Flow Battery Membrane

Energy Storage Systems Program (ESS) Peer Review and Update Meeting 2012

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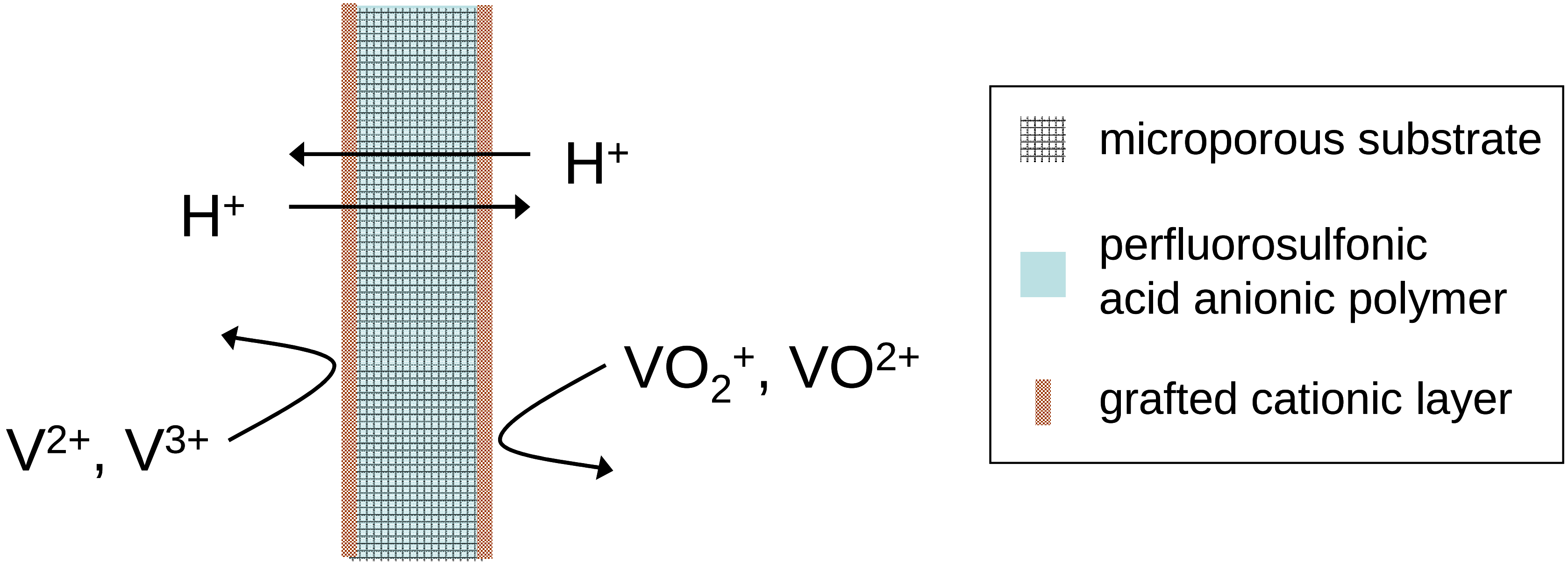
Vanadium redox batteries (VRB) for energy storage require improved ion-selective membranes.

- Vanadium permeation across current membranes leads to self-discharge and decreases cycling efficiency:
  - Negative half cell: $V^{2+} \leftrightarrow V^{3+} + e^{-}$ $E_o = -0.255V$
  - Positive half cell: $e^{-} + VO_2^{+} + 2H^{+} \leftrightarrow VO^{2+} + H_2O$ $E_o = 1.00V$.
- Current perfluorosulfonic acid polymer membranes are costly.
- TIAX is developing a novel composite bipolar membrane:
  - Composite anionic membrane minimizes content of costly perfluorosulfonic acid polymer
  - Made bipolar by a cationic surface layer to improve selectivity for monovalent protons over larger, poly-cationic vanadium species
- TIAX has completed a Phase I SBIR program
  - contract # DE-SC0006457

The bipolar composite membrane is designed to maximize selectivity for proton conductance while minimizing vanadium permeation and content of costly perfluorosulfonic acid polymer (PFSA).

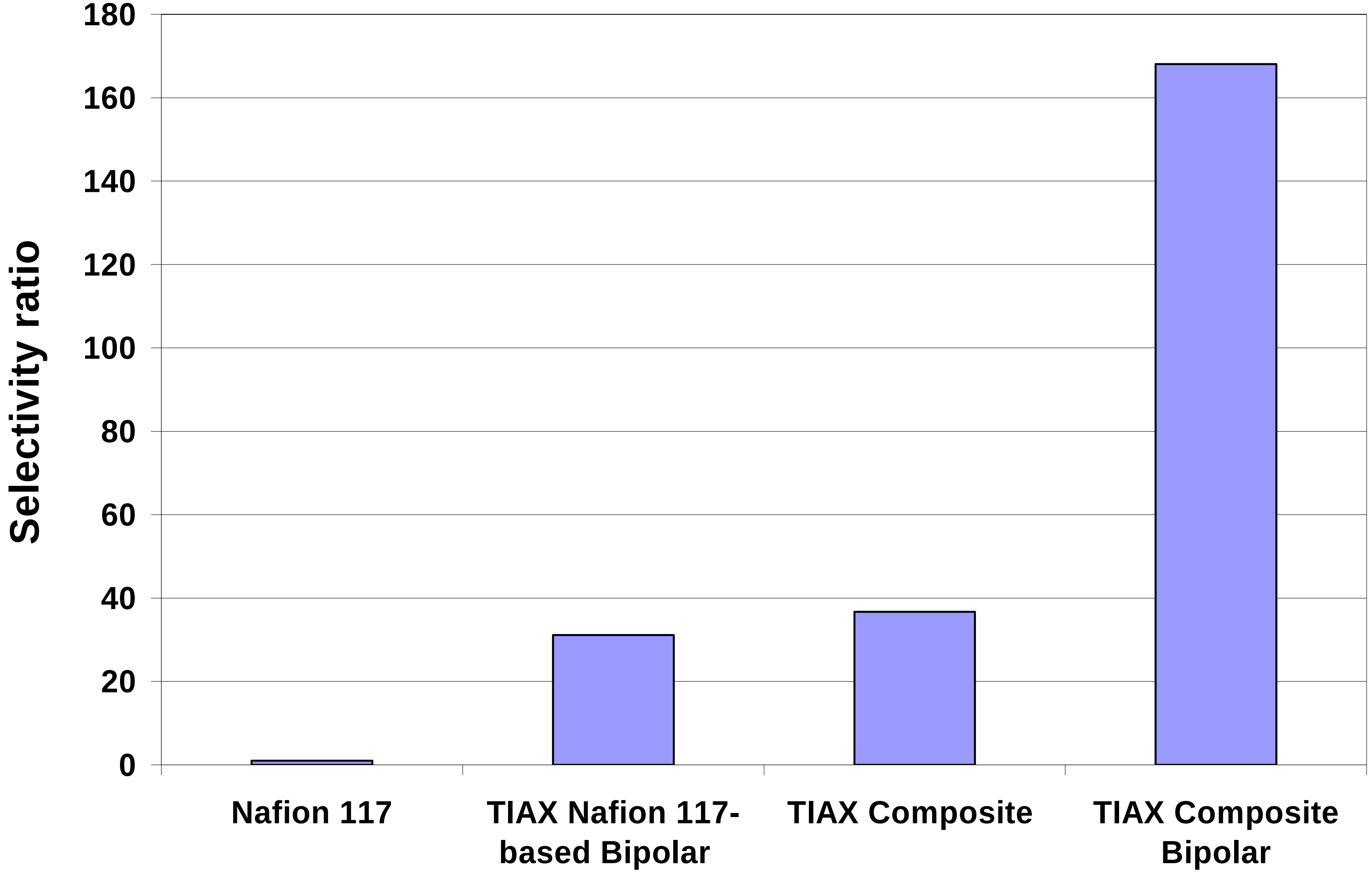


We have achieved a >10X increase in vanadium rejection with no proton conductance sacrifice, a >100X increase in vanadium rejection with modest proton conductance loss, and >90% reduction in content of costly PFSA.

Proton Conductance and Vanadium Rejection Results

Membrane	VO^{2+} Permeation moles/cm^2/day	Proton area specific resistance: ohm·cm^2	Vanadium Rejection: Ratio to Nafion 117	Thickness: microns	PFSA content: mg/cm^2
Bipolar 117	6.0×10^{-6}	0.30	32X	180-185	18
Composite	5.0×10^{-6}	0.30	38X	19-20	1.2
Composite Bipolar	3.95×10^{-7}	0.83	480X	19-20	1.2
Nafion 117 control	1.9×10^{-4}	0.29	1X	180-185	18

We monitor selectivity ratio = (test membrane ratio of proton conductance to vanadium permeation)/(Nafion membrane ratio of proton conductance to vanadium permeation).



Phase I results show very favorable permeability characteristics, with chemical stability and electrochemical performance remaining to be assessed.

- Very promising results to date:
  - Bipolar modification of Nafion 117 achieved 32X reduction in vanadium permeation with no loss of proton conductance.
  - Composite membrane achieved 38X reduction in vanadium permeation and 93% reduction in PFSA content with no loss of proton conductance relative to Nafion 117.
  - Bipolar composite membrane achieved 480X reduction in vanadium permeation and 93% reduction in PFSA content relative to Nafion 117, with proton conductance 35% of Nafion's.

- Important questions remaining to be investigated:
  - Membrane oxidative stability/durability (VO_2^+ exposure)
  - Permeability to monovalent VO_2^+ ions
  - VRB performance measurements