Development of a CO_2 Chemical Sensor for Downhole CO_2 Monitoring in Carbon Sequestration

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Project goals and objectives

Objectives:

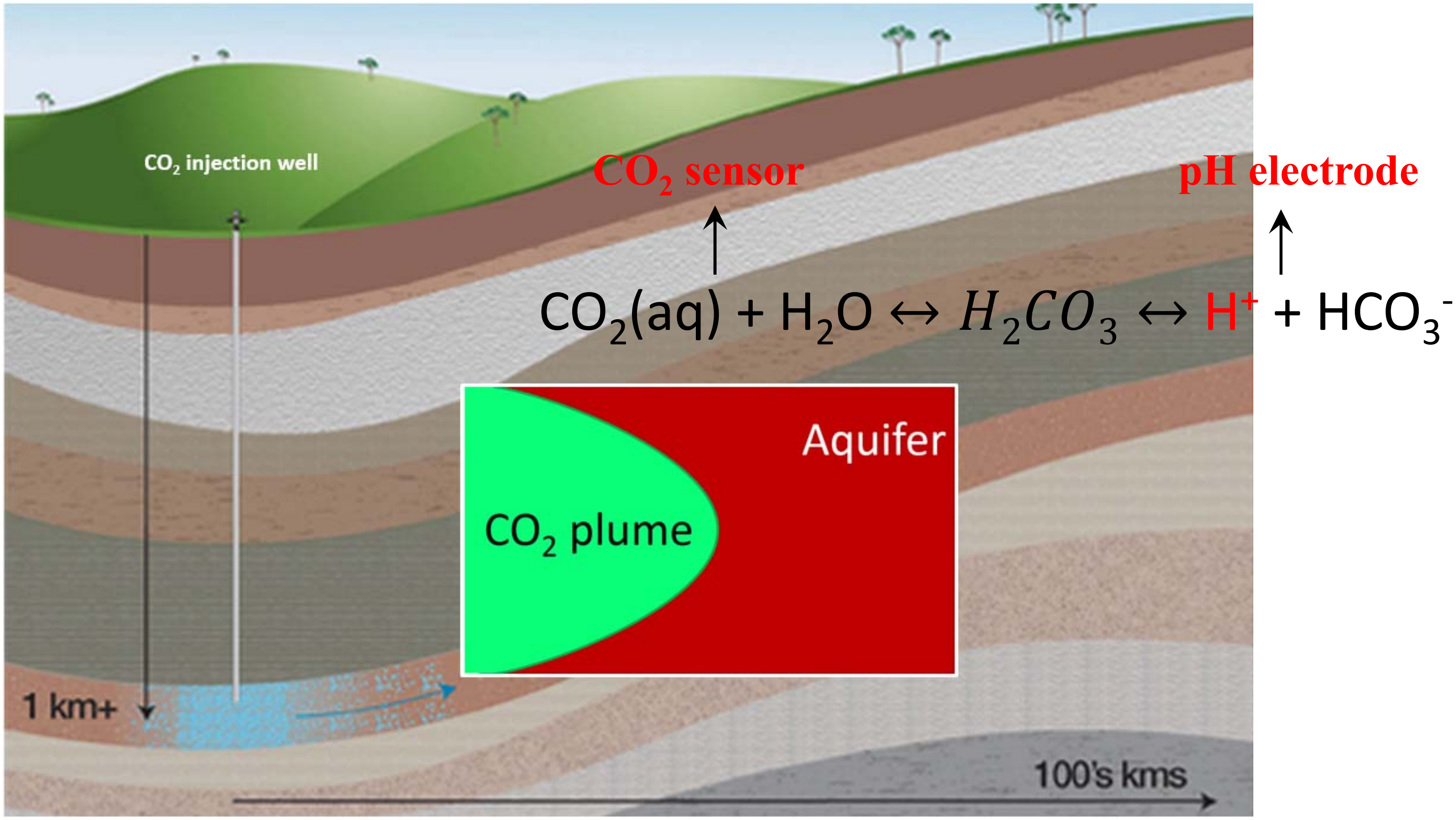
to develop a downhole CO_2 sensor that can monitor CO_2 plume migration in carbon sequestration. The proposed downhole CO_2 sensor can resist high pressure, temperature, and high salinity.

Phase I – To develop a metal-oxide pH electrode with good stability and to understand different factors' effects on the performance of the electrode.

Phase II – To develop a downhole CO_2 sensor and determine sensor performance under high pressure and high salinity.

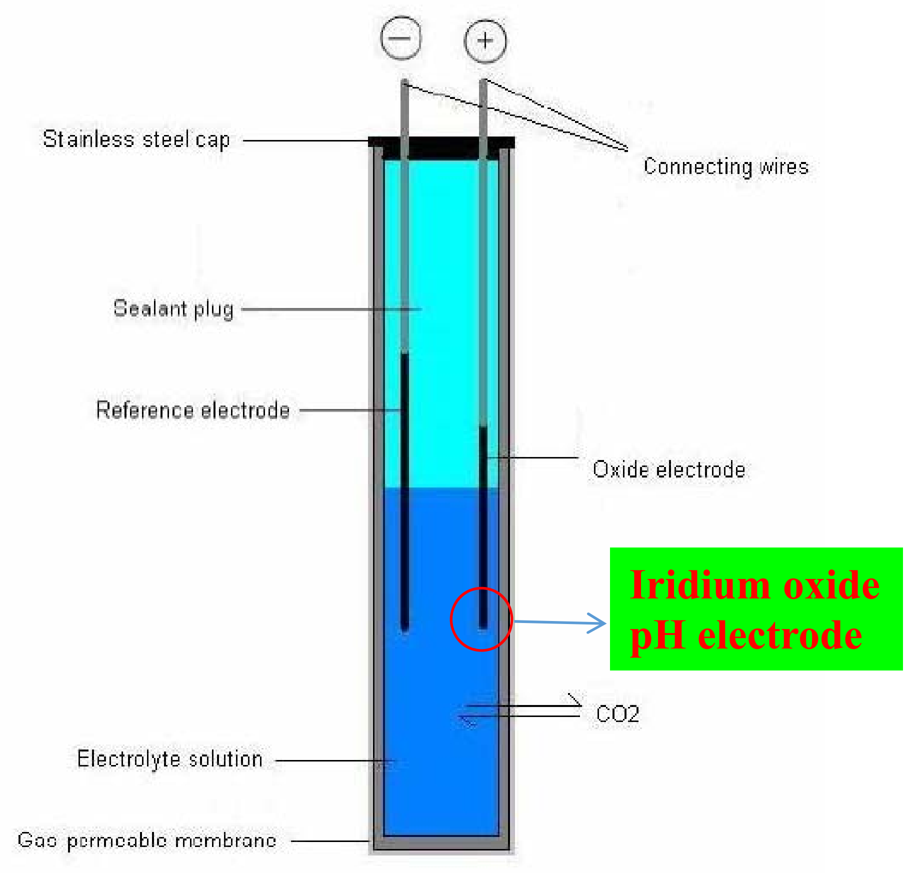
Phase III – To evaluate the CO_2 sensor's response in CO_2/brine coreflooding tests, and to develop a data acquisition system for the developed CO_2 sensor.

Background



Schematic of CO_2 sequestration.

CO_2 chemical sensor design



Schematic structure and picture of the fabricated CO_2 sensor.

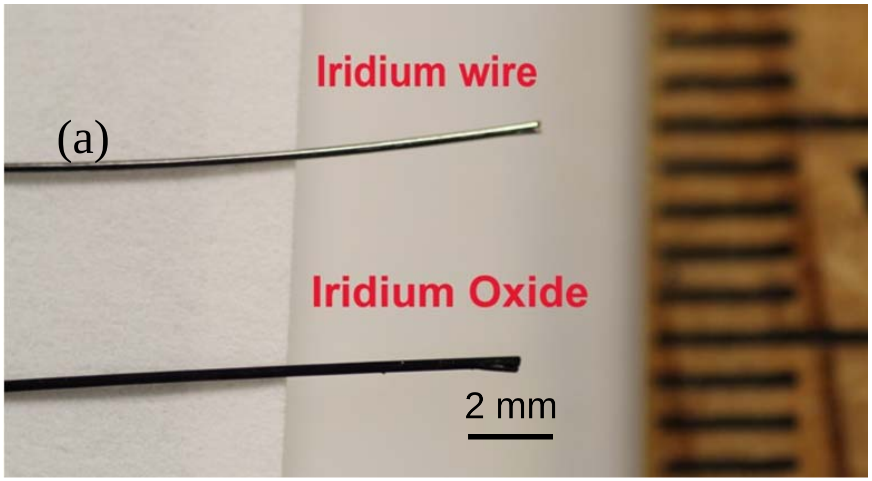
$$CO_2(g) + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

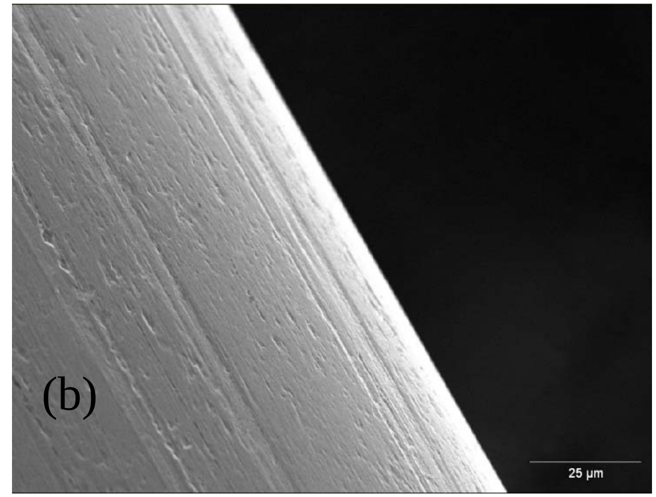
$$E = E^o + \frac{2.303RT}{F}\log[H^+]$$

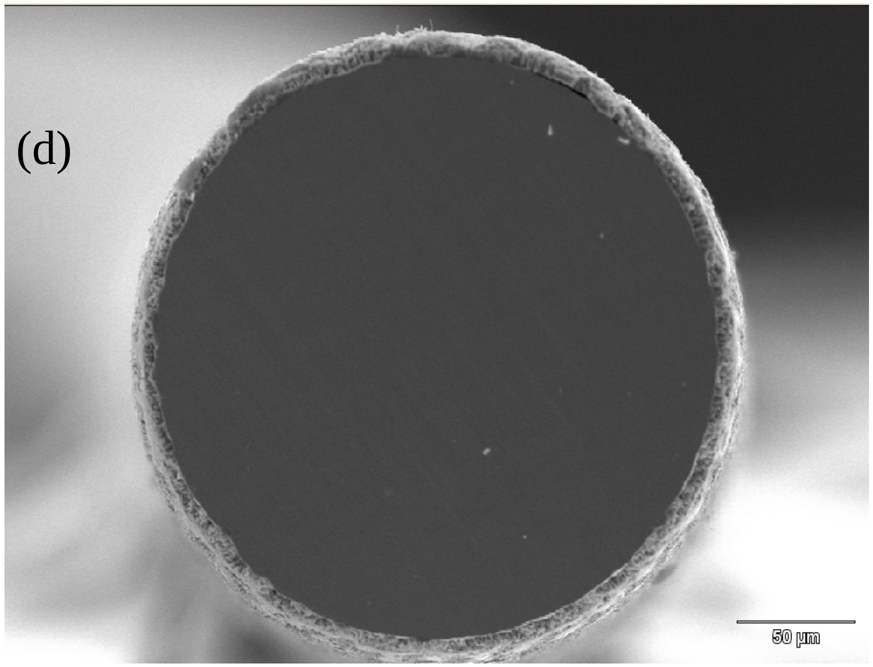
$$E = E^o + 59.15\log\frac{k}{[HCO_3^-]} + 59.15\log[CO_2]$$

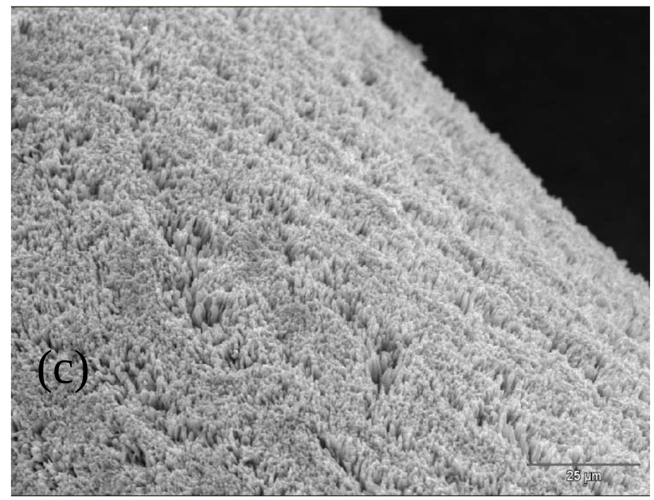
$$\Delta E = 59.15\log[CO_2] + k$$

Previous work





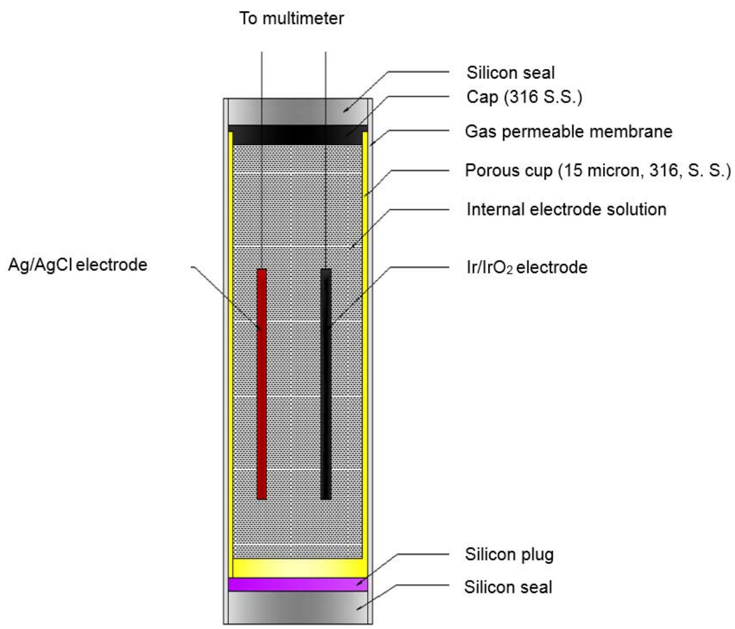




Iridium oxide films preparation

. Micrograph of iridium oxide film prepared under 870° C and 5h: (a) overview of iridium wires before and after oxidation; (b) surface morphology of bare iridium wire; (c) surface morphology of iridium oxide; (d) Cross section of iridium oxide.

CO_2 sensor preparation



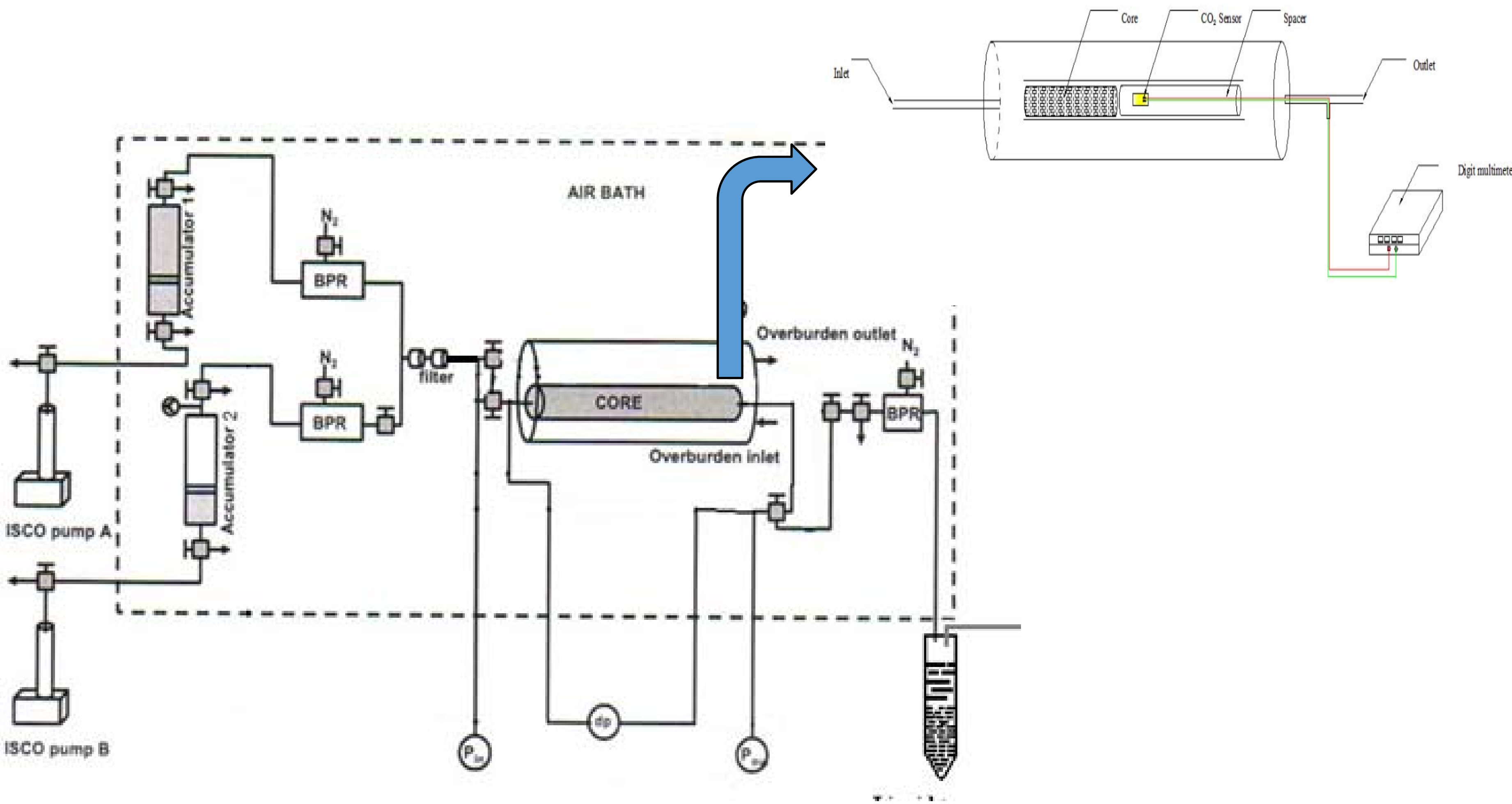
Schematic design and image of the downhole CO_2 sensor.

Current Work

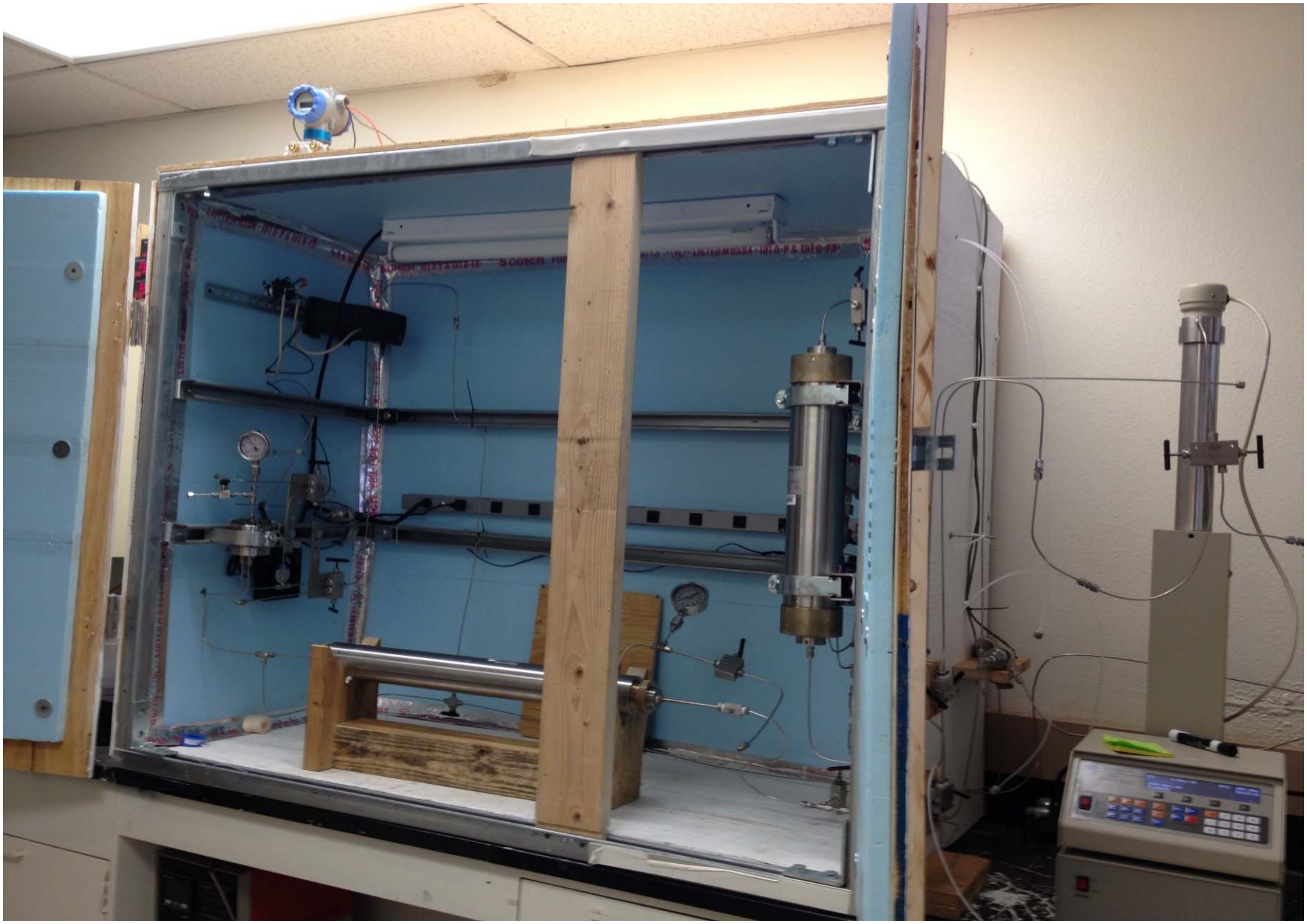
Task 4.0 (1 year) Evaluate the CO_2 sensor in CO_2/brine coreflooding tests and develop a data acquisition system for the downhole CO_2 sensor.

- Subtask 4.1 Design and conduct CO_2/brine coreflooding tests
- Subtask 4.2 Develop a data acquisition system to convert the output of the sensor signal into digital data
- Subtask 4.3 Final report

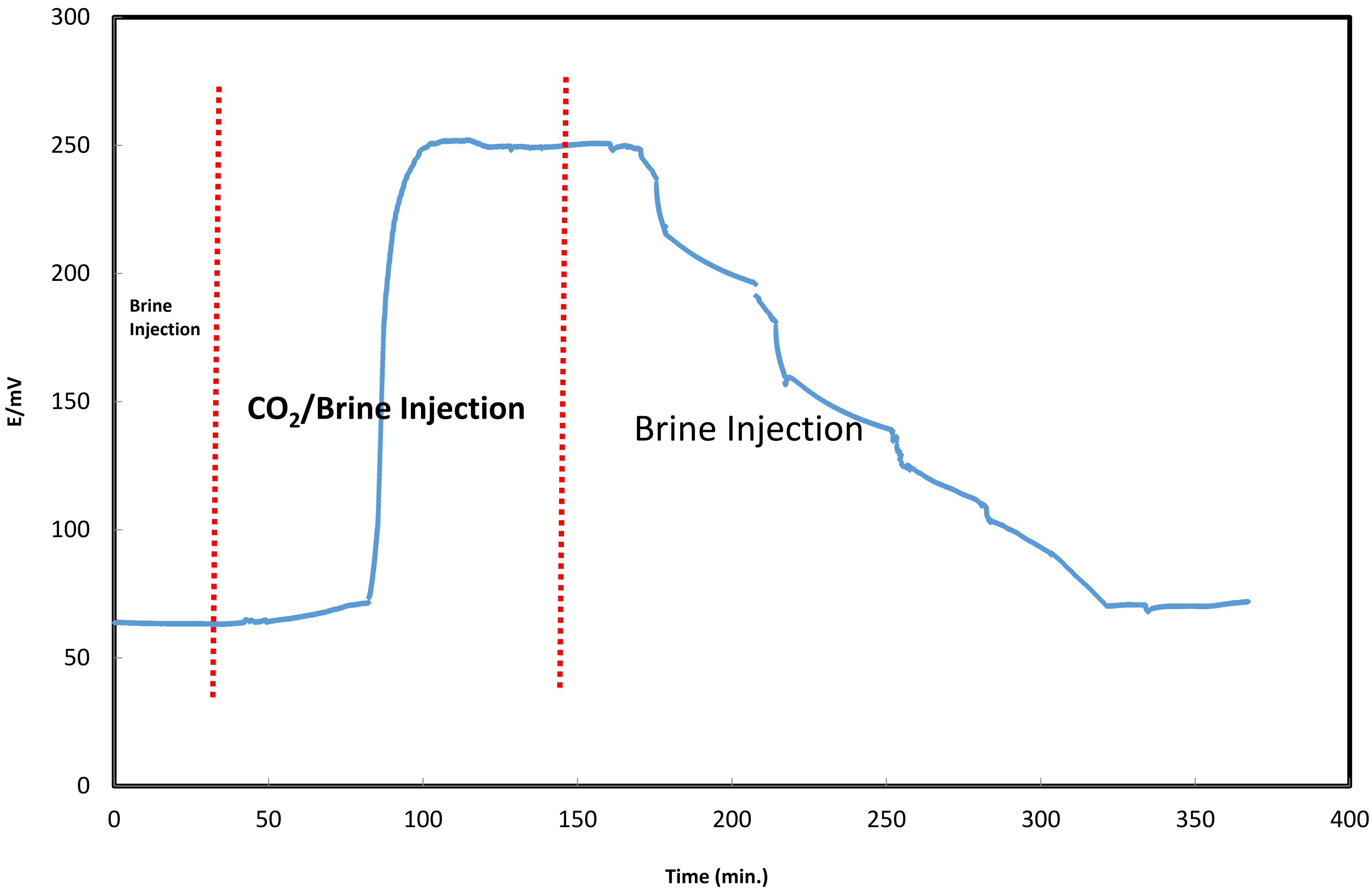
Schematic diagram of the coreflooding system



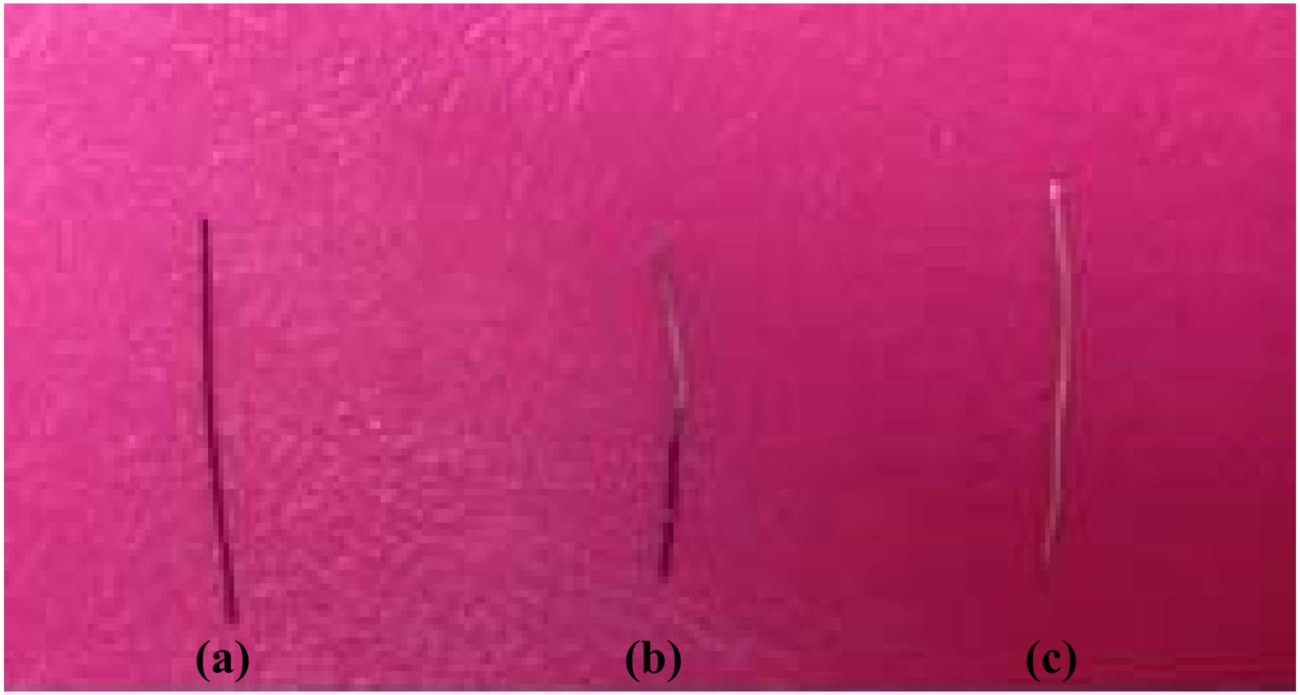
Picture of the coreflooding system



CO_2 sensor performance during CO_2/brine the corefloading test

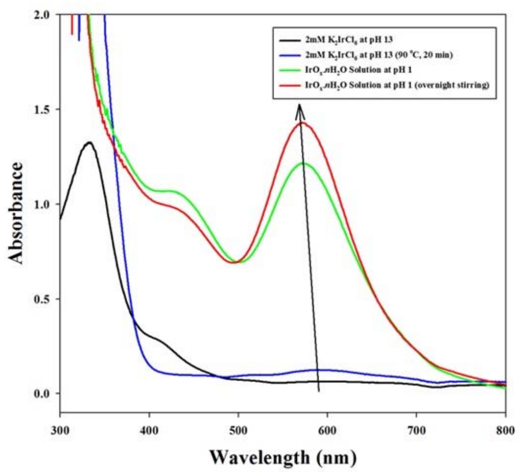


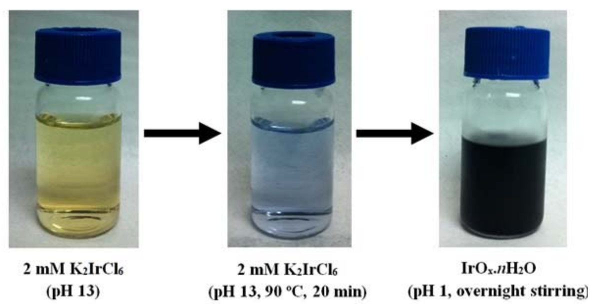
Iridium oxide electrode after high pressure tests

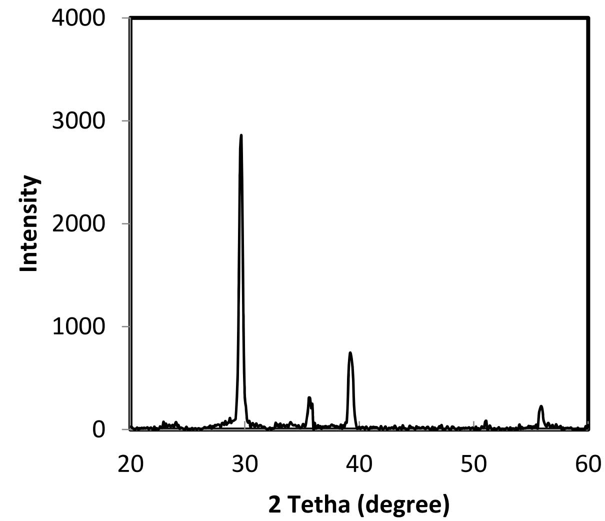


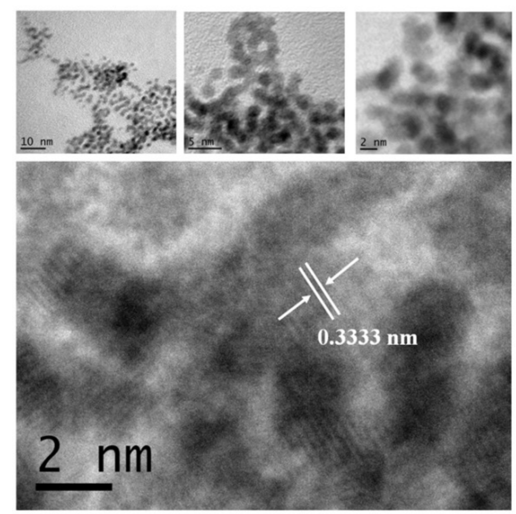
picture of IrOx electrode (a), before high pressure test; (b) after high pressure testing three times; (c) after five times.

Iridium oxide nanoparticles



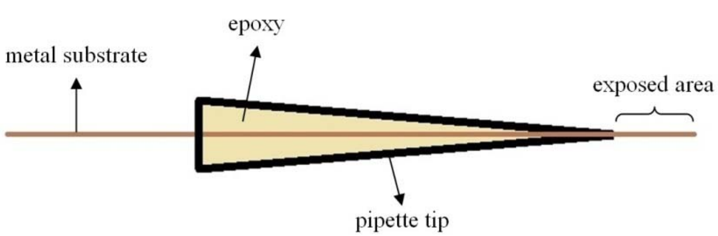




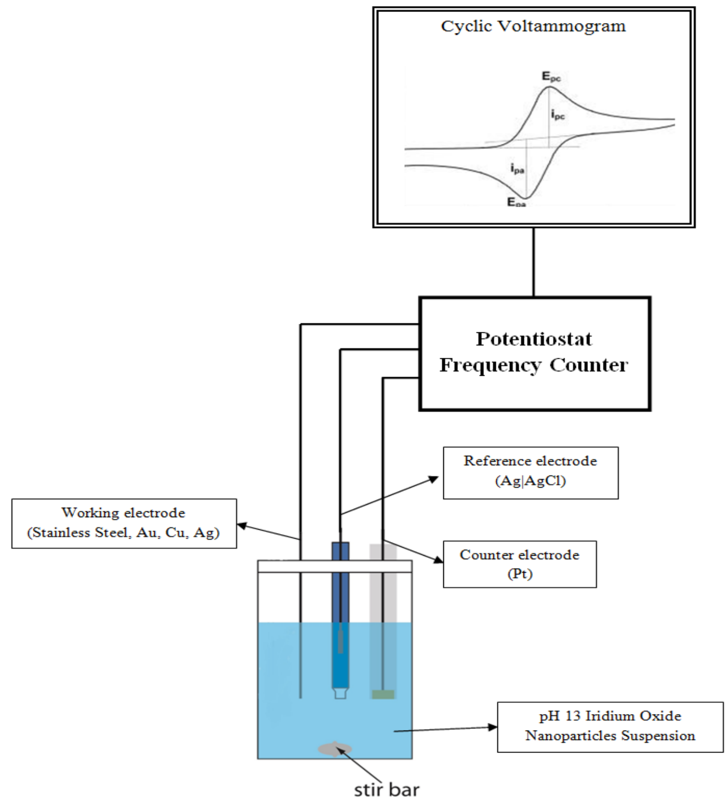


UV-Vis spectra of heated and unheated 2 mM aqueous K_2IrCl_6 solutions at pH 13 and after acid condensation at pH 1; solutions prepared by hydrolysis and acid condensation.

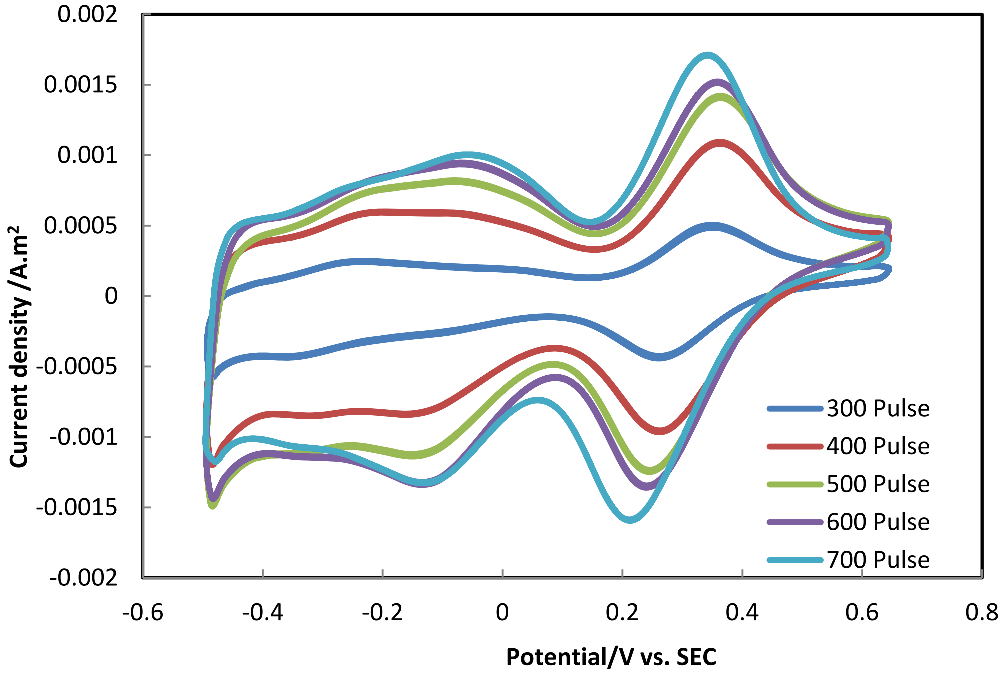
Preparation of iridium oxide electrode by electrodeposition method



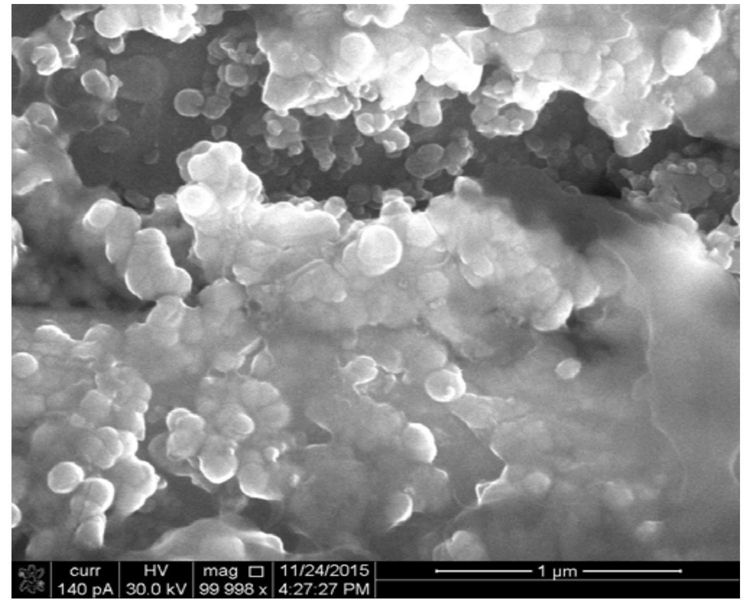
Schematic illustration of the electrode



Schematic diagram of the electrodeposition cell of cyclic voltammetry instrumentation

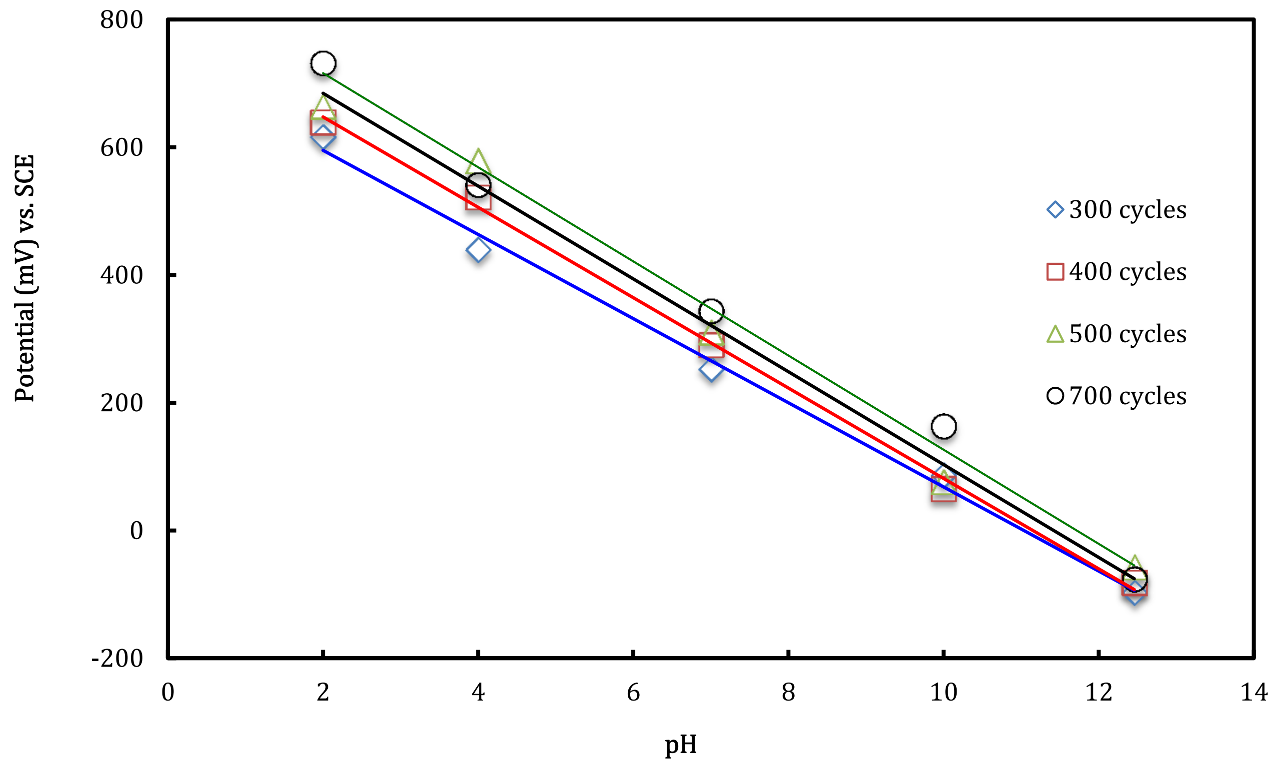


Cyclic voltammogram of electrodeposition of iridium oxide nanoparticles with different deposition cycles.

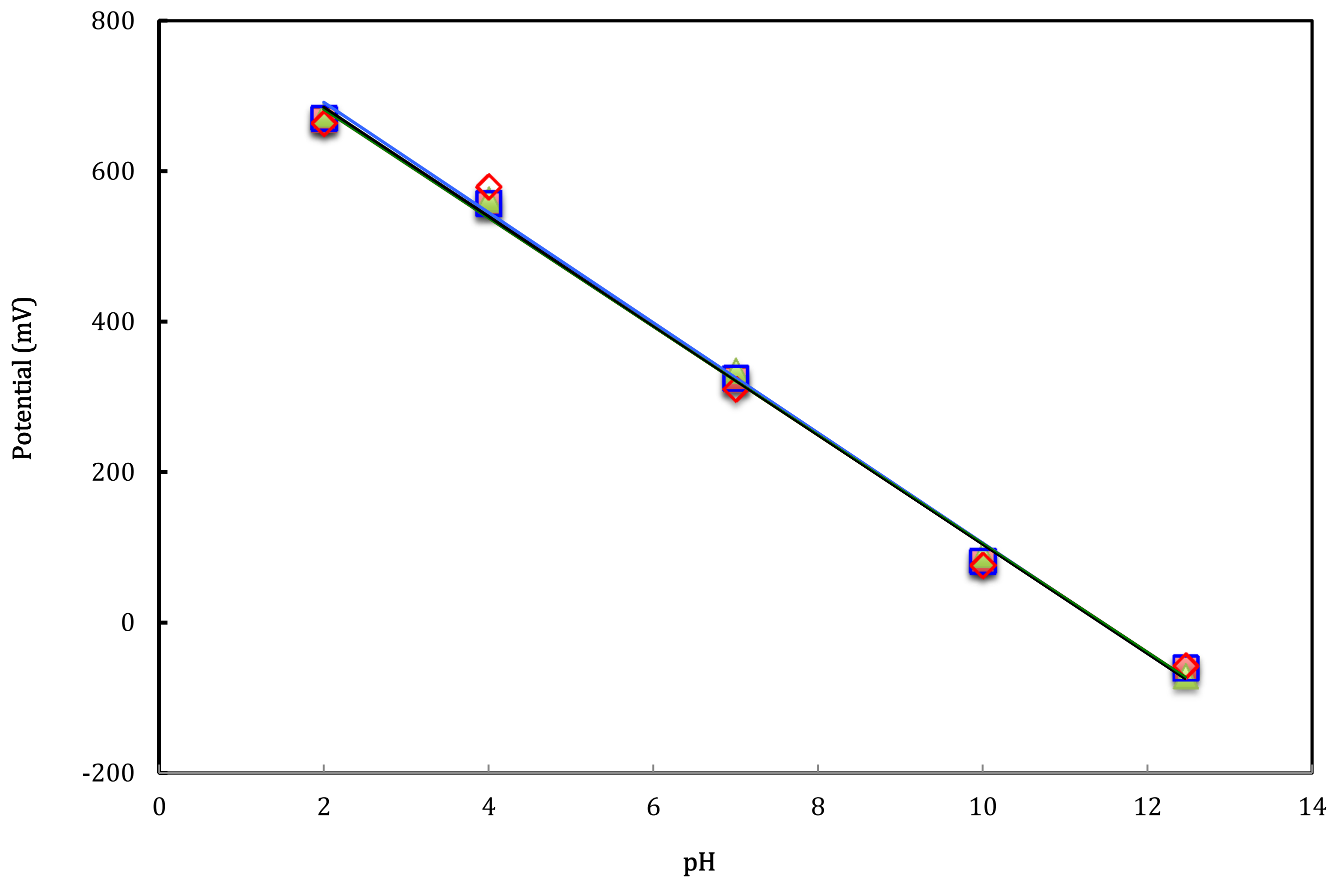


SEM image of IrO_2 deposited on stainless steel.

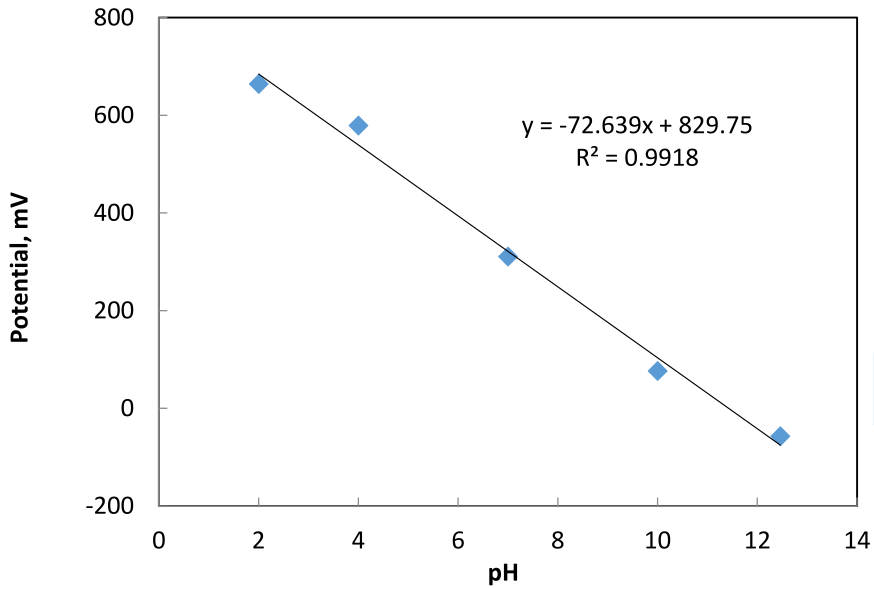
pH response of the prepared electrodes



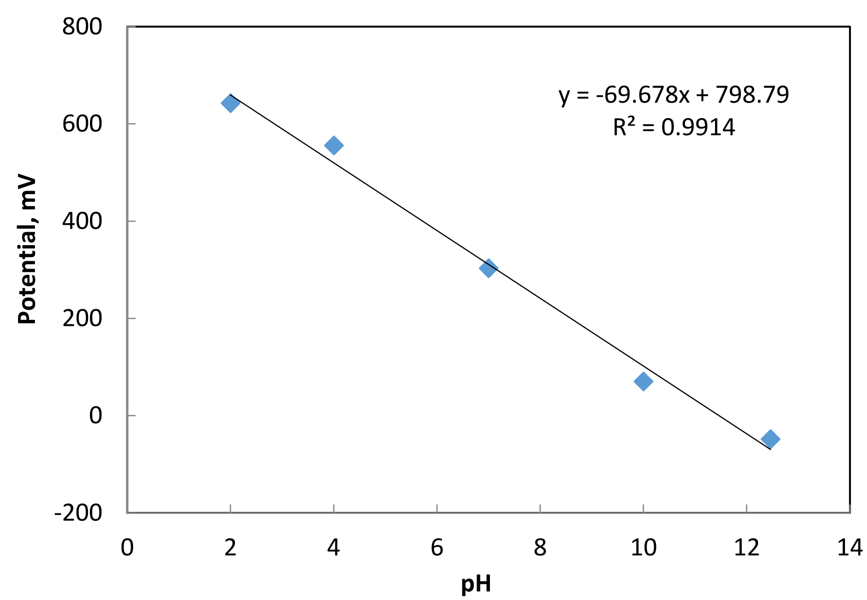
Reproducibility of the electrode fabrication



Performance of the electrode under high pressure test



pH response of the electrode before high pressure test



pH response of the electrode after high pressure tests (2,000 psi, 5 cycle tests)

Conclusions

- **A downhole CO_2 sensor was constructed. The downhole CO_2 sensor could measure the dissolved CO_2 concentration at reservoir conditions. CO_2/brine coreflooding system was construct and the CO_2 sensor was tested in different coreflooding tests. The sensor output potential was observed to increase after CO_2 was injected into the core.**

- **The CO_2 sensor could be recovered by waterflooding after CO_2/brine flushed the core.**

- **An electrodeposition approach to prepare iridium oxide electrode was developed. The iridium oxide electrode thus prepared displayed excellent pH sensitivity, obtaining super-Nernstian behavior with pH sensitivity value of -72.6 mV/pH.**

- **The performance of the iridium oxide electrode was tested under high pressure. The results indicated that the prepared electrode displayed excellent pressure resist.**

Future work

- ***Develop a data acquisition system to convert the output of the sensor signal into digital data.***

- ***Techno-economic Assessment/Final report***

Acknowledgement

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