Integrated Blue Energy Power System for Hydrogen Production through Seawater Electrolysis

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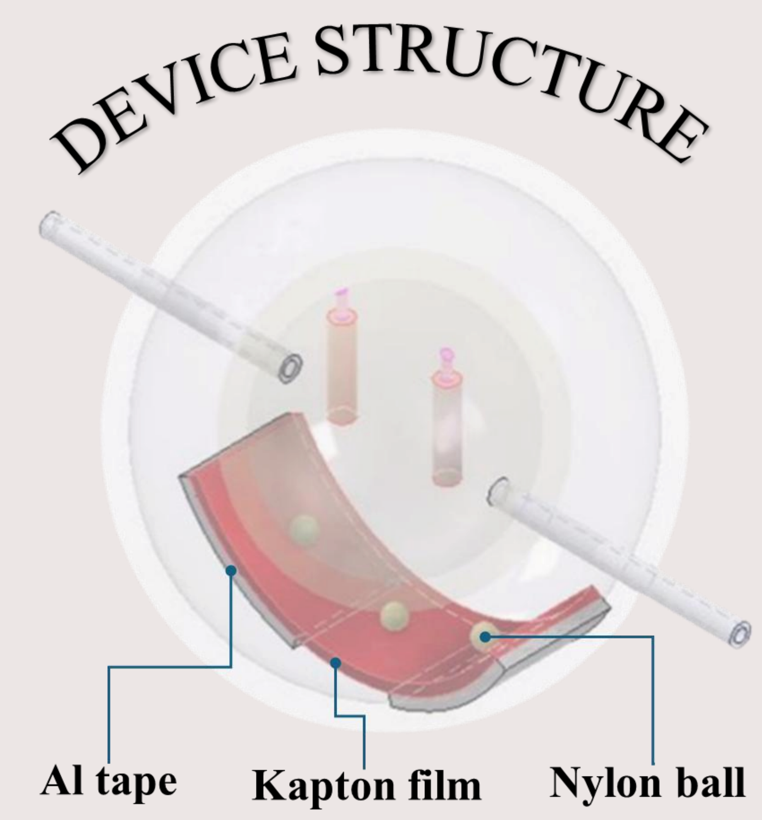
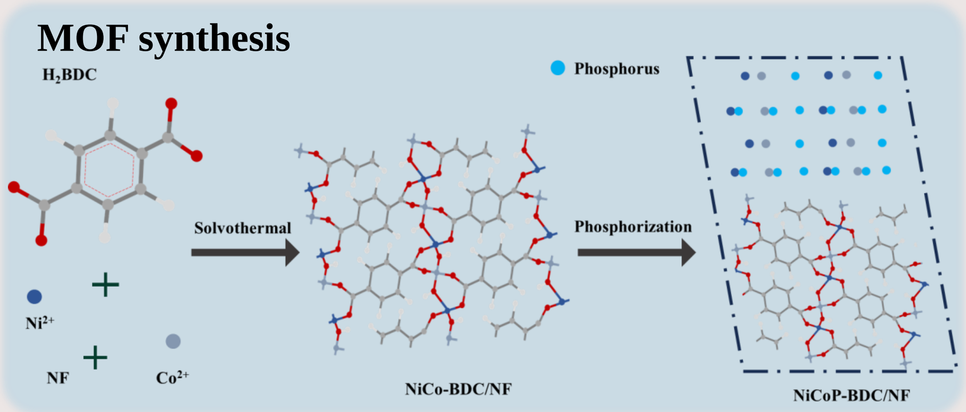
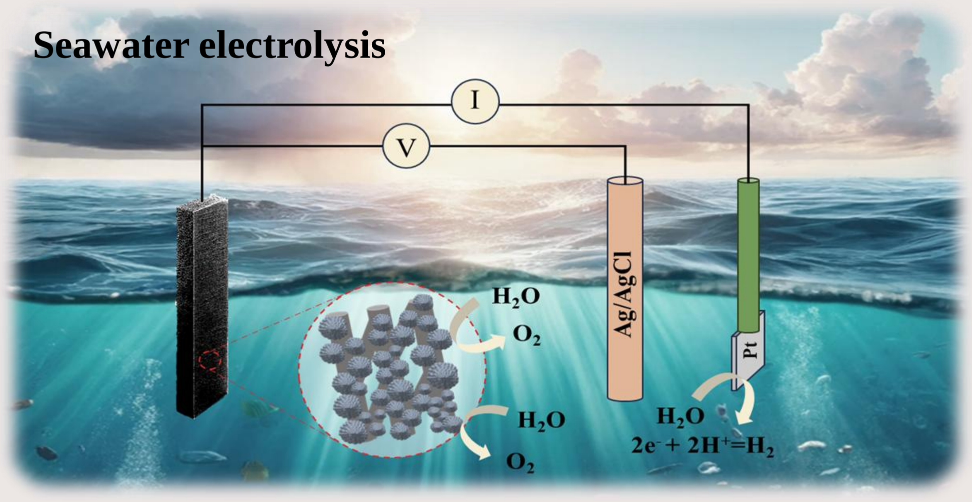
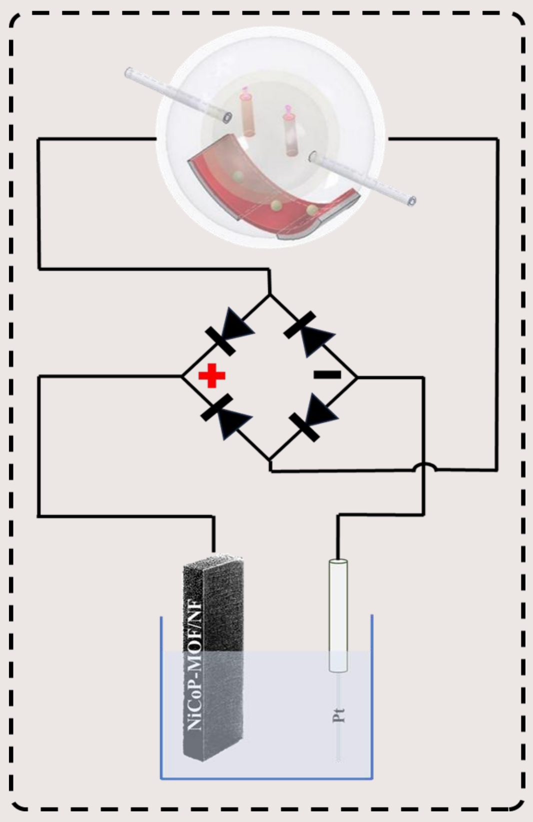
Addressing energy and environmental challenges essential for societal progress, this research harnesses blue energy—a clean yet difficult-to-harvest resource due to its irregularity and low frequency. Using triboelectric nanogenerators (TENGs), wave motion is converted into electricity. A self-sustained system integrates TENG and seawater electrolysis within a nested sphere structure, where friction between a Nylon ball, Kapton film, and aluminum electrodes generates power for electrolysis on Ni foam coated with a NiCoP-based Metal–Organic Framework (MOF) catalyst. Initial tests show that the TENG can generate 120 V and 1.2 μA with only 8 nylon balls. Electrochemical analysis revealed that the system achieved a low overpotential of 195.4 mV after 5 CV cycles and further reduced to 33.57 mV after 1000 cycles, demonstrating high hydrogen evolution efficiency and excellent long-term catalytic stability. These results provide a viable method for converting blue energy into sustainable hydrogen fuel.

Experimental



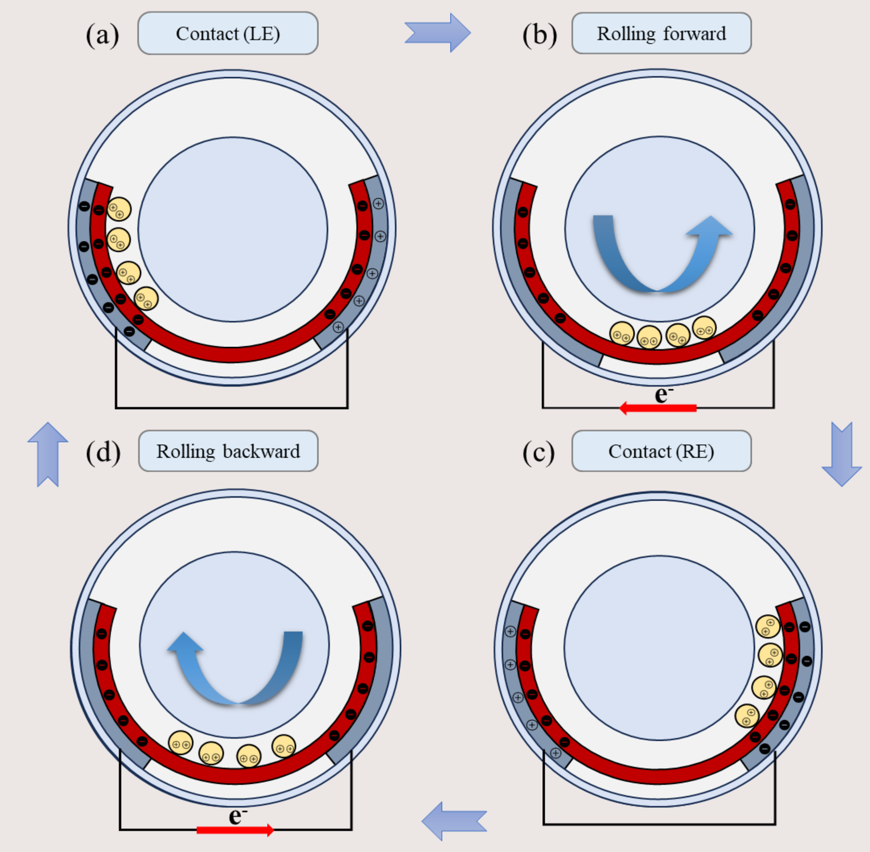






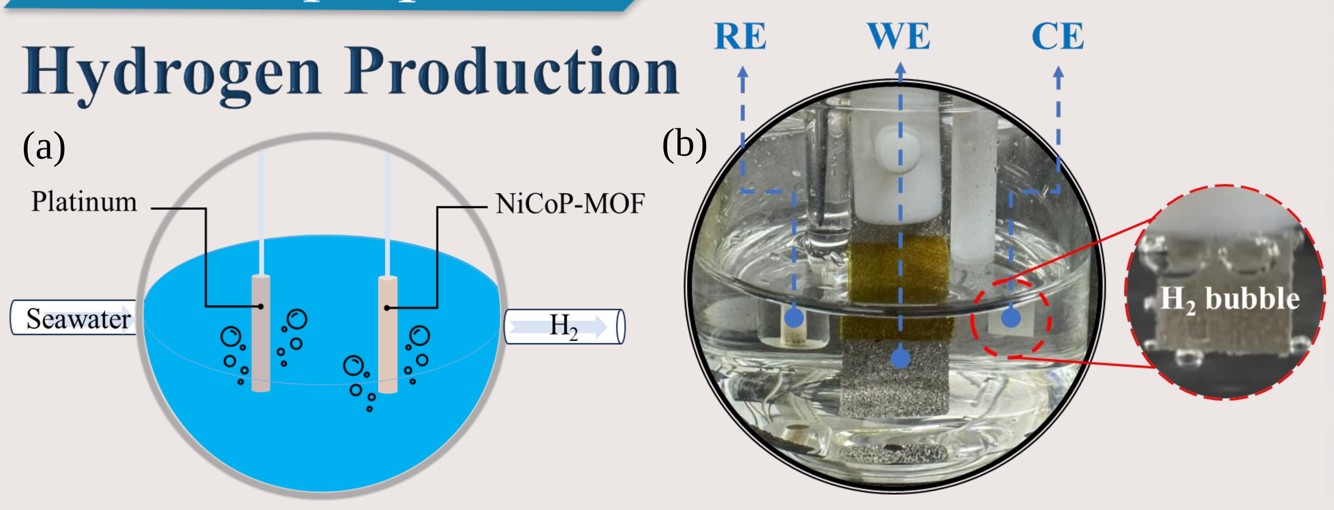
Structural circuit diagram

TENG working principle



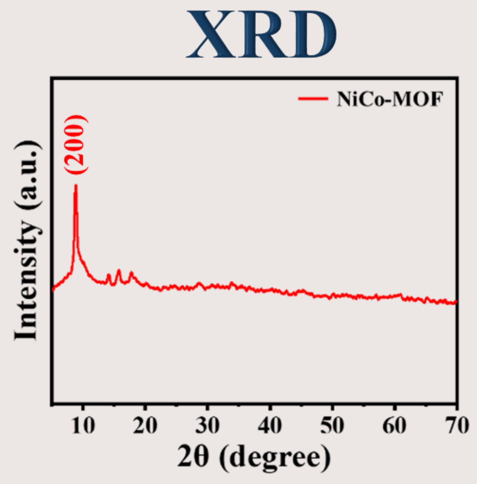
Material properties

Hydrogen Production

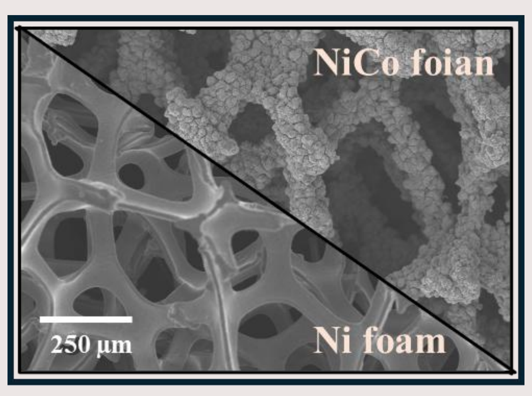


- (a) NiCoP-MOF was loaded on Ni foam as the working electrode, with Pt/graphite as the counter electrode. Seawater was used as the electrolyte for hydrogen generation.(b) Electrochemical tests used a three-electrode setup: NiCoP-MOF (WE), Pt (CE), and Ag/AgCl (RE).

XRD



SEM

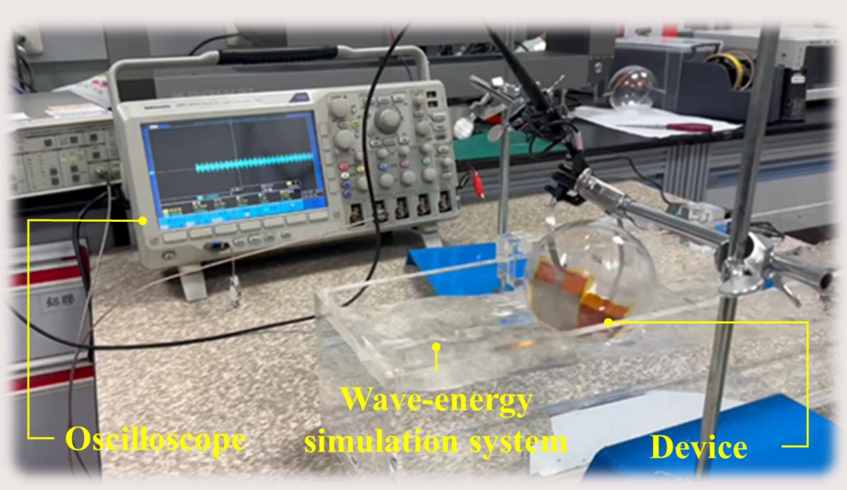


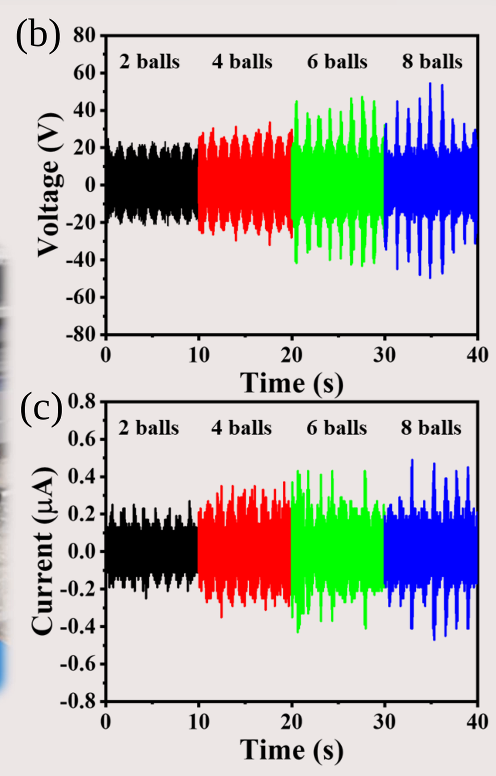
- The NiCoP-MOF has a layered crystal structure, with 2BDC ligands separating two-dimensional layers and octahedral metal centers interconnected along the (200) crystal plane. The surface morphology confirms successful growth on the nickel foam.

Electrical analysis

◆ Electrical measurement system

(a)



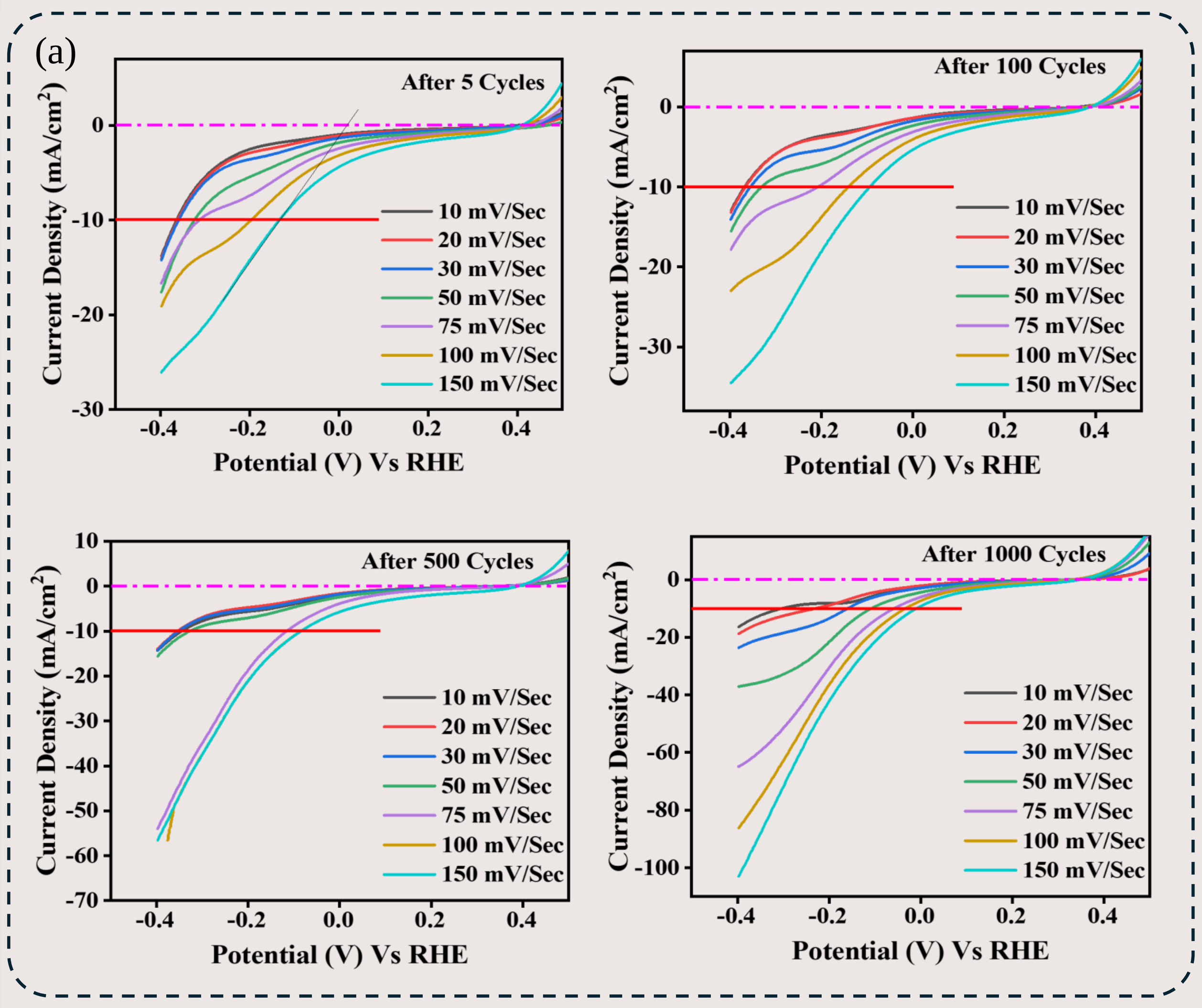


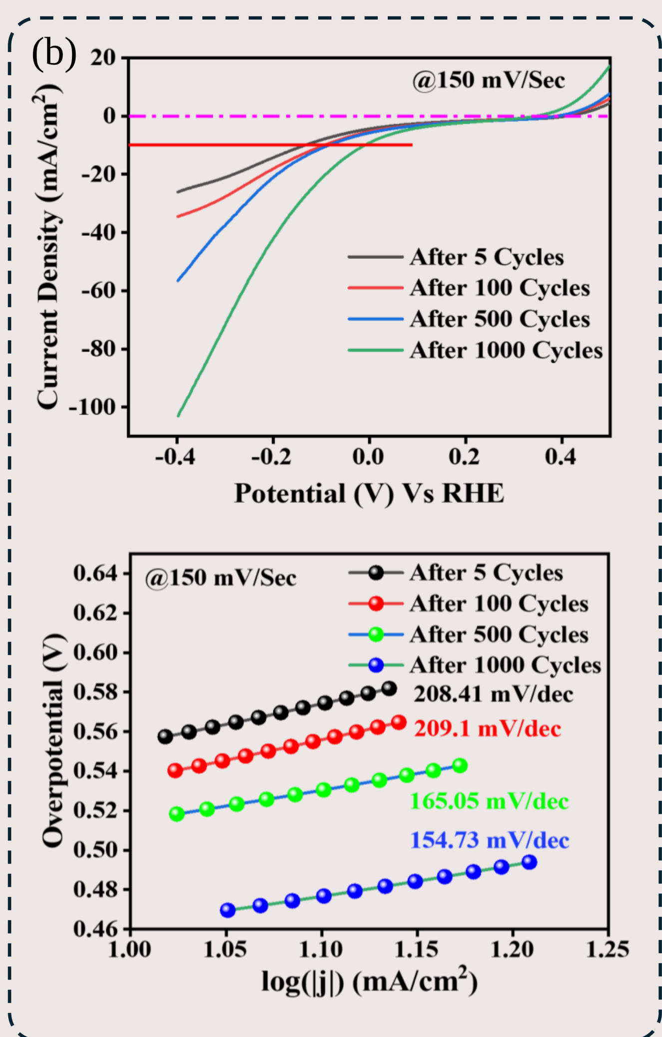
- By placing the device into the (a) wave simulation system, the oscilloscope readings showed that with only eight nylon balls,(b) the voltage reached 120 V and (c) the current reached 1.2 μA.

Electrochemical analysis

➤ Linear sweep voltammetry at different scan rate after different CV

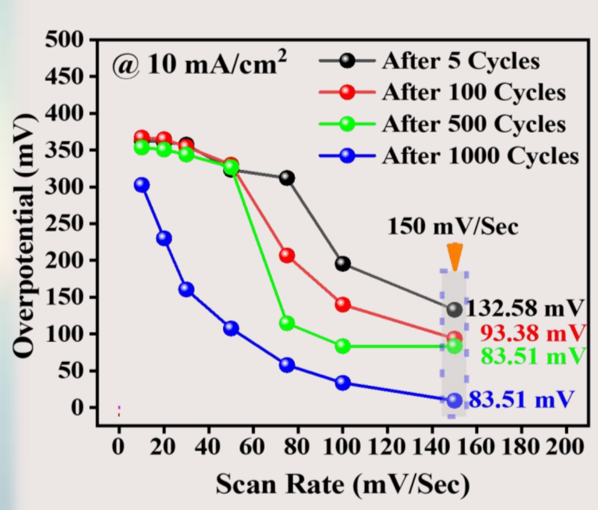
➤ Linear sweep voltammetry And Tafel slope





- (a) Linear sweep voltammetry (LSV) indicates that the NiCo MOF catalyst exhibits an excellent minimum overpotential at a benchmark current density of 10 mA/cm² after 1000 cycles, demonstrating high HER activity. (b) The Tafel plot shows that the Tafel slope for 1000 cycles is relatively small at 154.73 mV/dec, whereas the Tafel slopes for 100 cycles and 500 cycles are 209.1 mV/dec and 165.05 mV/dec, respectively.

➤ Overpotential



Scan Rate (mV/Sec)	Overpotential (mV)			
	After 5 Cycles	After 100 Cycles	After 500 Cycles	After 1000 Cycles
10	363.35	367.1	353.56	302.67
20	360.96	364.83	350.64	230.01
30	357.52	354.44	343.81	160.57
50	323.225	330.22	326.81	107.57
75	312.077	206.78	114.71	57.77
100	195.4	139.87	83.51	33.57
150	132.85	93.72	83.51	9.35

- At a scan rate of 100 mV/sec, a relatively low overpotential of 195.4 mV was achieved after just 5 simple cycles, and an even lower overpotential of 33.57 mV was reached after 1000 cycles.

Conclusion

✓ **An integrated TENG-electrolysis system was developed, achieving efficient energy conversion and self-powered hydrogen production with reduced transmission loss and simplified design.**

✓ **The rolling-ball TENG generated up to 120 V and 1.2 μA using only 8 nylon balls, demonstrating strong potential for wave-driven power supply in marine environments.**

✓ **NiCoP-MOF showed excellent catalytic performance and long-term stability, with overpotential dropping from 195.4 mV to 33.57 mV after 1000 cycles in natural seawater.**