Supplementary Information (SI) for Journal of Materials Chemistry A.

Supplementary information for

Four-way diffusion in miniaturised devices of reverse electrodialysis

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The PDF file includes:

Figs. S1 to S8
Tables. S1 and S2

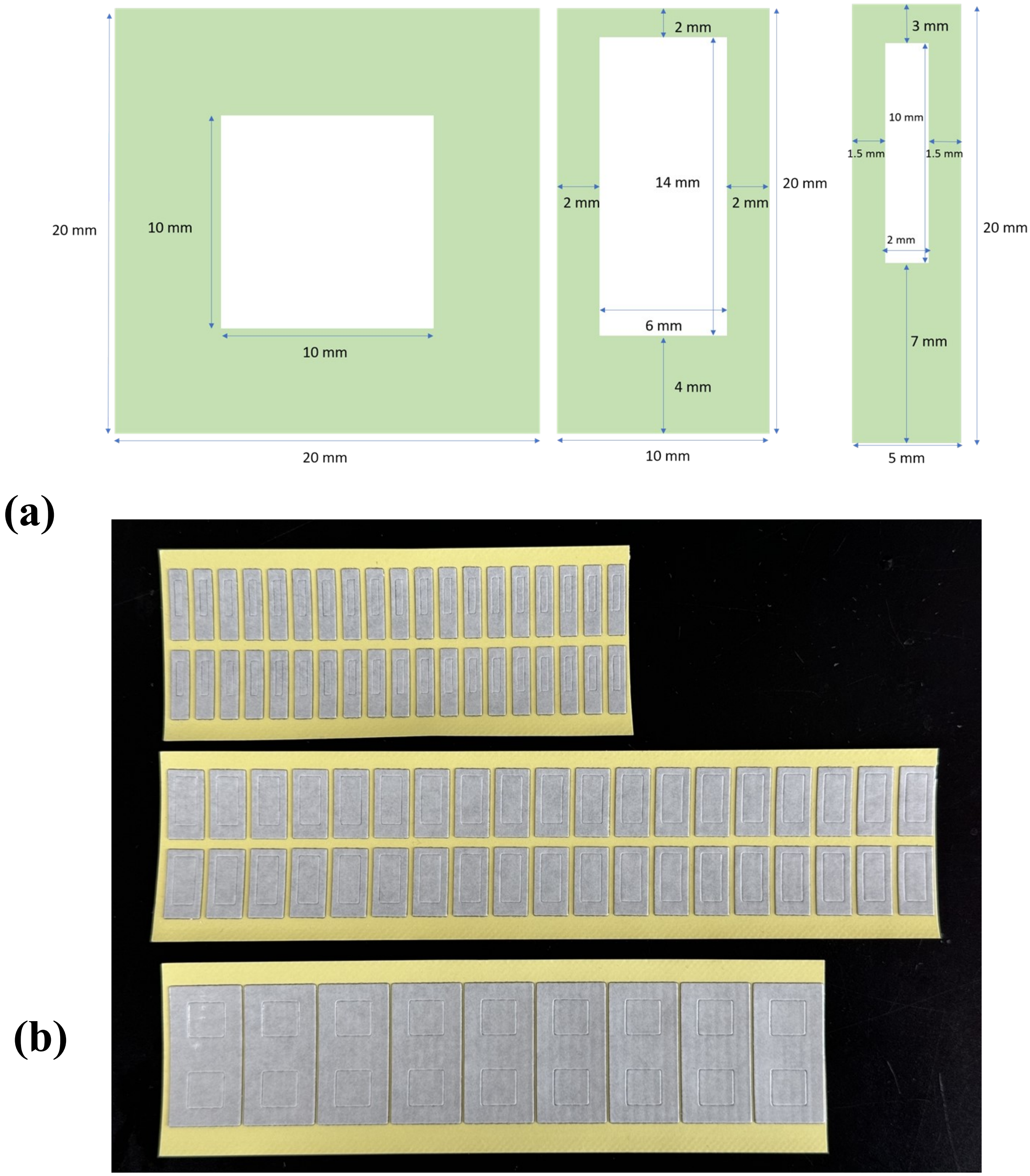
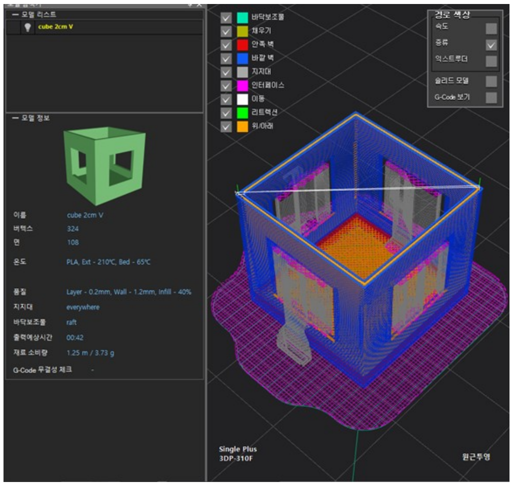
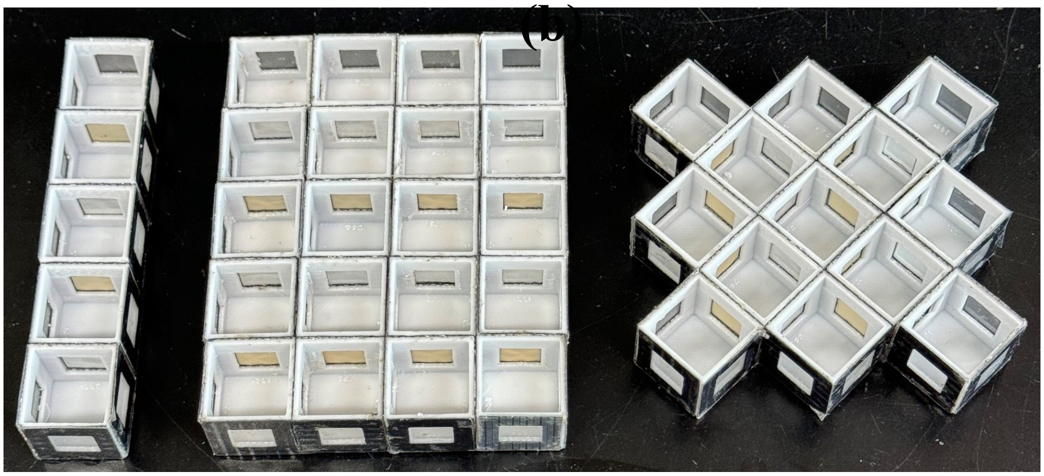


Fig. S1. (a) Specification of the waterproof tape. (b) Picture of the customized waterproof tape.



(a)

(b)



(c)

Fig. S2. (a) 3D rendering process of the unit cell. (b) Printed unit cell before post-processing. (c) Fabricated 2 cm unit cell REDs (series RED, pRED, cRED).

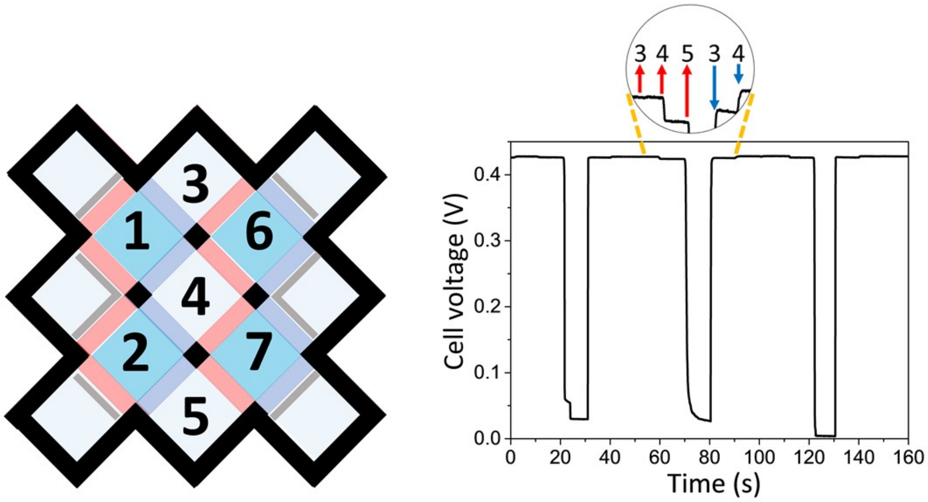


Fig. S3. Voltage stability test of cRED. The red arrow means removing the solution from the numbered unit cell while the blue arrow means refilling the solution. The experiment was conducted at intervals of 10 s. The cell voltage of cRED remained constant, fluctuating very slightly (within 0.005 V) during the experiment.

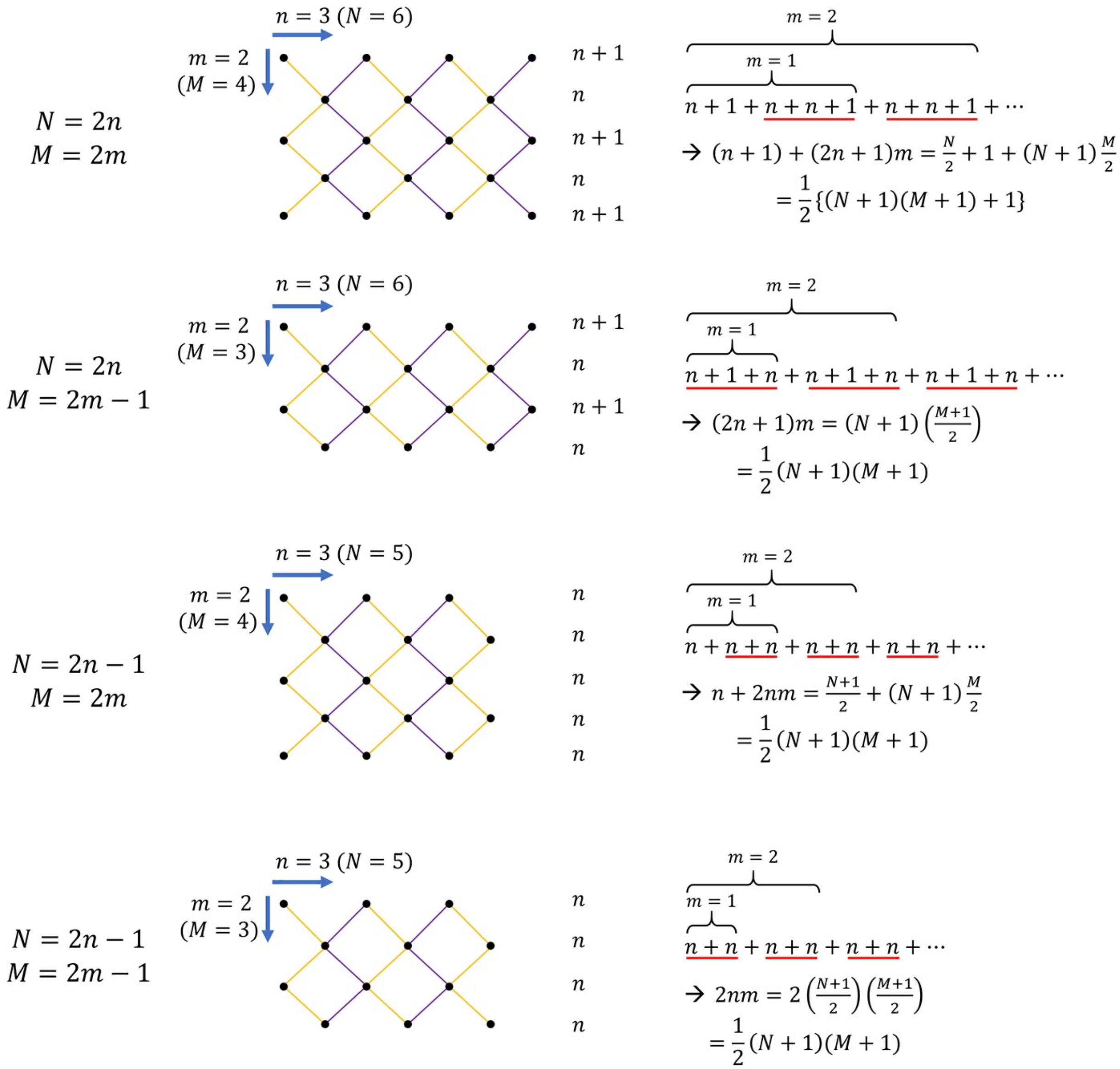


Fig. S4. The calculation of the volume of cRED according to (N,M) value in general term. Black dots are nodes of RED. N represents the number of membranes stacking in the serial direction for voltage accumulation and M represents the number of membranes stacking in the parallel direction for current increment. Red lines within the formula indicate repetition as m increased.

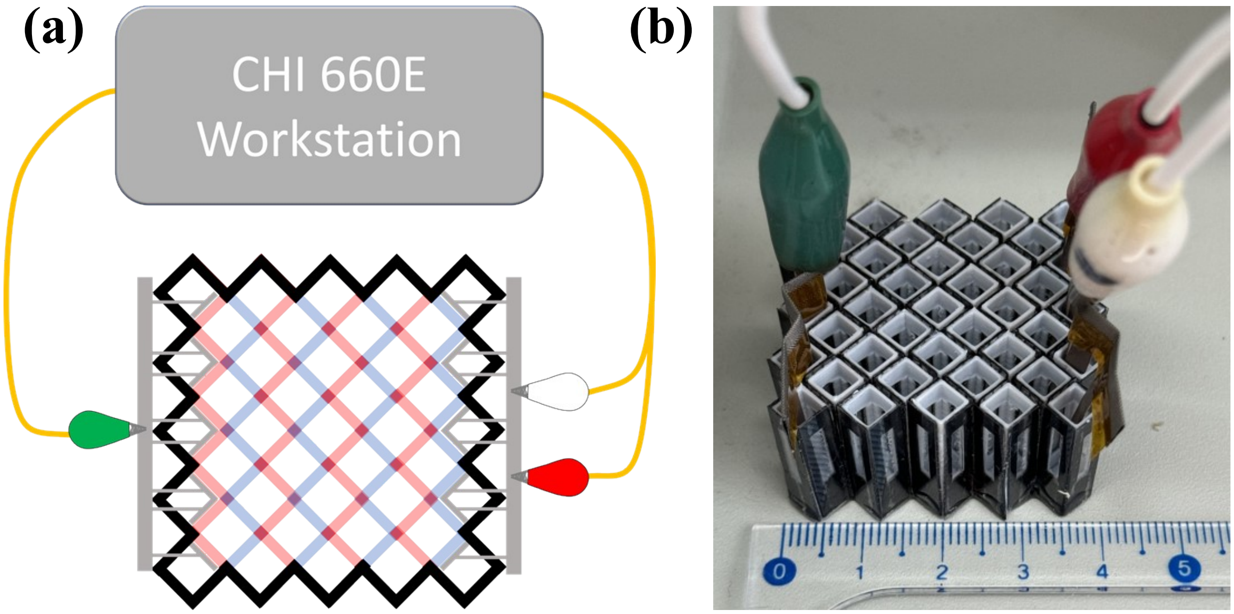


Fig. S5. (a) Scheme of the test system configuration. (b) Real image of N = 8 cRED (0.5 cm unit cell length).

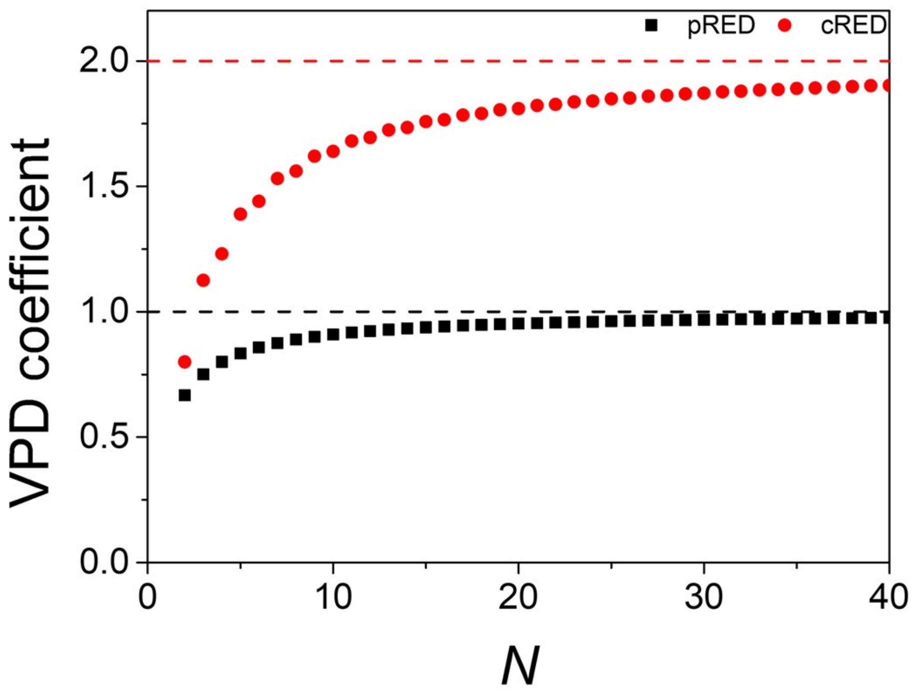


Fig. S6. Theoretical VPD coefficient of pRED and cRED according to N value. Each coefficient shows that pRED's coefficient converges to 1 while cRED's coefficient converges to 2.

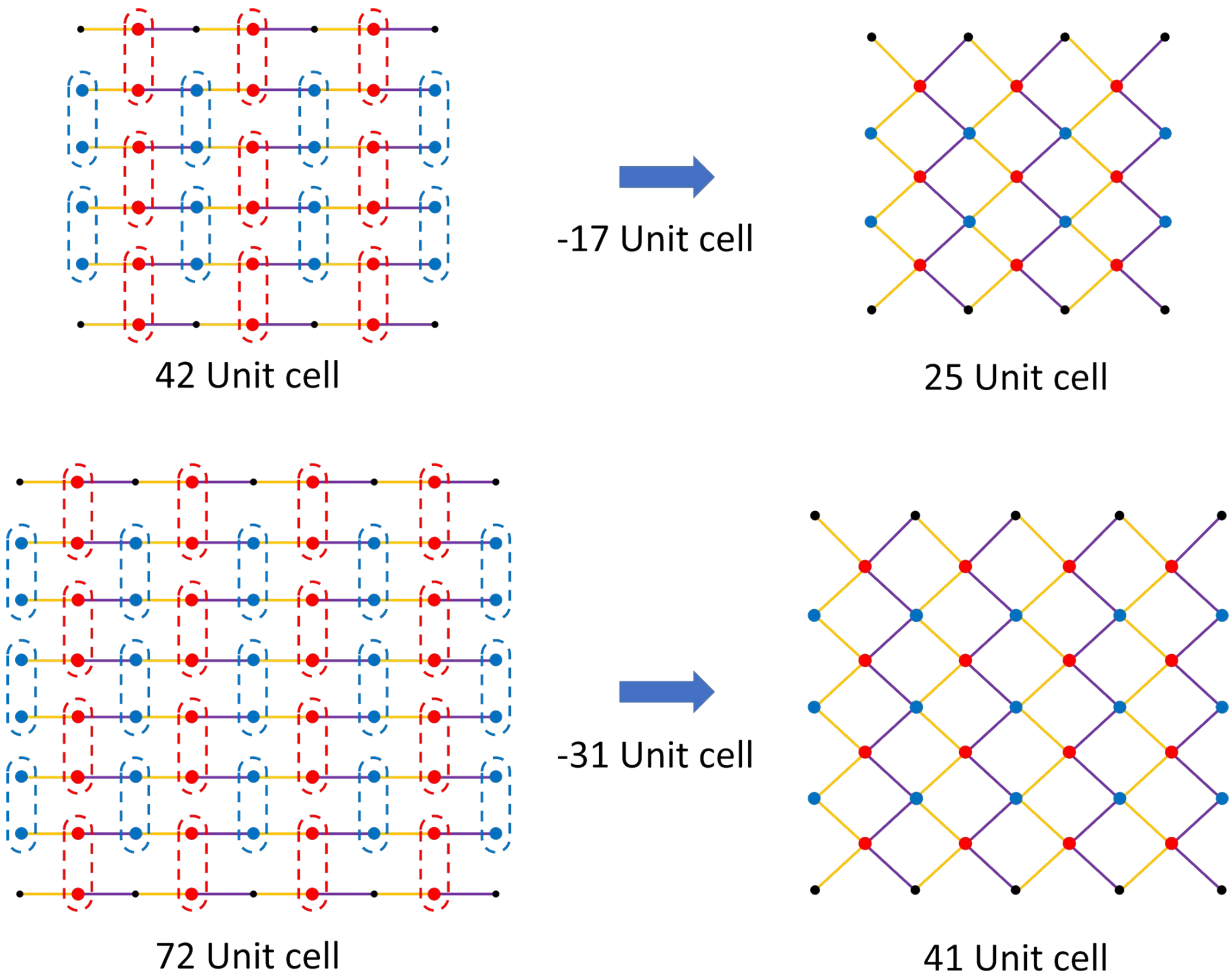


Fig. S7. Scheme of merging of adjacent nodes in pRED form cRED in $N = 6, 8$**. The number of unit cells that decreased is the same as the number of nodes merged.**

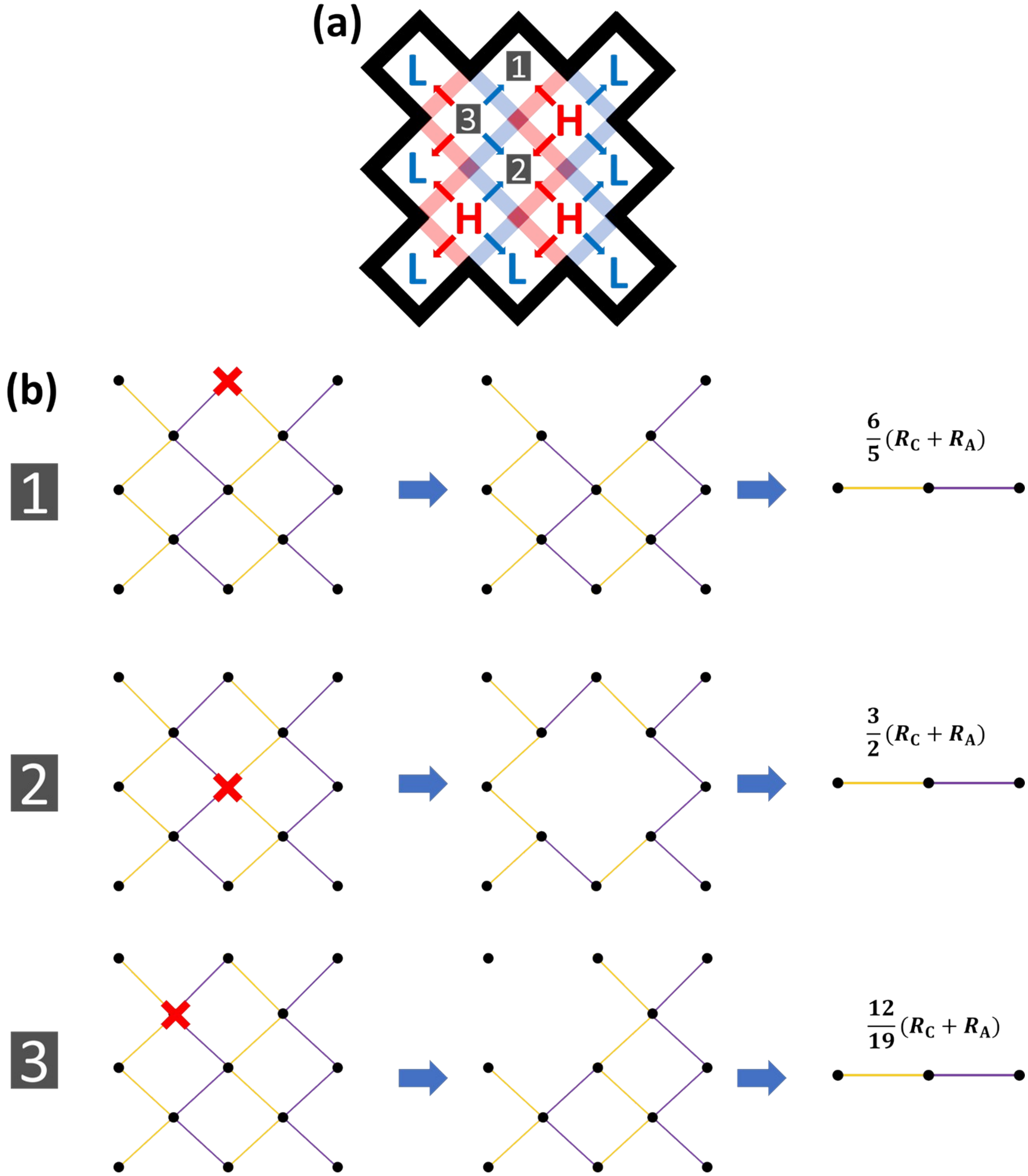


Fig. S8. Resistance analysis of cRED when the solution from a specific unit cell is removed. (a) indicates the number of the unit cell, and (b) shows the resistance analysis results for that condition. Theoretically, removing the solution from nodes 1, 2, and 3 results in approximately 83%, 67%, and 63% of total power density respectively. Three nodes placed at both ends of the RED are the input and output terminals (see Fig. 3).

Table S1. Theoretical property of (N, M) : membrane voltage, : membrane resistance, : unit membrane area (cm^2), : volume of unit cell, : number of membrane serial connected, : number of membrane parallel connected R_{M_1}, R_{M_2}

	(N, M) value	Voltage	Resistance	Current	Power	APD	Volume	VPD	$R_{M_1} \approx R_{M_2} = R_M$
Series RED	$N = 2n$	NE_m	$n(R_{M_1} + R_{M_2})$	$E_m\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$NE_m^{\ 2}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{E_m^{\ 2}}{A_m}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$(N+1)V_c$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$
	$N = 2n-1$	NE_m	$n(R_{M_1} + R_{M_2}) - R_{M_2}$	$E_m\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$NE_m^{\ 2}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{E_m^{\ 2}}{A_m}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$(N+1)V_c$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$
pRED	$N = 2n$	NE_m	$\frac{n}{M}(R_{M_1} + R_{M_2})$	$ME_m\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$NME_m^{\ 2}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{E_m^{\ 2}}{A_m}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$M(N+1)V_c$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$
	$N = 2n-1$	NE_m	$\frac{n(R_{M_1} + R_{M_2}) - R_{M_2}}{M}$	$ME_m\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$NME_m^{\ 2}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{E_m^{\ 2}}{A_m}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$M(N+1)V_c$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{N}{N+1}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$
cRED	$N = 2n$, $M = 2m$	NE_m	$\frac{n}{M}(R_{M_1} + R_{M_2})$	$ME_m\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$NME_m^{\ 2}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{E_m^{\ 2}}{A_m}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{1}{2}\{(N+1)(M+1)+1\}V_c$	$\frac{2NM}{(N+1)(M+1)+1}\frac{E_m^{\ 2}}{V_c}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{2NM}{(N+1)(M+1)+1}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$
	$N = 2n$, $M = 2m-1$	NE_m					$\frac{(M+1)(N+1)}{2}V_c$	$\frac{2NM}{(N+1)(M+1)}\frac{E_m^{\ 2}}{V_c}\left(\frac{2}{R_{M_1} + R_{M_2}}\right)$	$\frac{2NM}{(N+1)(M+1)}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$
	$N = 2n-1$	NE_m	$\frac{n(R_{M_1} + R_{M_2}) - R_{M_2}}{M}$	$ME_m\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$NME_m^{\ 2}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{E_m^{\ 2}}{A_m}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{(M+1)(N+1)}{2}V_c$	$\frac{2NM}{(N+1)(M+1)}\frac{E_m^{\ 2}}{V_c}\left(\frac{2n-1}{n(R_{M_1} + R_{M_2}) - R_{M_2}}\right)$	$\frac{2NM}{(N+1)(M+1)}\frac{E_m^{\ 2}}{V_c} \times \frac{1}{R_M}$

Table S2. The parameter used to calculate the power density of pRED and cRED. Unit cell volume was calculated based on the volume of water contained in each unit cell.

Unit cell length	Unit membrane area (cm^2)	Unit cell volume(cm^3)
2 cm	1	6.56
1 cm	0.84	1.55
0.5 cm	0.2	0.22