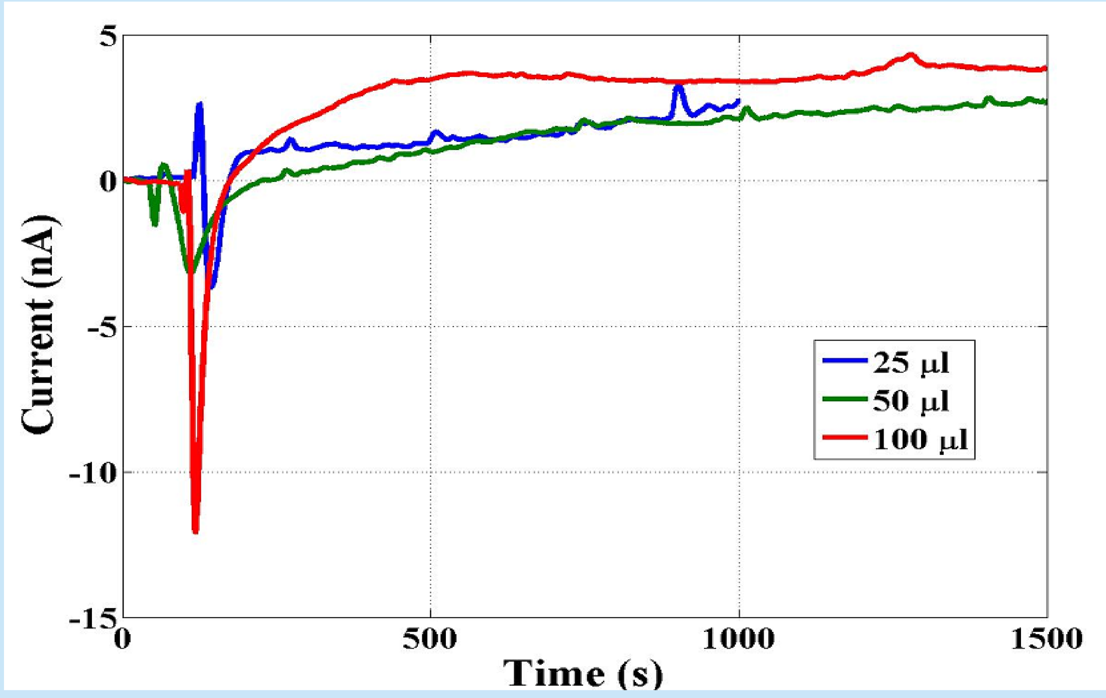
Experimental Setup

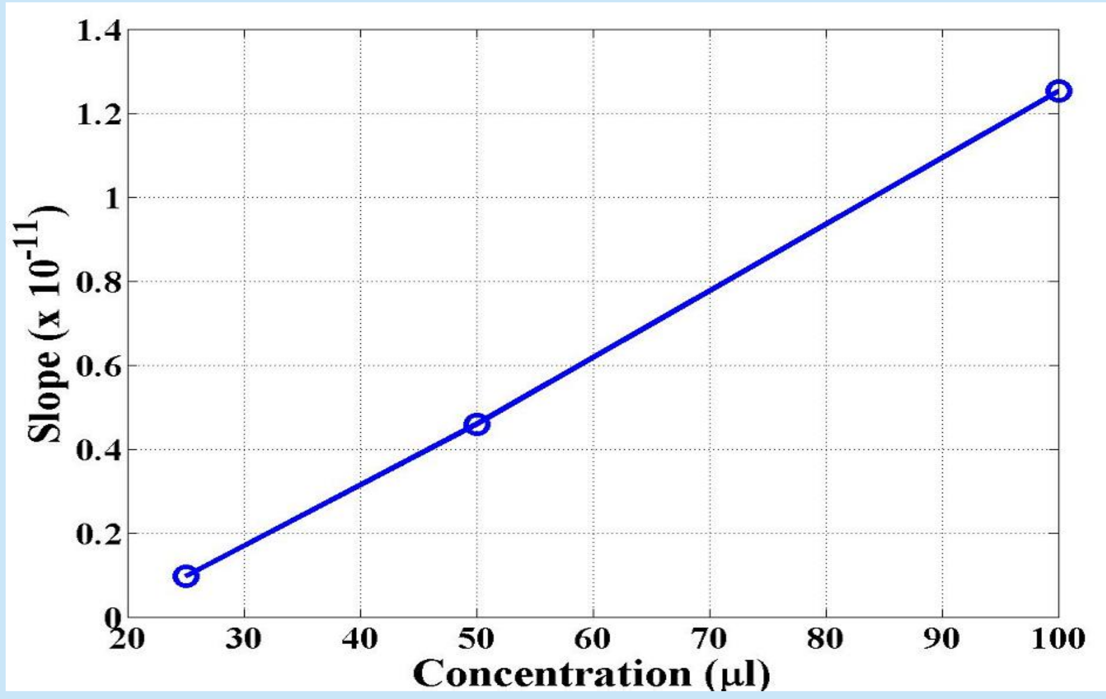
A conventional three-electrode electrochemical amperometric method was used to determine the current change which is interpreted to phosphate concentration.



Results







Conclusions

The low concentration of the [PO_4^{3-}] solutions were detected and quantified via employing the newly developed enzyme-linked biosensor in our laboratory. Further in situ studies need to be performed to assess if the device is field deployable.

Future Work

Upon successful completion of biosensor, there will be an endeavor towards in situ application and field deployed wireless sensing.

Acknowledgements

Touhidur Rahman, Ph.D., Oak Ridge National Lab.

References

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3. Rahman, A., Park, D.S., Chang, S.C., McNeil, C.J., Shim, Y.B., The biosensor on the pyruvate oxidase ions determination, *Biosensors and Bioelectronics*, 2006, 21, 1116-1124