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

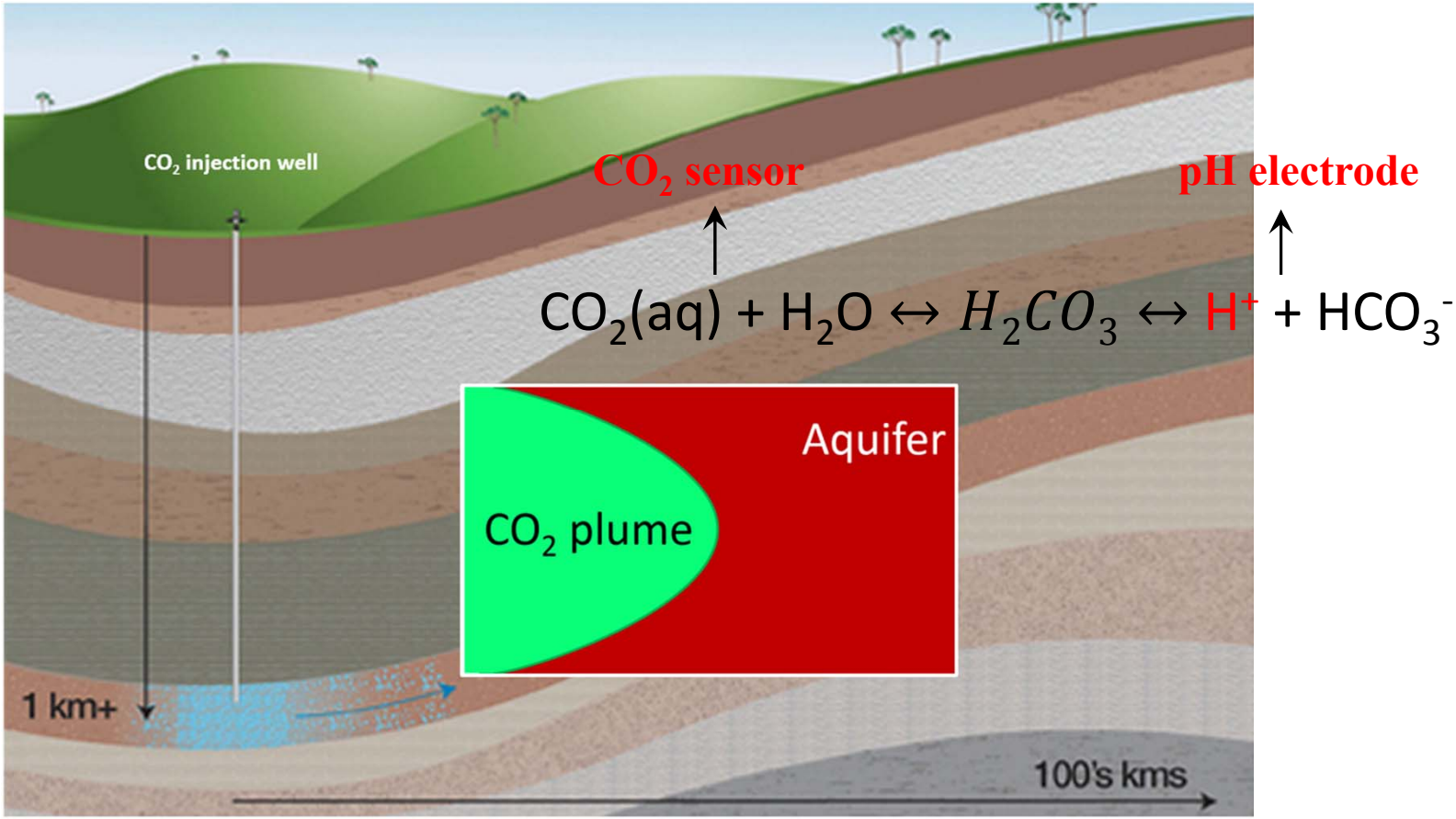


Figure 1. Schematic of CO_2 sequestration.

CO_2 chemical sensor design

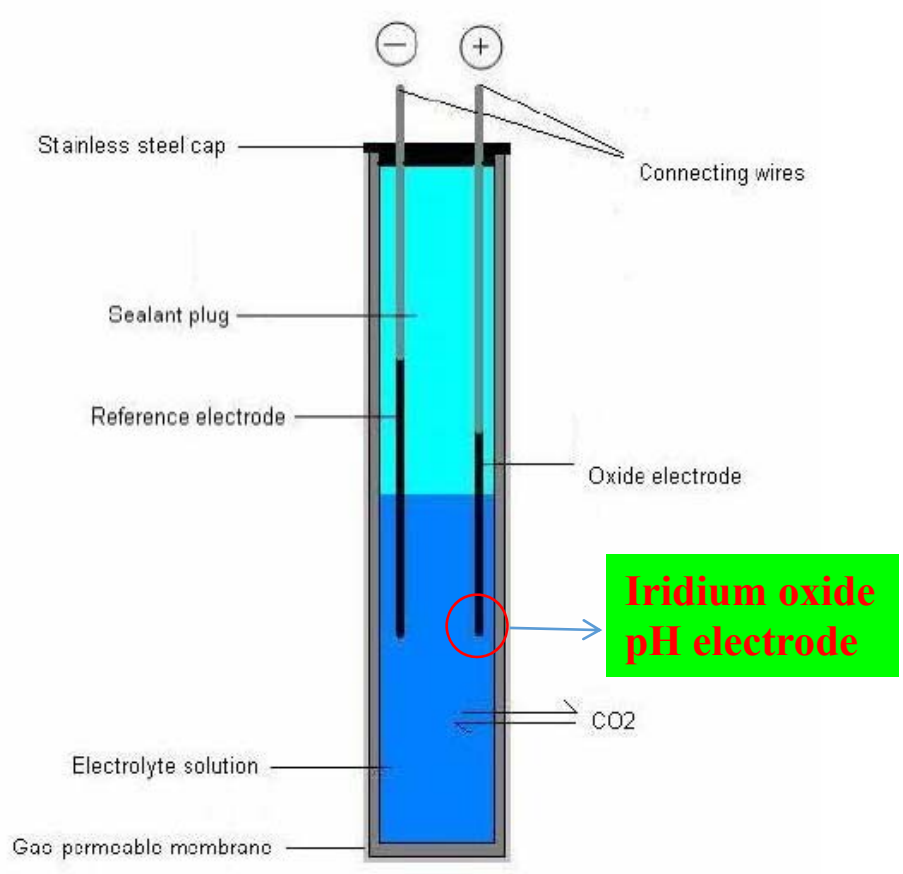


Figure 2. Schematic structure and picture of the fabricated CO_2 sensor.

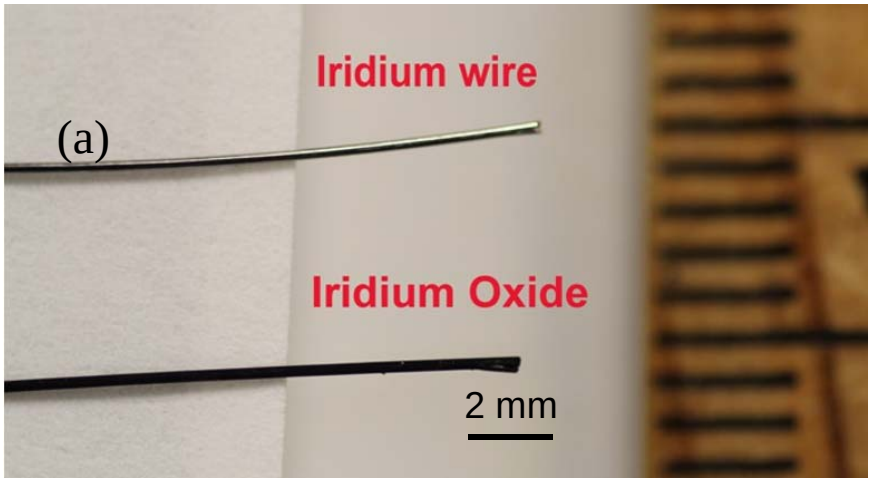
$$\mathbf{CO_2(g) + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-}$$

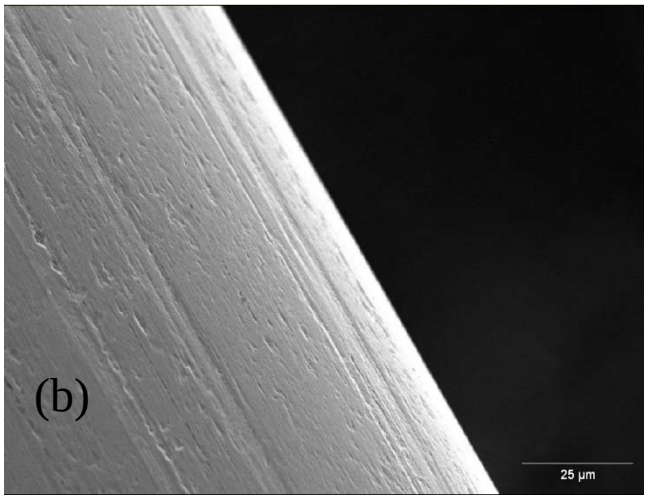
$$E = E^o + \frac{2.303RT}{F}\log[H^+]$$

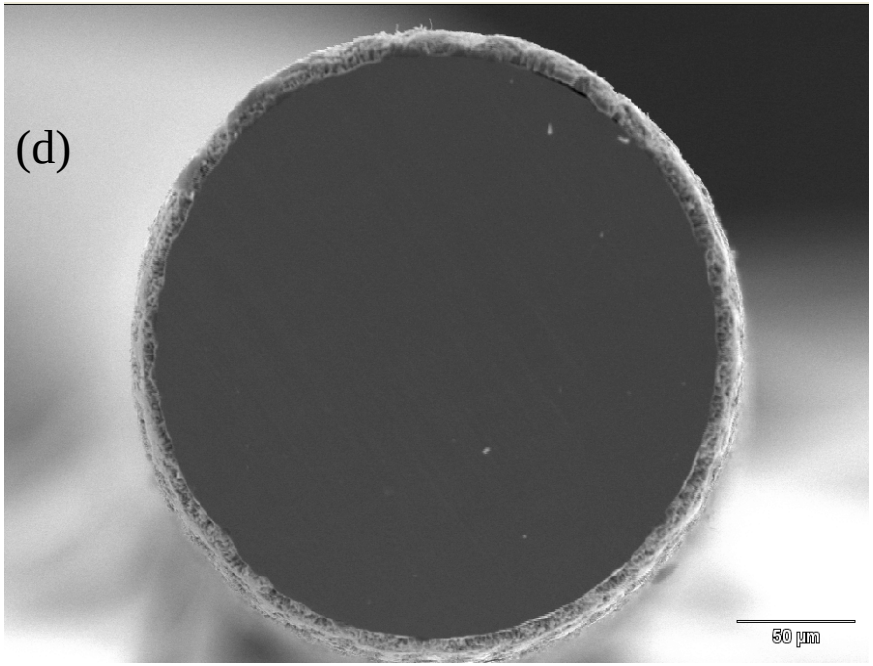
$$E = E^o + 59.15\log\frac{k}{[HCO_3^-]} + 59.15\log[CO_2]$$

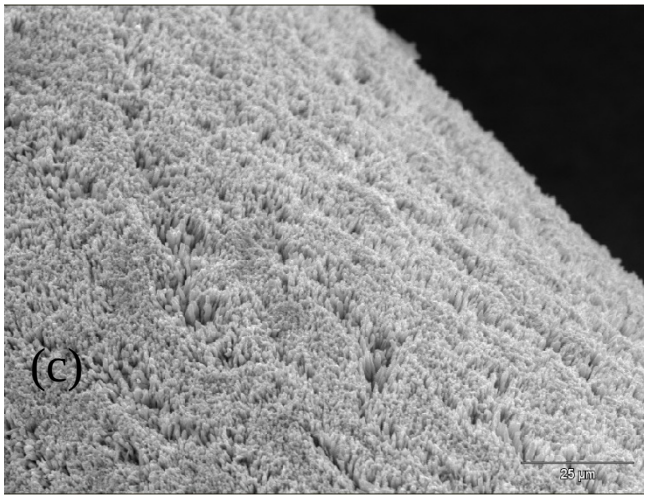
$$\Delta E = 59.15\log[CO_2] + k$$

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.

Current Work

Task 3.0 (1 year) Fabricate downhole CO_2 sensor and test the sensor at high pressure.

- Subtask 2.1 Construct downhole CO_2 sensor
- Subtask 2.2 Test the performance of the CO_2 sensor
- Subtask 2.3 Evaluate the CO_2 sensor in brine solution and high pressure

CO_2 sensor preparation

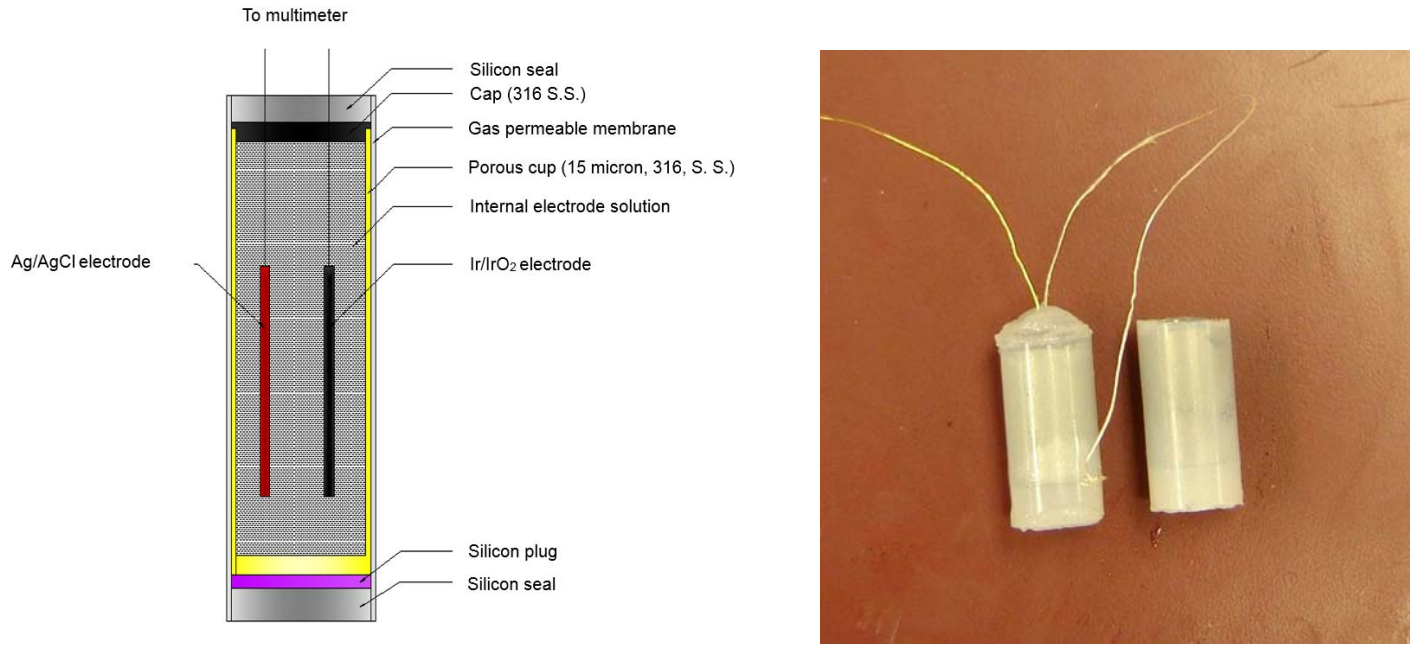
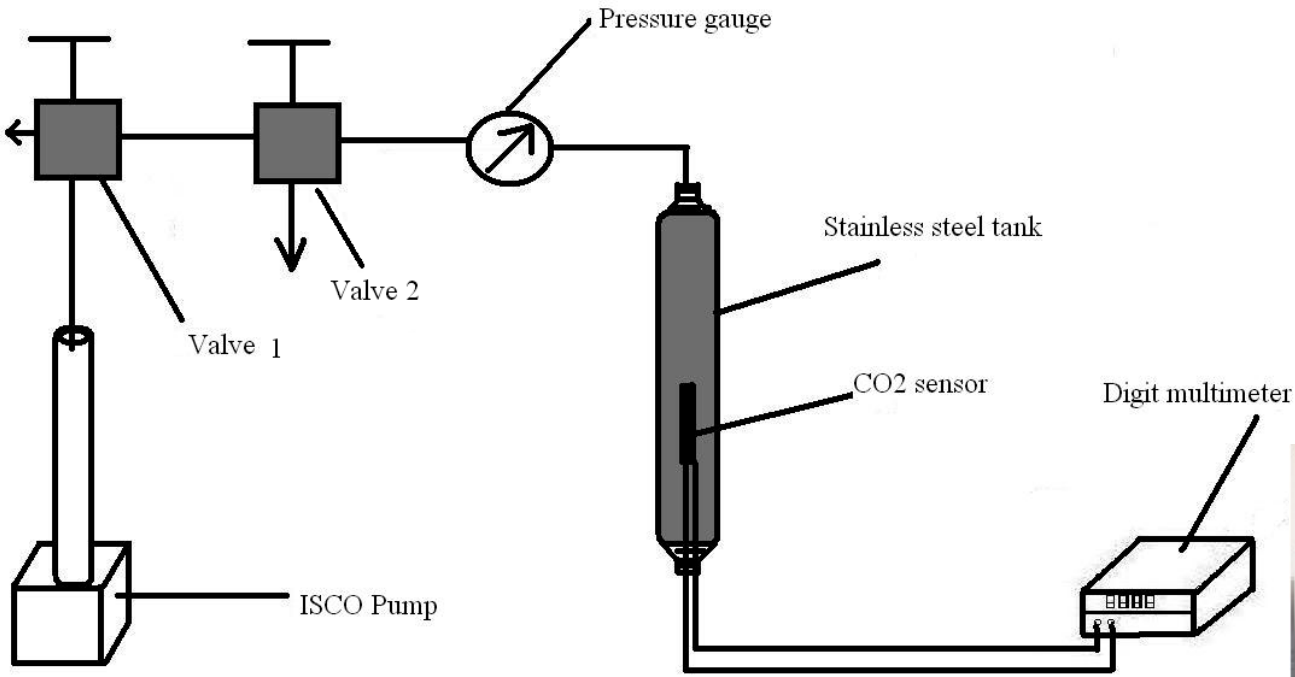
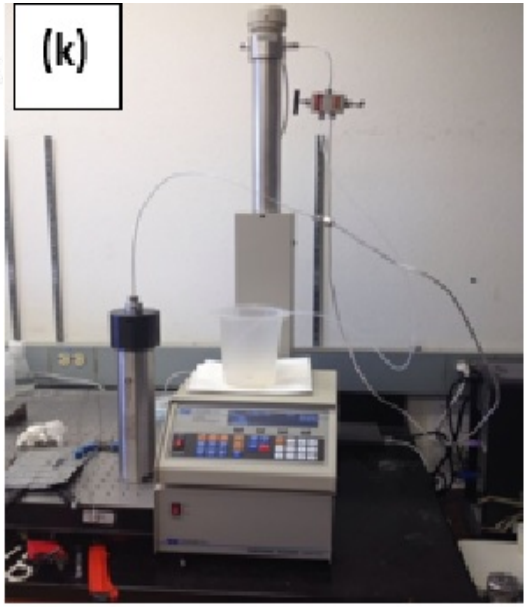
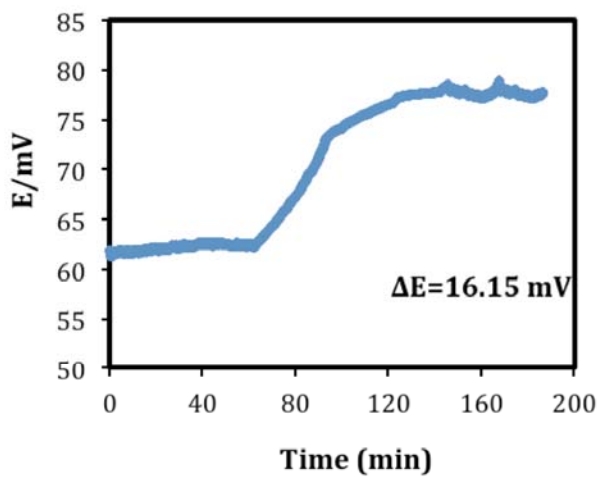


Figure. 29 Schematic design and image of the downhole CO_2 sensor.

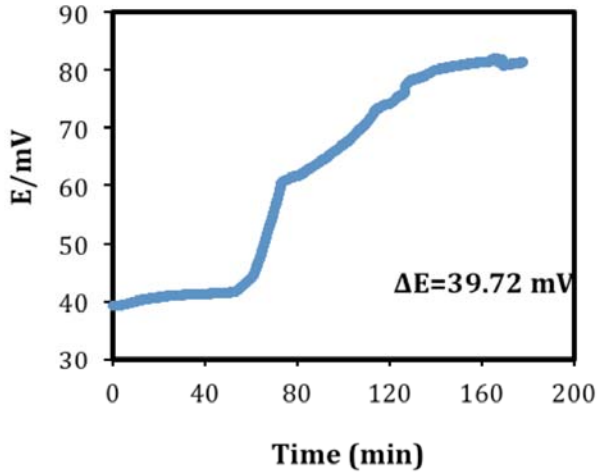
Schematic diagram of the downhole CO_2 sensor test.



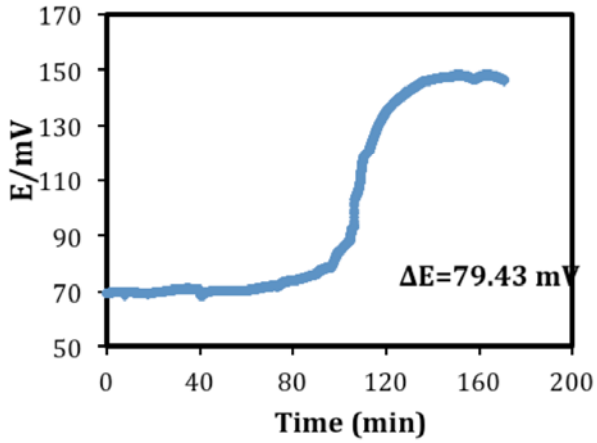




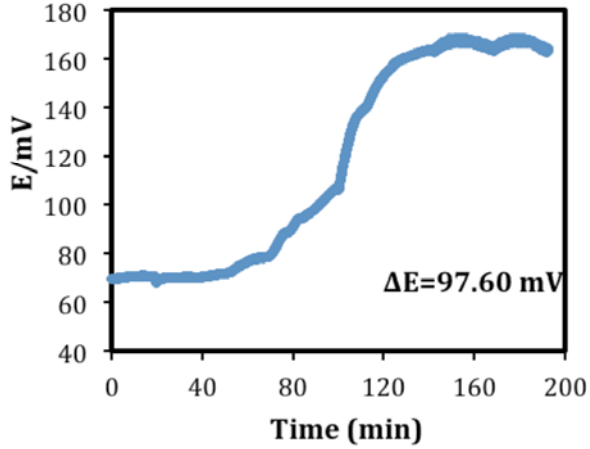
(a) 0.001 M



(b) 0.002 M

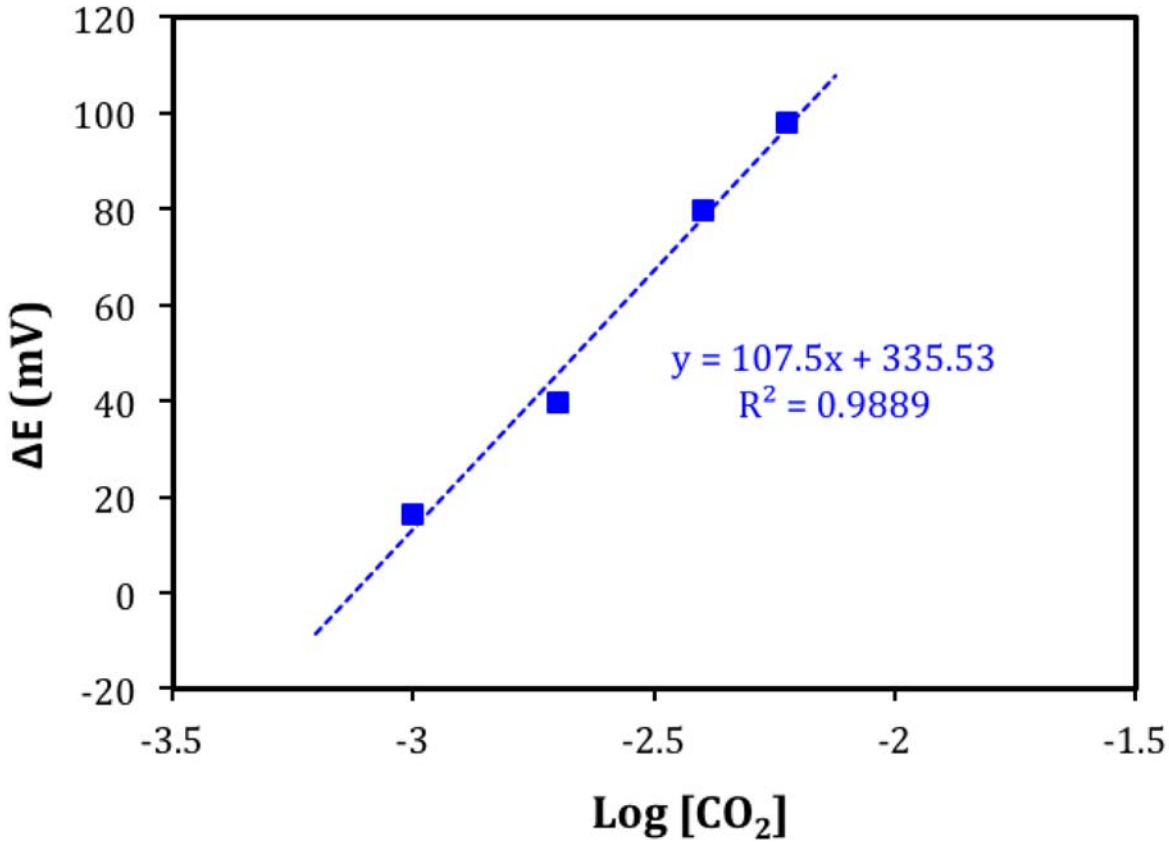


(c) 0.004 M

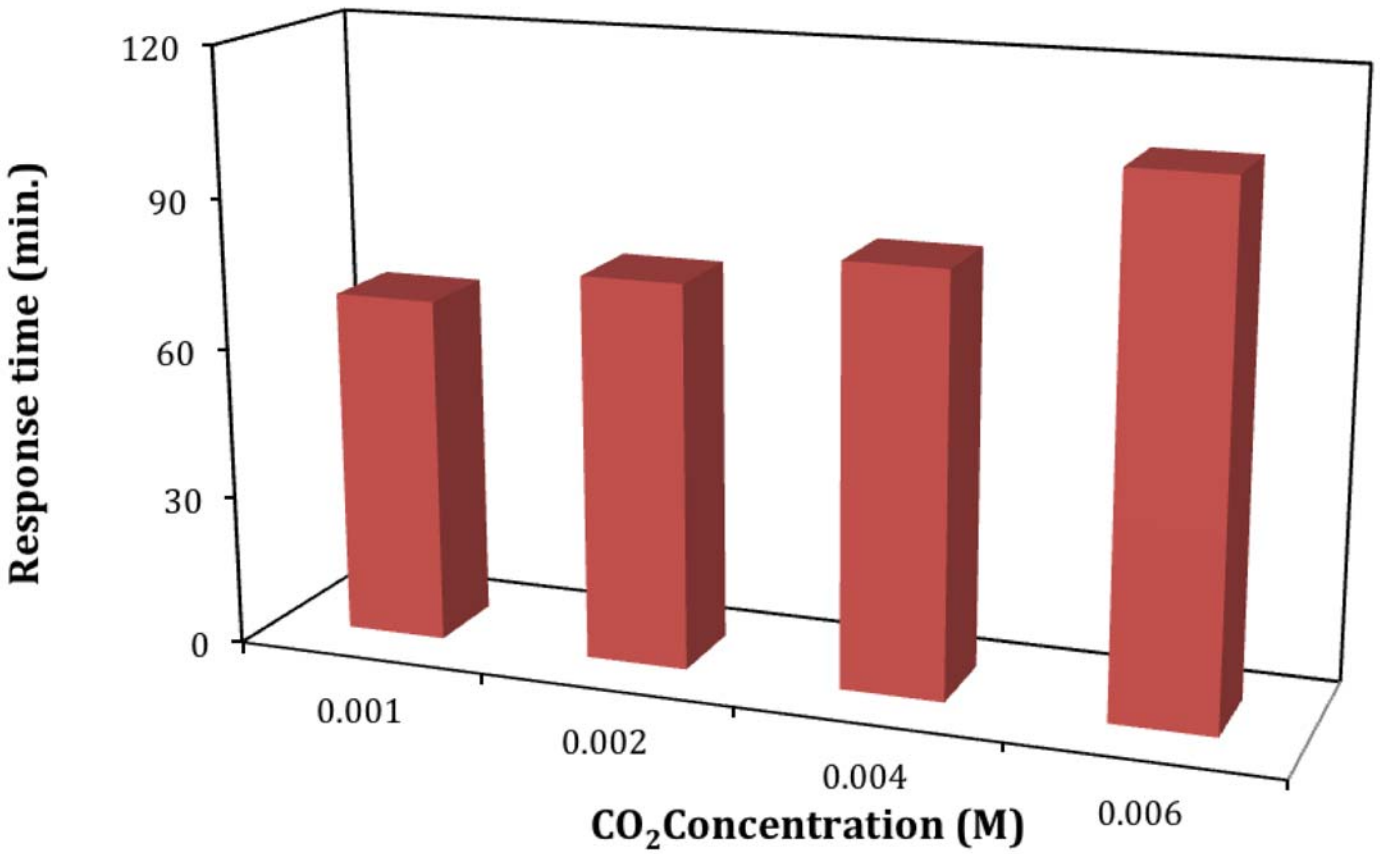


(d) 0.006 M

Potential response of the CO_2 sensor with time in different concentrations of CO_2 under 2000 psi



log[CO_2] as a function of potential change at the pressure of 2000 psi.



Plot of response time of CO_2 sensor against CO_2 concentration at room temperature under 2,000 psi.

Performance of the CO_2 sensor under different pressure

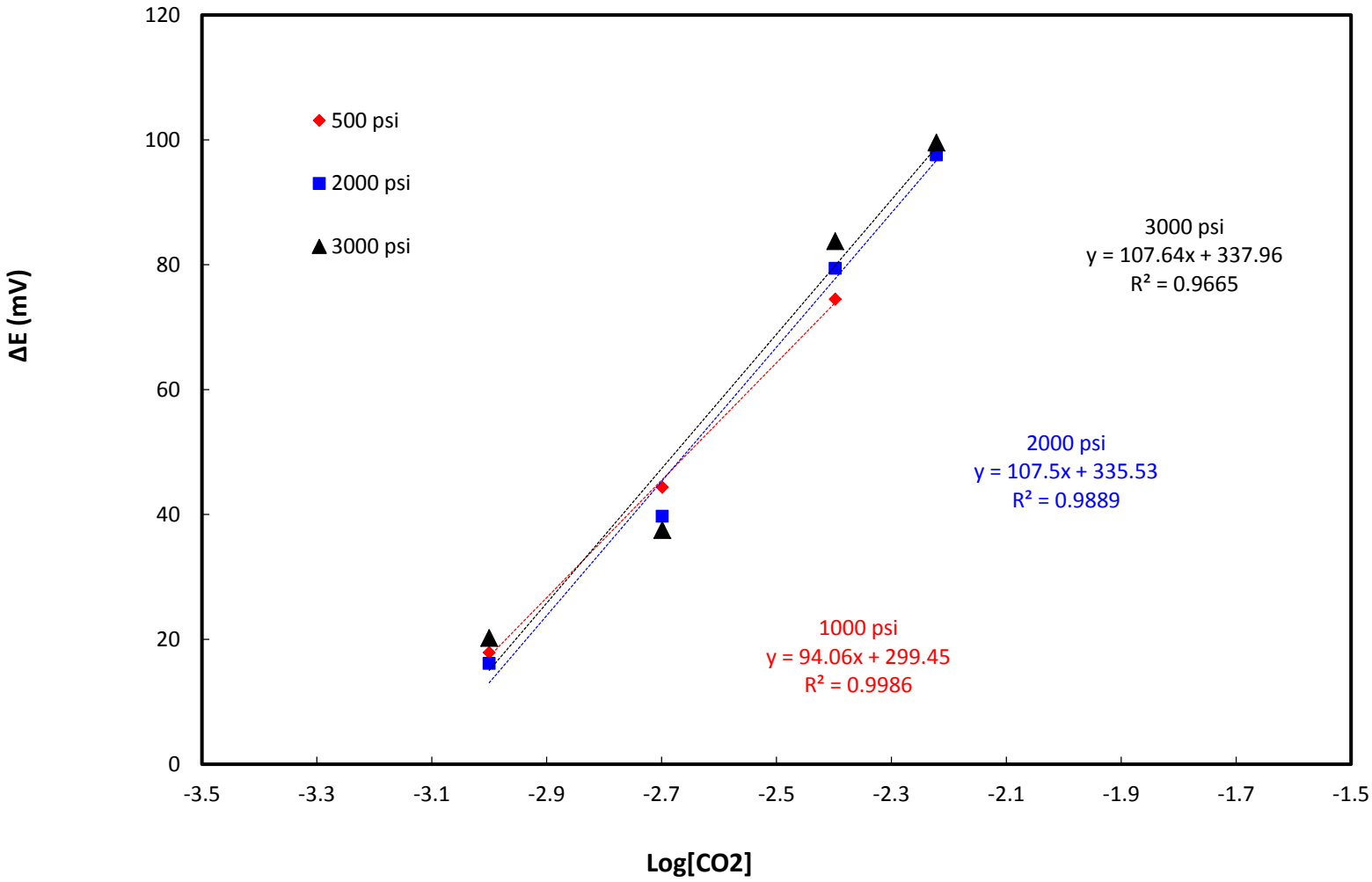
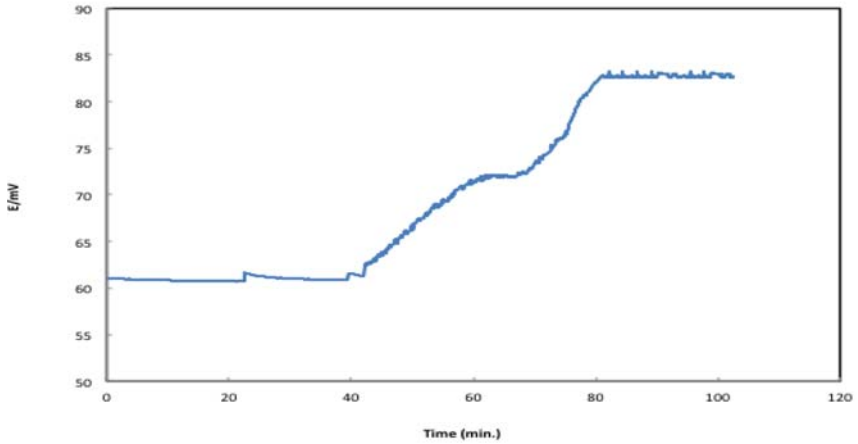
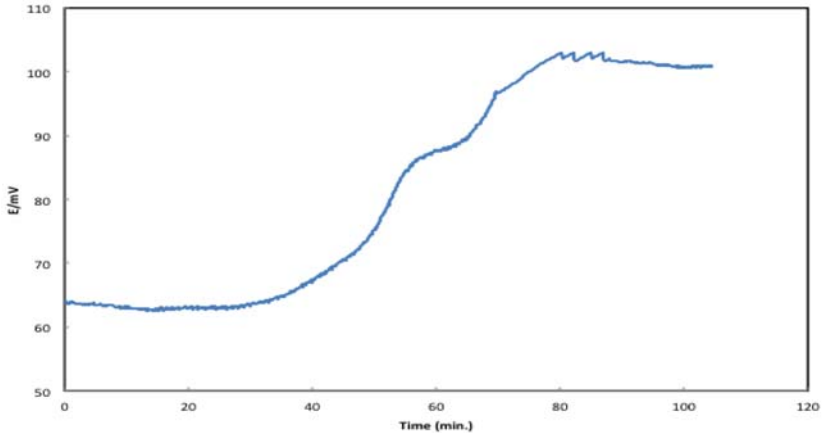


Table 1 The Compositions of Permian Basin Produced Waters [1]

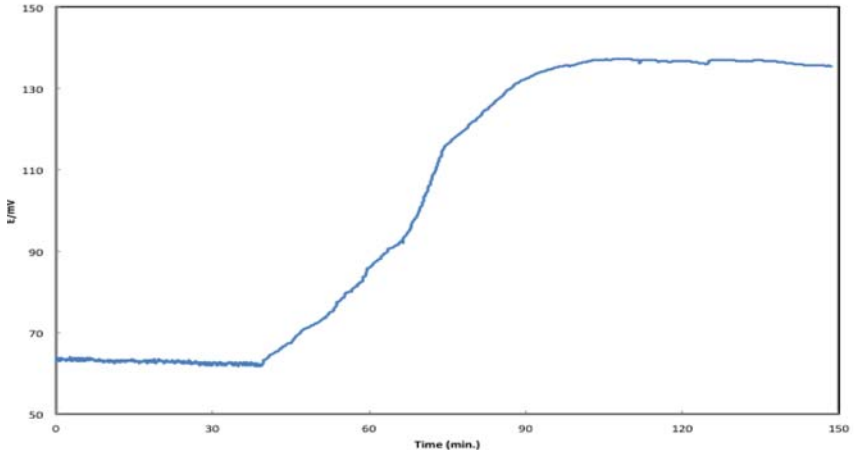
mg/L	Na^+	Ca^{2+}	Mg^{2+}	K^+	Cl^-	SO_4^{2-}	HCO_3^-	TDS
Permian Basin	61842	3486	3524	180	108486	2017	134	180013



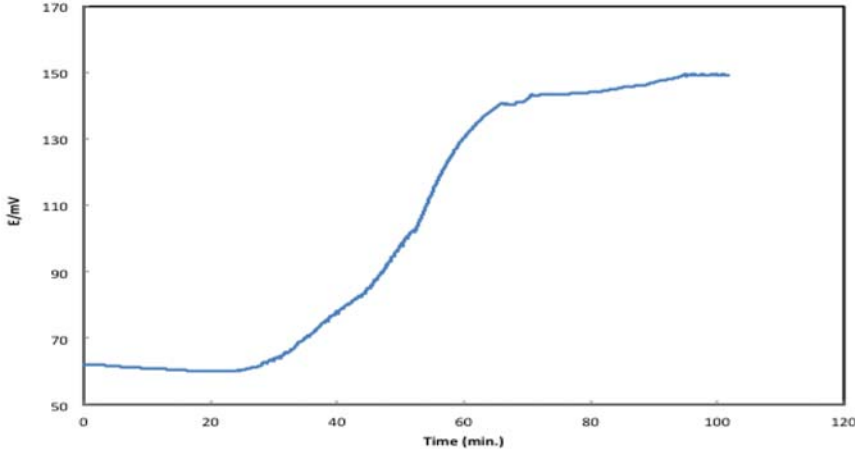
(a)



(b)

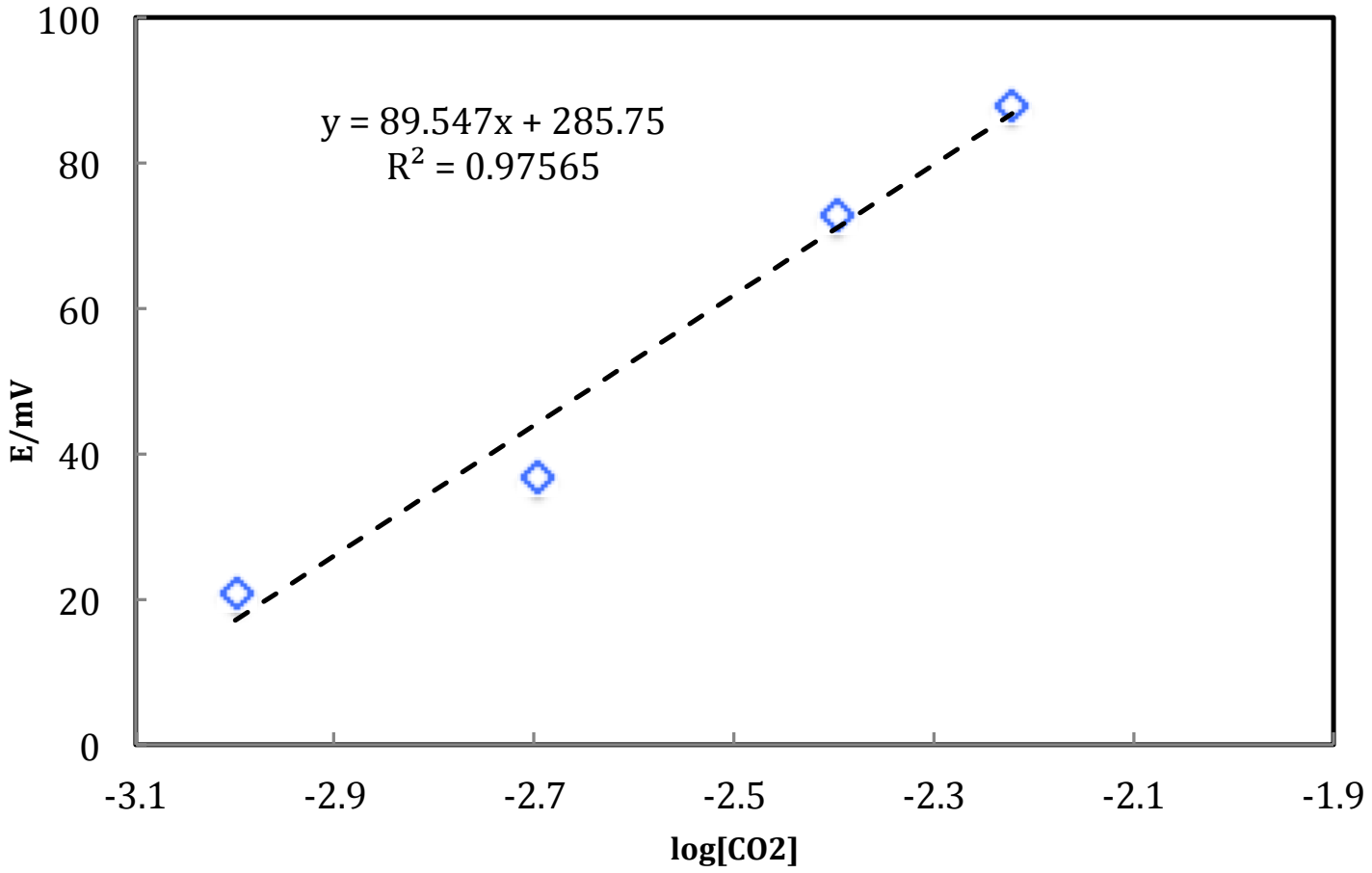


(c)

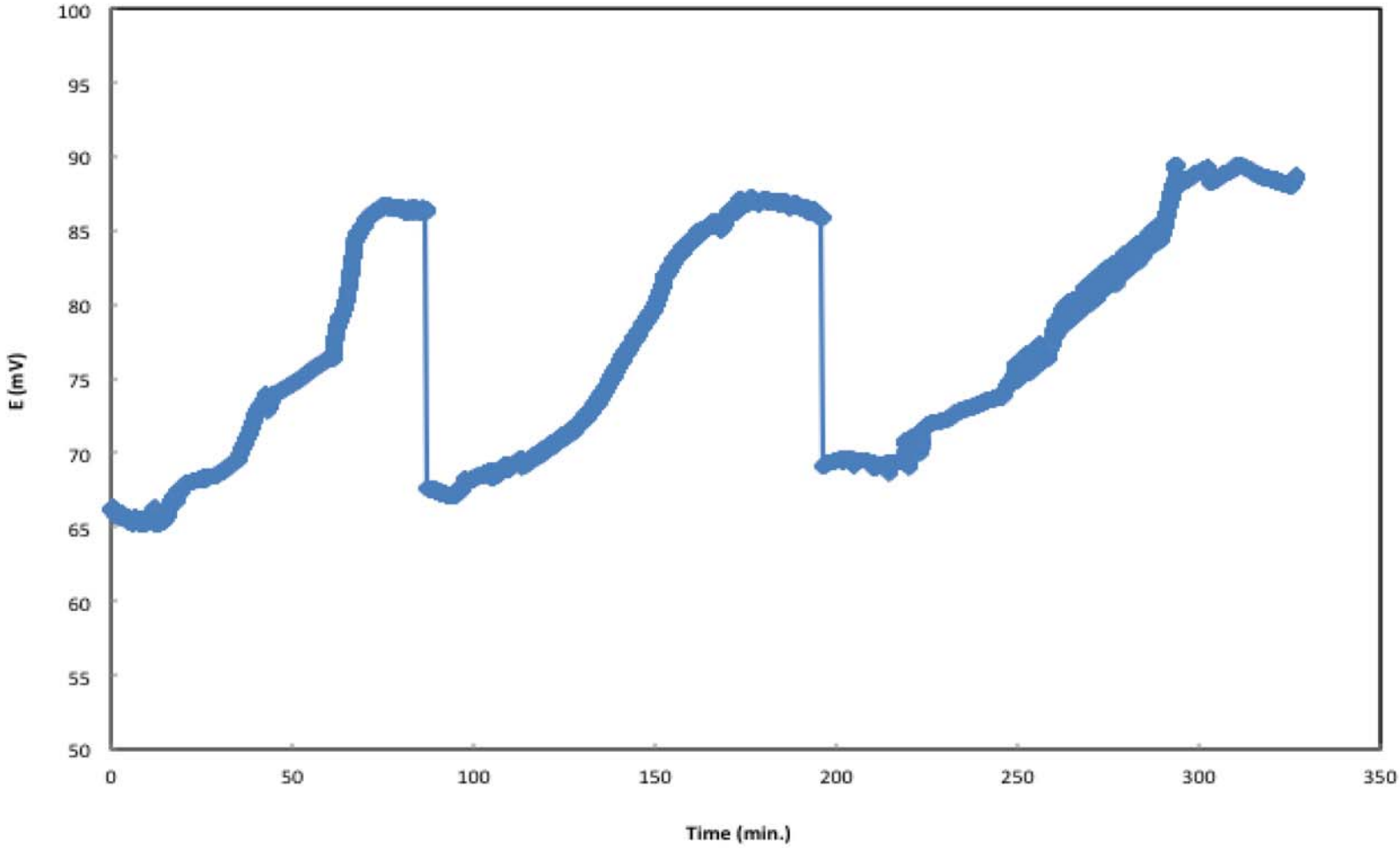


(d)

Performance of the CO_2 sensor in synthetic produced water, pressure=2,000 psi



Reproducibility test of the CO_2 sensor in $[CO_2]$=1mM and pressure=2,000 psi

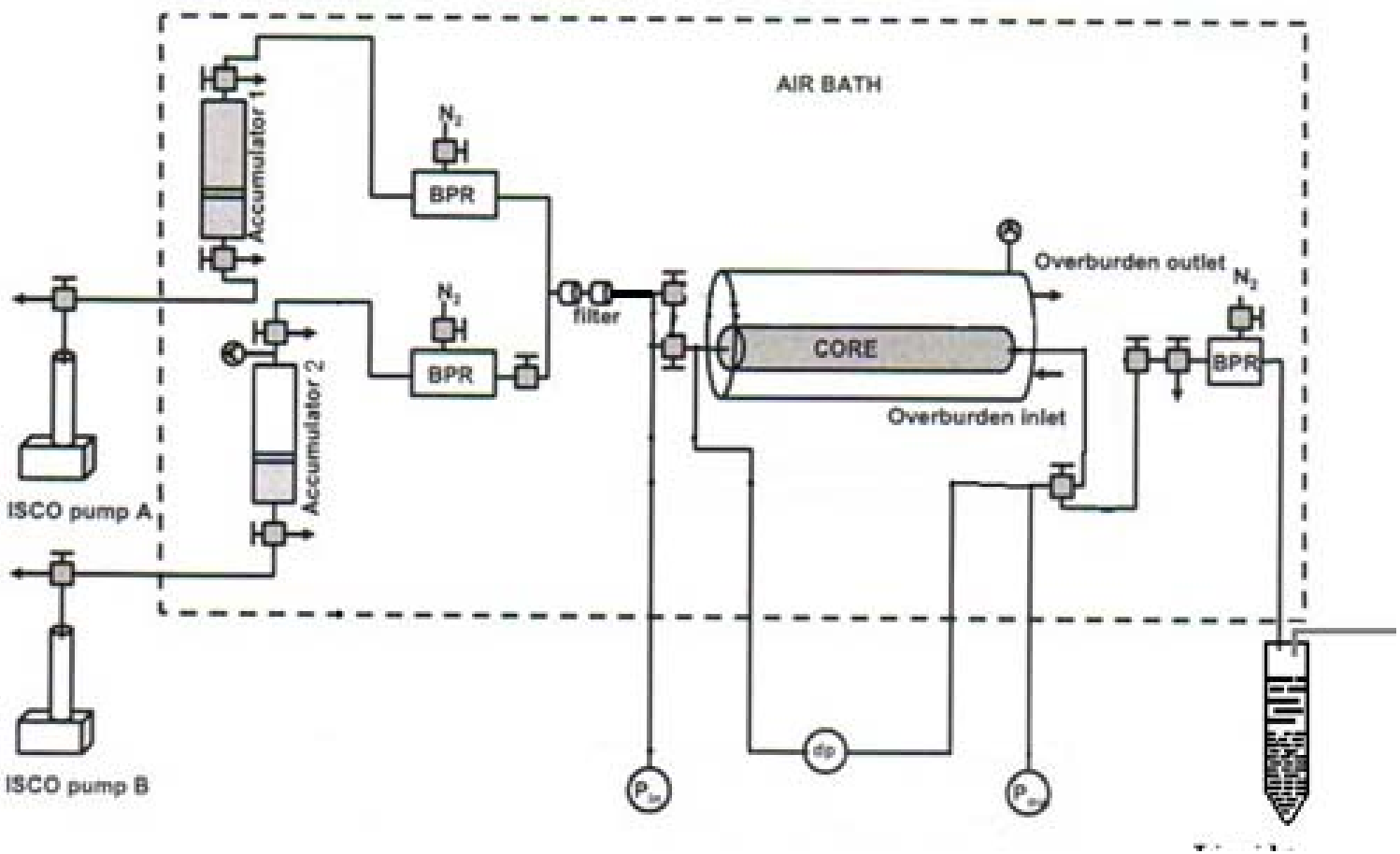


Current Work

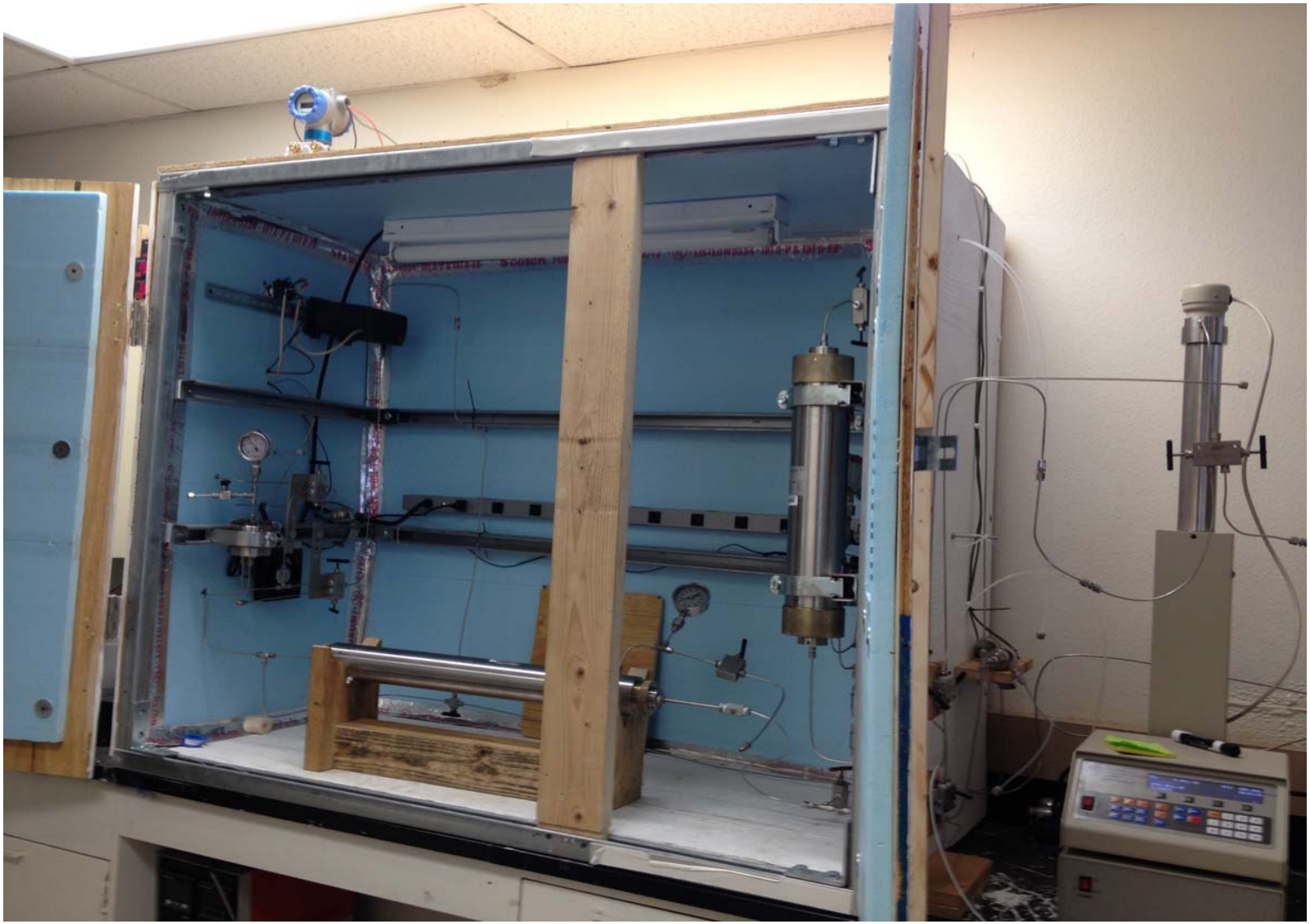
Task 4.0 (1 year) Evaluate the CO_2 sensor in CO_2/brine coreflooding tests and develop a data acquisition system for the downhole CO_2 sensor.

- 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

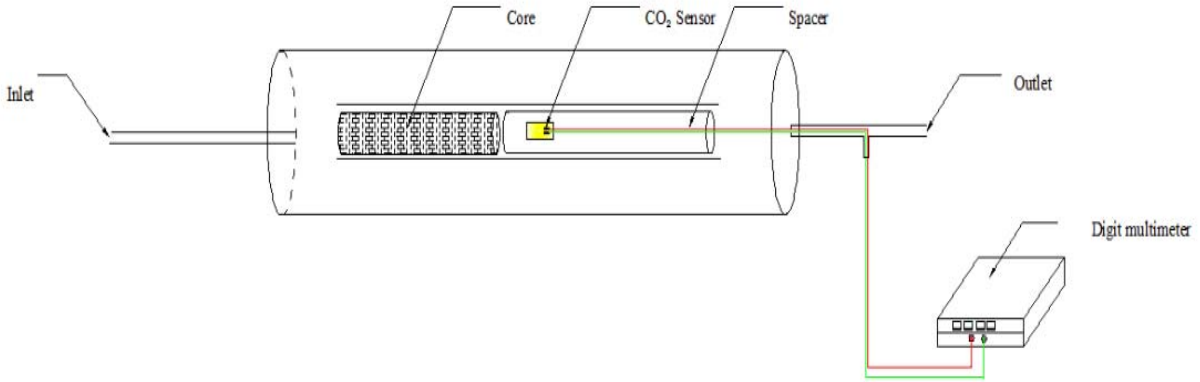
Schematic diagram of the coreflooding system

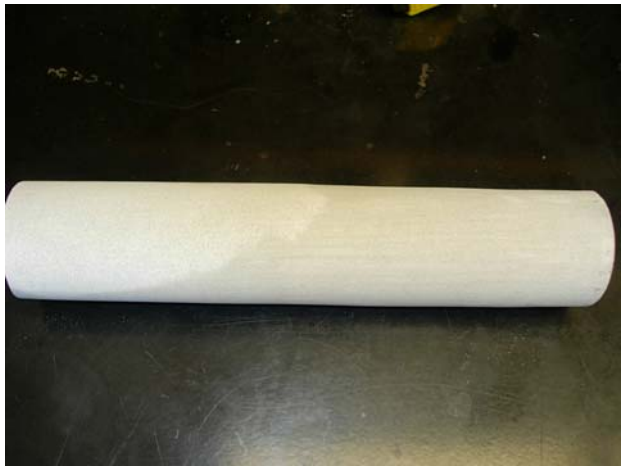


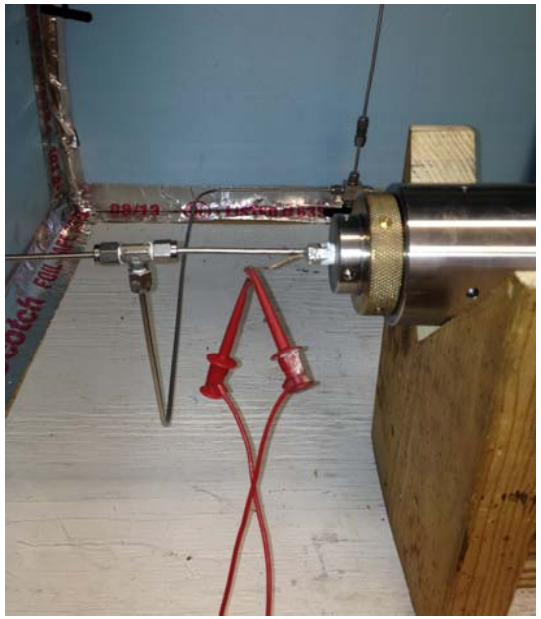
Picture of the coreflooding system



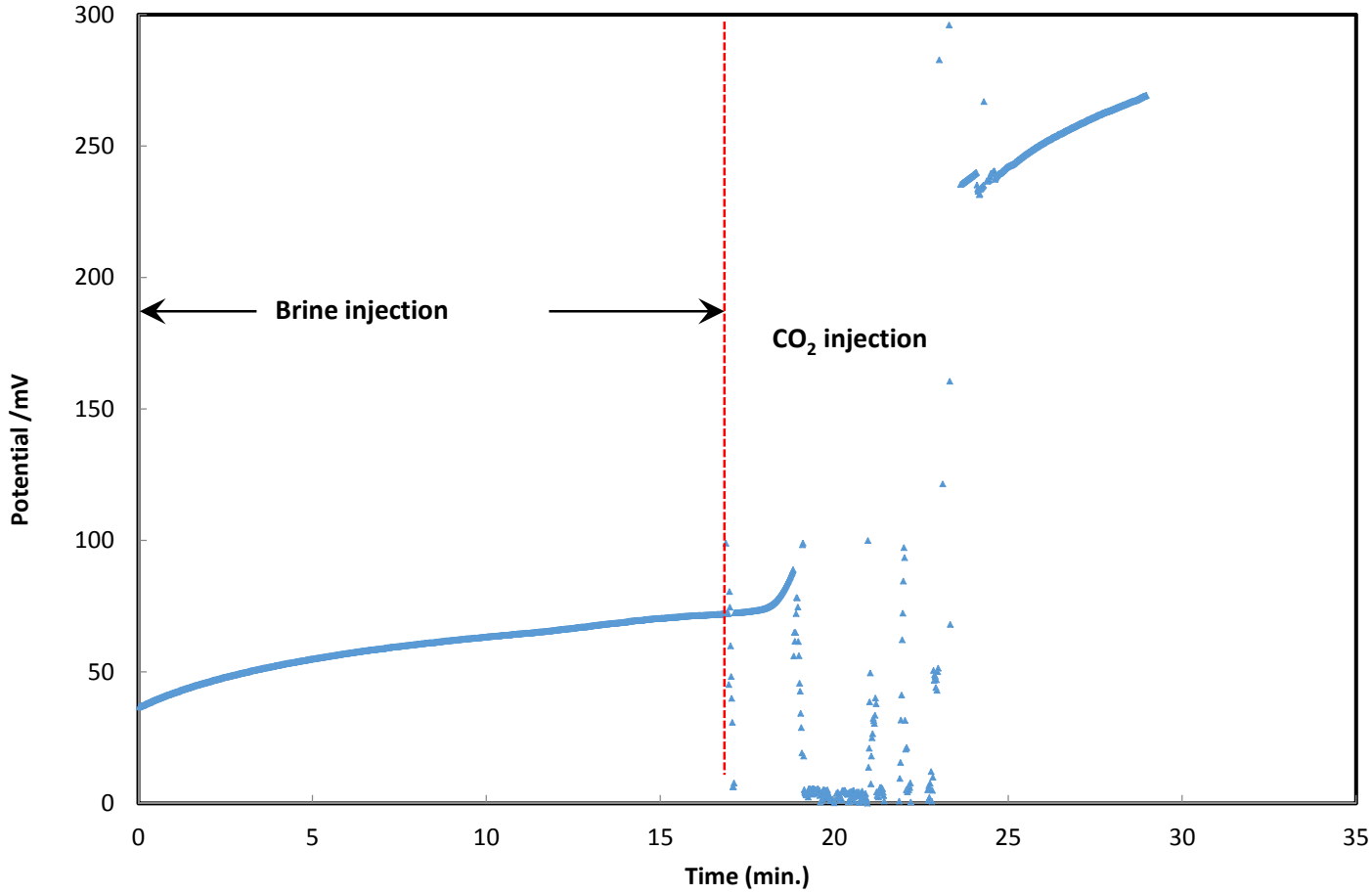
Mount the CO_2 sensor in the coreflooding system



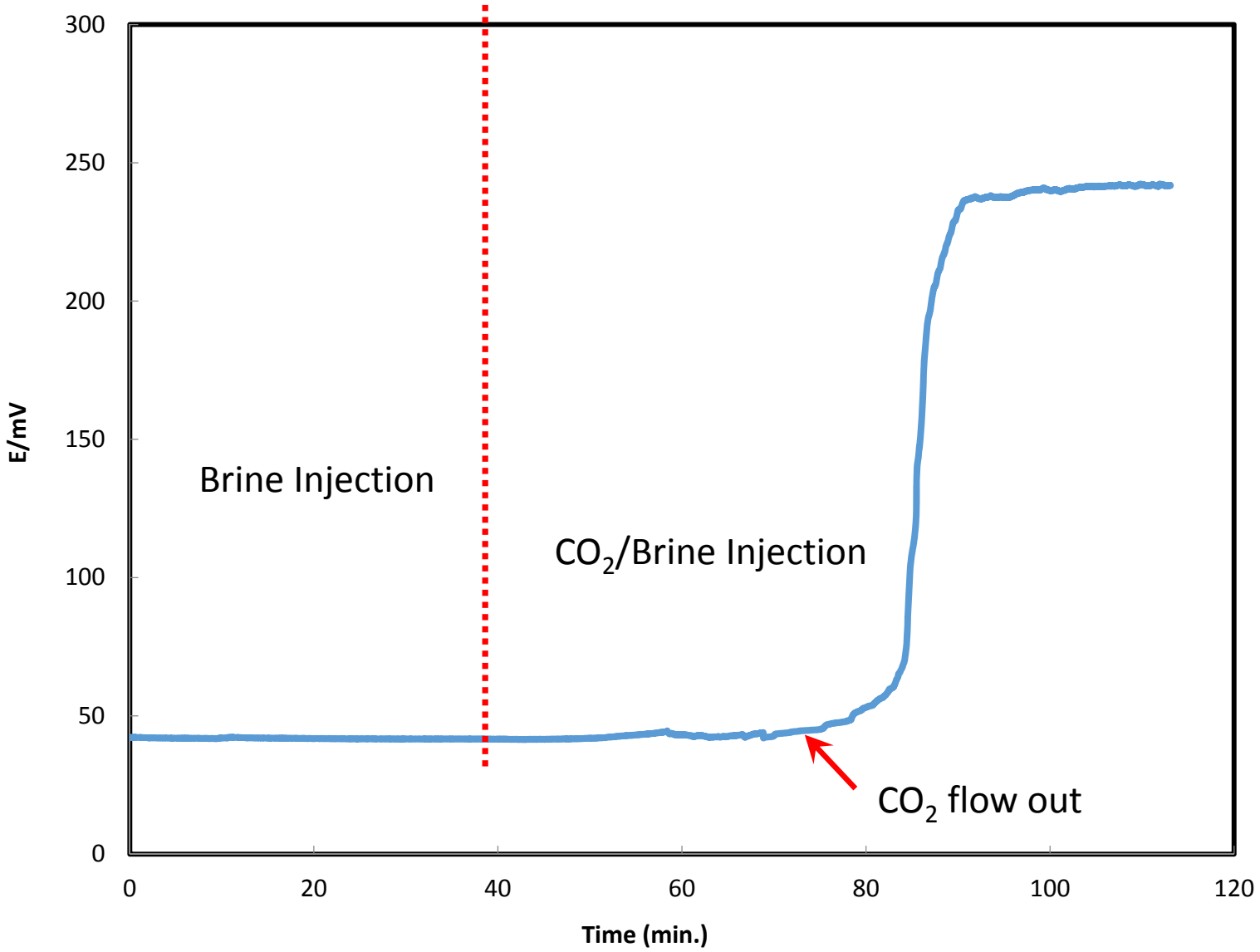




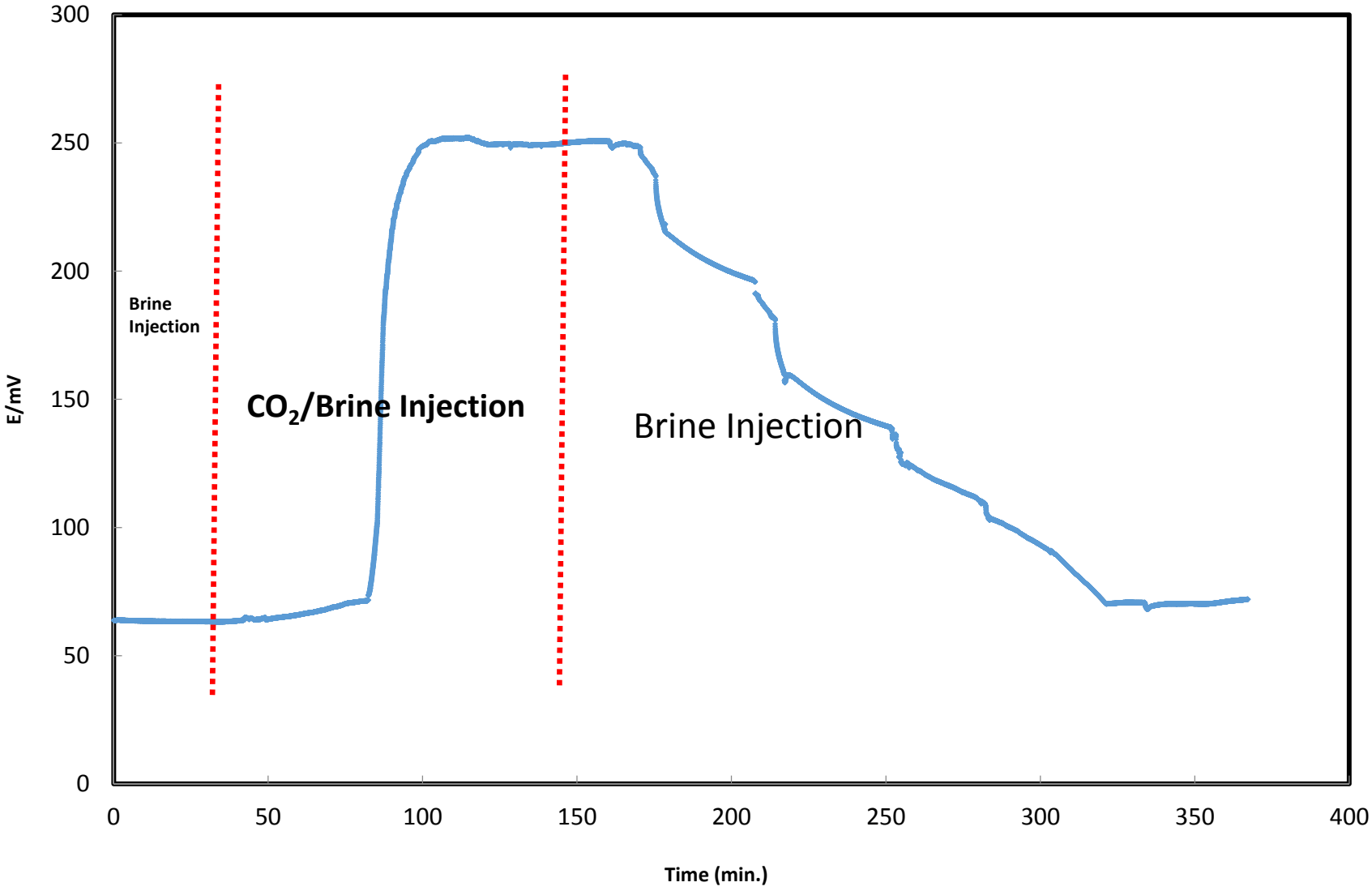
CO_2 sensor performance during CO_2/brine the coreflooding test



CO_2 sensor performance during CO_2/brine the coreflooding test



CO_2 sensor performance during CO_2/brine the coreflooding test



Conclusions

- A downhole CO_2 sensor was constructed. The downhole CO_2 sensor could measure the dissolved CO_2 concentration under high pressure.
- A linear correlation was observed between the CO_2 sensor potential change and CO_2 concentration in water under 500 psi, 2,000 psi, and 3,000 psi.
- The downhole CO_2 sensor performed very well in synthetic produced water under 1,000 psi and exhibited good reproducibility under high pressure. A little potential shift was observed during the test. The shift of the potential contributed to some residual CO_2 in the internal solution.
- 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.

Future 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

- ***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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