As the first true RFB, the Iron-Chromium redox flow battery (ICRFB) is very attractive in terms of its cost effectiveness, comprising cheap and abundant active materials. It has a standard overall cell potential of 1.18 V with the reactions occurring within the battery are listed below.

Positive Electrode: $Fe^{2+} \rightleftarrows Fe^{3+} + e^{-}$ $E^0 = +0.77V$ (1)

Negative Electrode: $Cr^{3+} + e^{-} \rightleftarrows Cr^{2+}$ $E^0 = -0.41V$ (2)

Overall: $Fe^{2+} + Cr^{3+} \rightleftarrows Fe^{3+} + Cr^{2+}$ $E^0 = +1.18V$ (3)

Despite the cost effectiveness of the ICRFB, it is prone to significant membrane crossover of the active species that results in irreversible capacity decay. This same capacity occurs for many other inexpensive RFB chemistries and has largely prevented their commercialization.

There is still a need for a selective sol-gel membrane that can reduce flow battery costs and enable new flow battery chemistries.

SUMMARY

This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

In one aspect, the present disclosure provides a nanoporous selective sol-gel ceramic membrane, generally including a porous support having a plurality of support pores that are 10 nm or greater in diameter; and a nanoporous composite comprising a nanoporous sol-gel ceramic composite filling at least a portion of the porous support; wherein the nanoporous composite comprises a plurality of nanopores of 5 nm or smaller in radius with a polydispersity index of 0.7 or lower.

In another aspect, the present disclosure provides a nanoporous selective sol-gel ceramic membrane, generally including a porous support having a plurality of support pores that are 10 nm or greater in diameter; and a nanoporous composite comprising a nanoporous sol-gel ceramic composite filling at least a portion of an active area of the porous support; wherein the nanoporous sol-gel ceramic has a fractal nanoporous