Wolfson School of Mechanical, Electrical and Manufacturing Engineering

Pathway to robust flow battery for solar energy storage: osmotically balanced neutral pH electrolytes

Jungmyung Kim, Dowon Bae*

Loughborough University

Engineering and Physical Sciences Research Council

Abstract

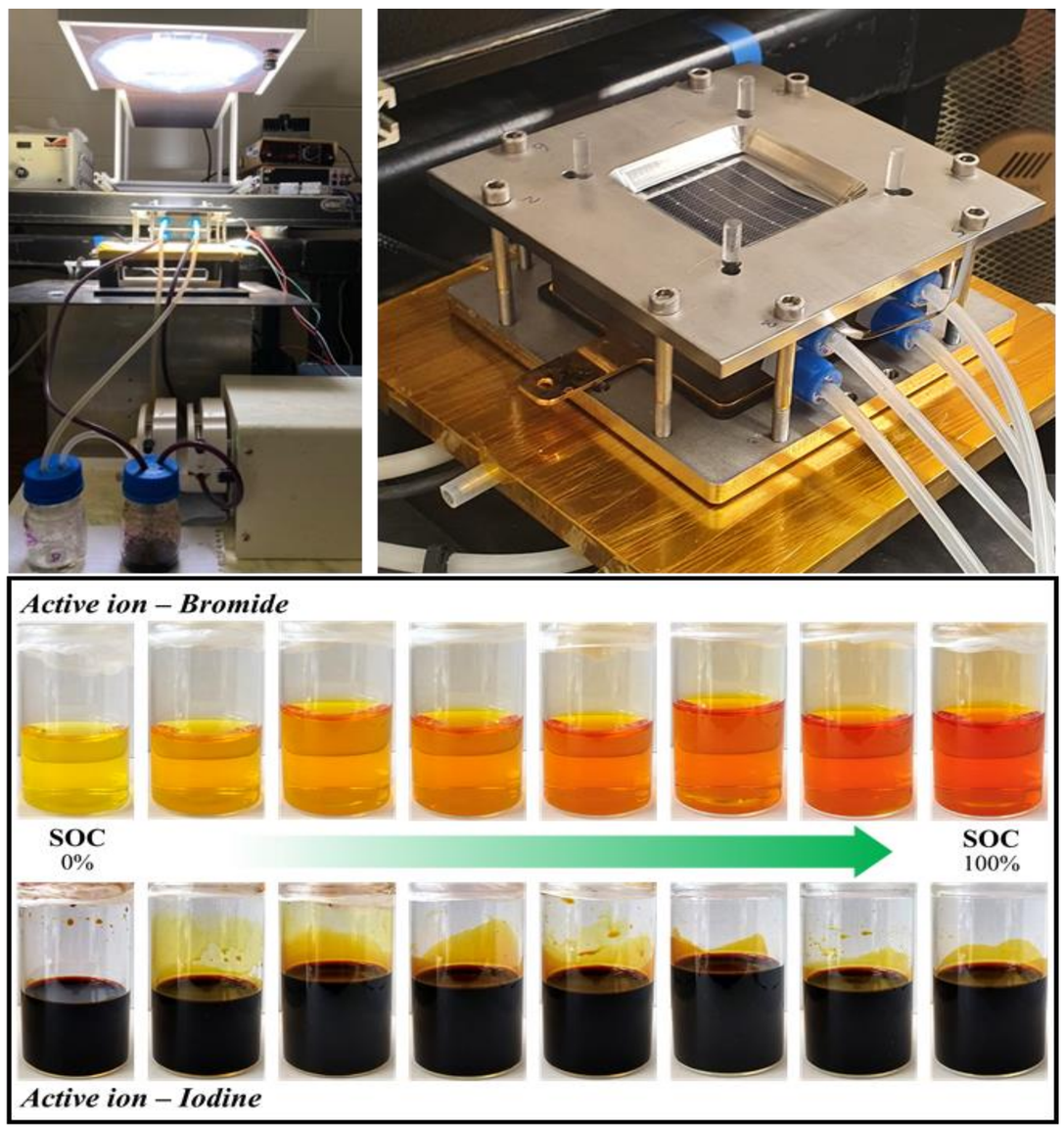
Solar redox flow battery (SRFB) technology offers a promising avenue for the efficient conversion and storage of solar energy, addressing the intermittency challenges associated with renewable energy sources. In this study, we experimentally investigate the feasibility of a 25 cm^2 single solar redox flow battery cell employing a neutral pH aqueous iodine-bromine redox couple. Through a comprehensive screening process, the iodine-bromine redox couple was selected based on its compatibility with silicon solar cells and desirable electrochemical properties. Experimental results demonstrate the successful integration of silicon solar cells with the SRFB system, showcasing efficient solar charging capabilities. Furthermore, the electrochemical characterization of the iodine-bromine redox couple reveals favorable reversibility and stability. Our findings underscore the potential of neutral pH aqueous iodine-bromine redox couples for scalable and sustainable solar energy storage applications, offering insights into the advancement of SRFB technology.

Summarize SRFB research with keywords

Selection Redox Couple → Voltage range matching → Suitable for PV cell

Make SRFB cell → Marge PV & RFB cell

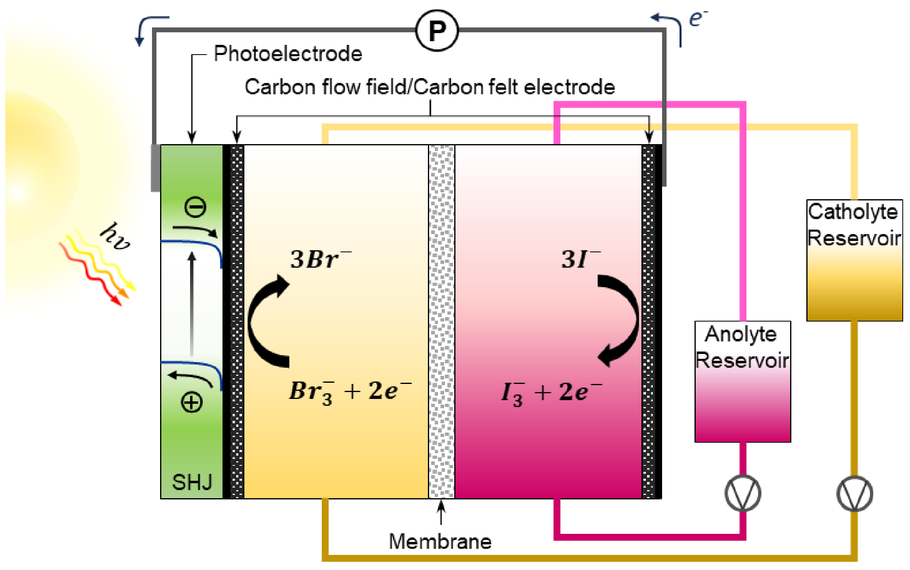
Solar Charging → Electrolytes → Repeatability



$$3I^- \leftrightarrow I_3^- + 2e^- \quad (E^0 = 0.54\,V)$$

$$3Br^- \leftrightarrow Br_3^- + 2e^- \quad (E^0 = 1.09\,V)$$

❖ Schematic diagram of Solar Redox Flow Battery

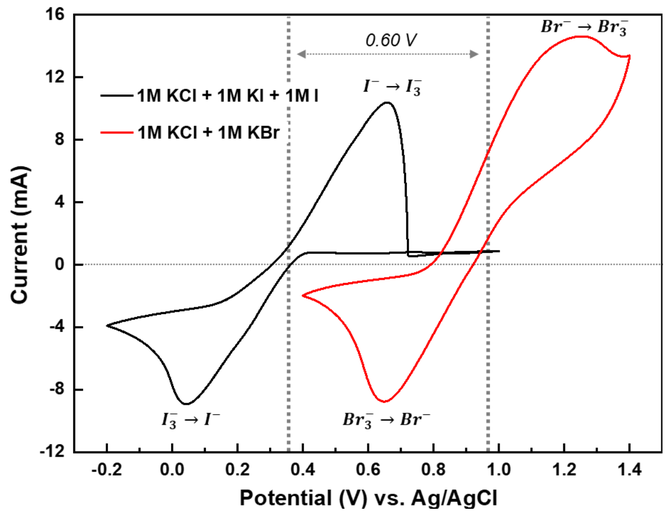


❖ Matrix for Redox Couple Screening

Anion \ Cation	MnO_4^-/MnO_4^{2-}	Fe^{3+}/Fe^{2+}	VO_2^+/VO^{2+}	$3Br^-/Br_3^-$	$Cr_2O_7^{2-}/2Cr^{3+}$	MnO_4^-/Mn^{2+}	IO_4^-/IO_3^-	MnO_4^-/MnO_2
E_0 (V)	0.56	0.77	1.00	1.09	1.33	1.51	1.60	1.68
I_2 0.54	0.02 N	0.23 sA	0.46 sA	0.55 N	0.79 sA	0.97 N	1.06 sA	1.14 N
$KMnO_4$ 0.56	0.21 sA	0.44 sA	0.53 N	0.77 sA	0.95 sB	1.04 sA	1.12 sB	
$FeCl_2$ 0.77	0.23 A	0.32 sA	0.56 sA	0.74 sA	0.83 sA	0.91 sA		
$VOSO_4$ 1.00	0.09 sA	0.33 A	0.51 sA	0.60 A	0.68 sA			
KBr 1.09	0.24 sA	0.42 N	0.51 sA	0.59 N				
$K_2Cr_2O_7$ 1.33	0.18 sA	0.27 sA	0.35 sA					
$KMnO_4$ 1.51	0.09 sA	0.17 sB						
$NaIO_4$ 1.60	0.08 sA							

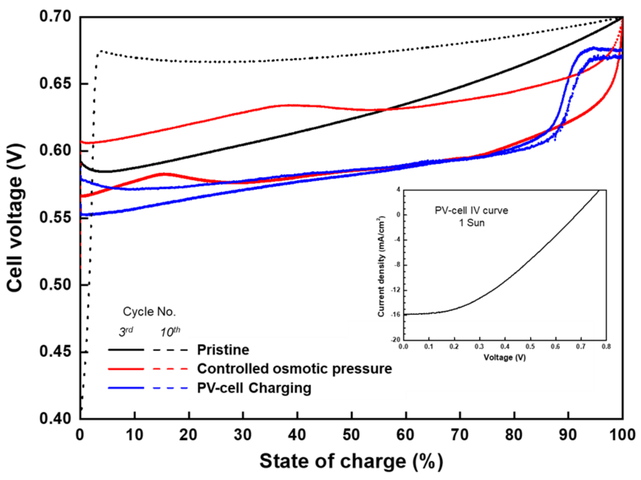
pH: A 0 - 2.9; sA 3 - 6.4; N 6.5 - 7.5; sB 7.6 - 11; B 11.1 - 14

Solubility (mol/L): 0.37 | 0.4-0.42 | 3.28 | 5.40 | 5.70

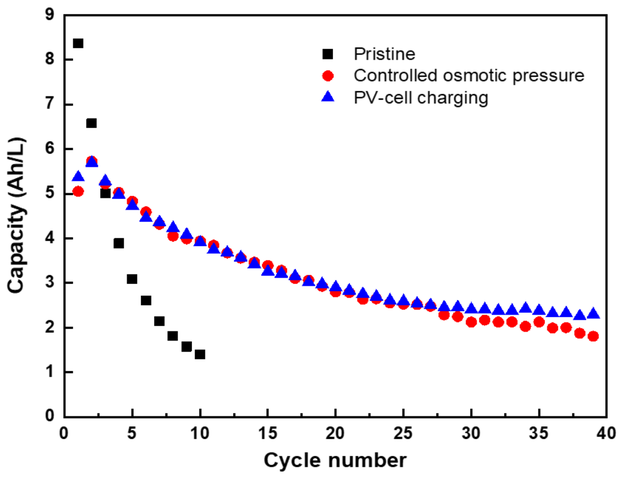


Linear relationship between oxidation/reduction peak current and square root of scan rate ($v^{1/2}$) (a) Bromine and (b) Iodine

❖ Solar Charging



❖ SRFB Cycle



Warp-up

In this study, we investigated a 25 cm^2 Single Solar Redox Flow Battery Cell using a neutral pH aqueous iodine-bromine redox couple for solar energy storage. Our research identified the iodine-bromine redox couple as a promising candidate based on its operating voltage range, redox potential, solubility, and pH compatibility, which matched well with silicon solar cells.

Experimental results showed efficient integration and solar charging capabilities, with IV curves indicating optimal performance and stable operation. Cyclic voltammetry and charge/discharge tests confirmed the redox couple's favorable reversibility and stability. The use of osmotically controlled electrolyte solutions improved cycle reversibility and discharge capacity retention.

Overall, our findings demonstrate the potential of neutral pH aqueous iodine-bromine redox couples for efficient solar energy storage in SRFB systems, paving the way for cost-effective and sustainable energy storage solutions.

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CONTACT INFORMATION

Wolfson School of Mechanical, Electrical and Manufacturing Engineering
Loughborough University
Leicestershire LE11 3TU UK
j.kim@lboro.ac.uk
www.lboro.ac.uk/meme