Supplementary Data

Bioinspired Succinyl-β-cyclodextrin Membranes for Enhanced Uranium Extraction and Reclamation

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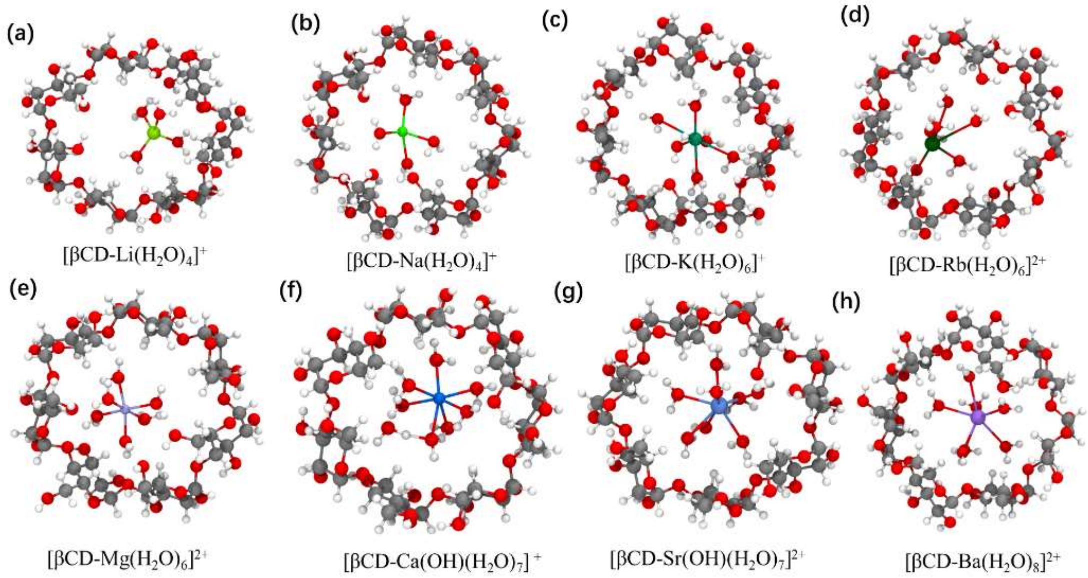

Fig. S1 Optimized structures of βCD-hydrated metal ions complexes.

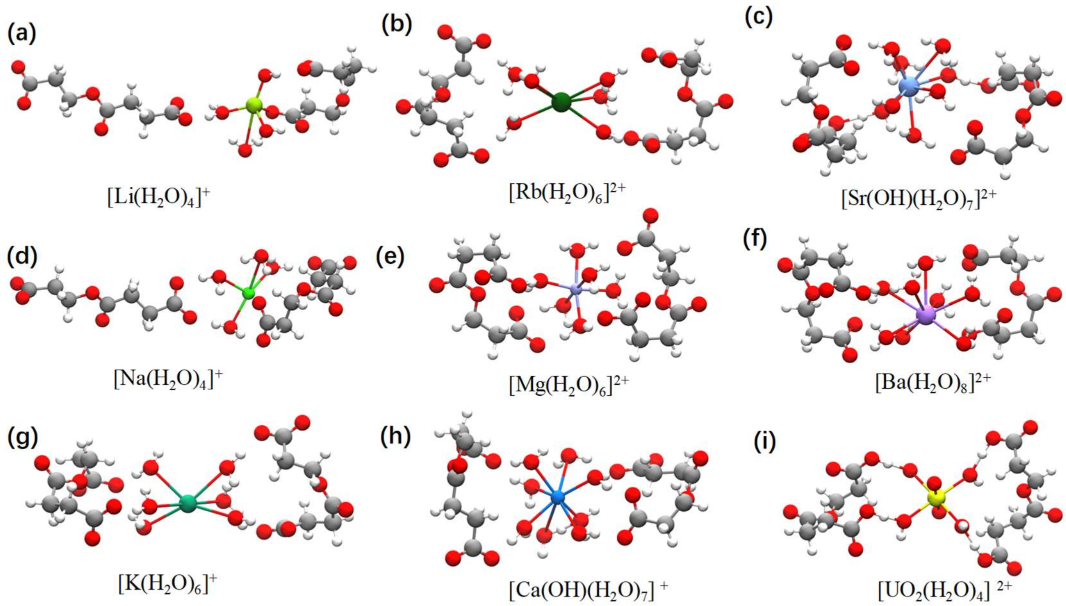

Fig. S2 Optimized structures of succinate, 1-(2-carboxyethyl) ester-hydrated metal ions complexes

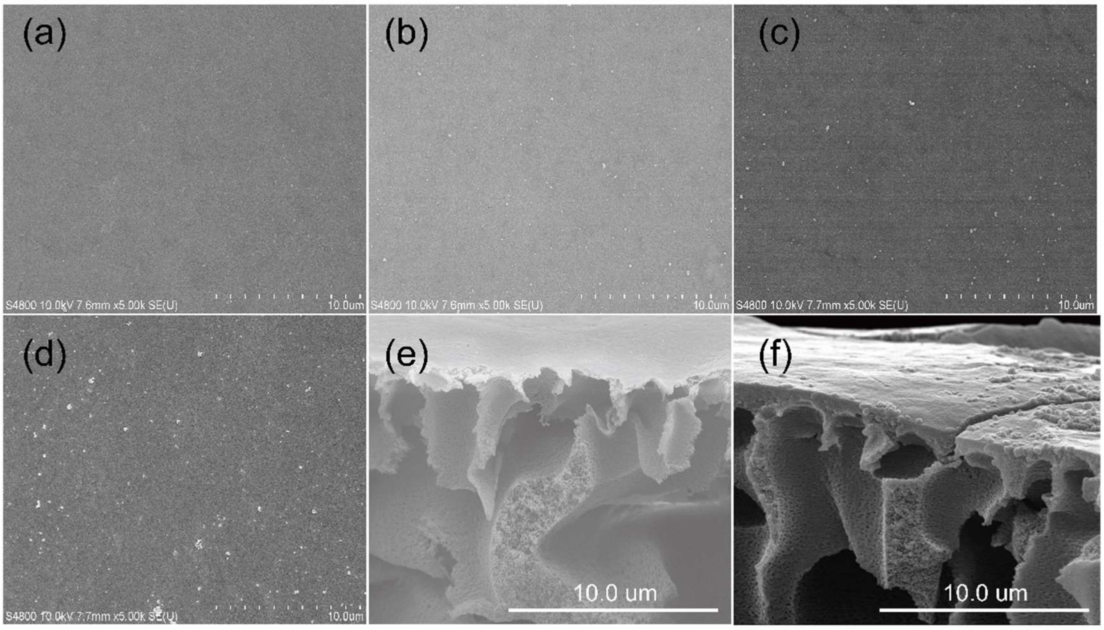

Fig. S3 SEM of (a) DA-PAN, (b) SβCDM-1, (c) SβCDM-2, (d) SβCDM-5, MAG×10000. (f) cross-section of (e) PAN and (f) SβCDM.

Fig. S4 Marine field study site location at Qingdao on the local map of the Yellow Sea in China. Image was acquired from Maps of World.

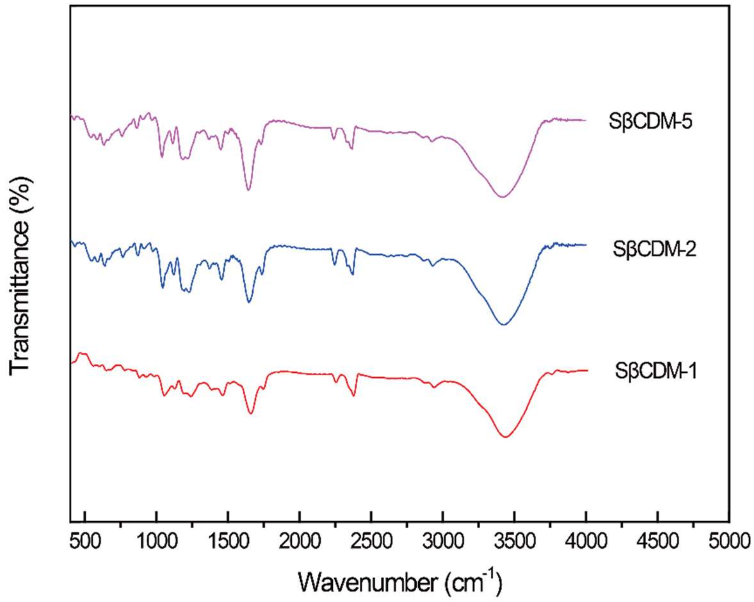

Fig. S5 XPS spectra of SβCDM-1, SβCDM-2 and SβCDM-5.

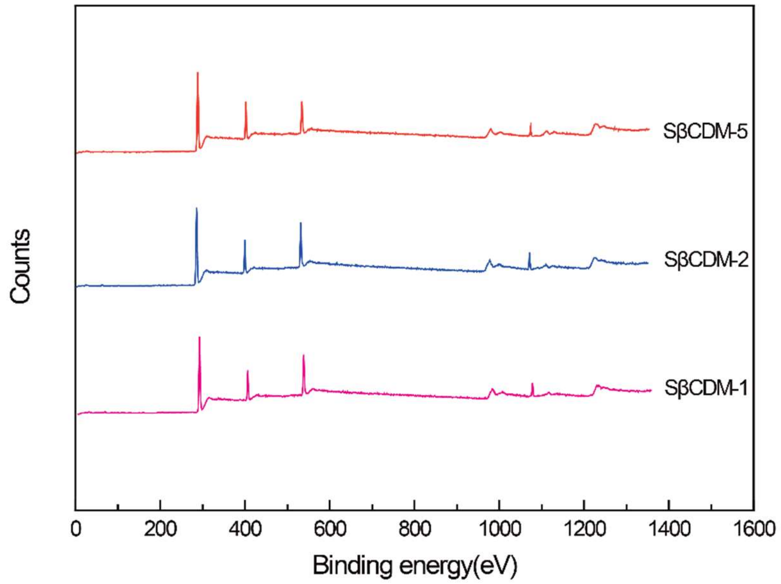

Fig. S6 FT-IR spectra of SβCDM-1, SβCDM-2 and SβCDM-5.

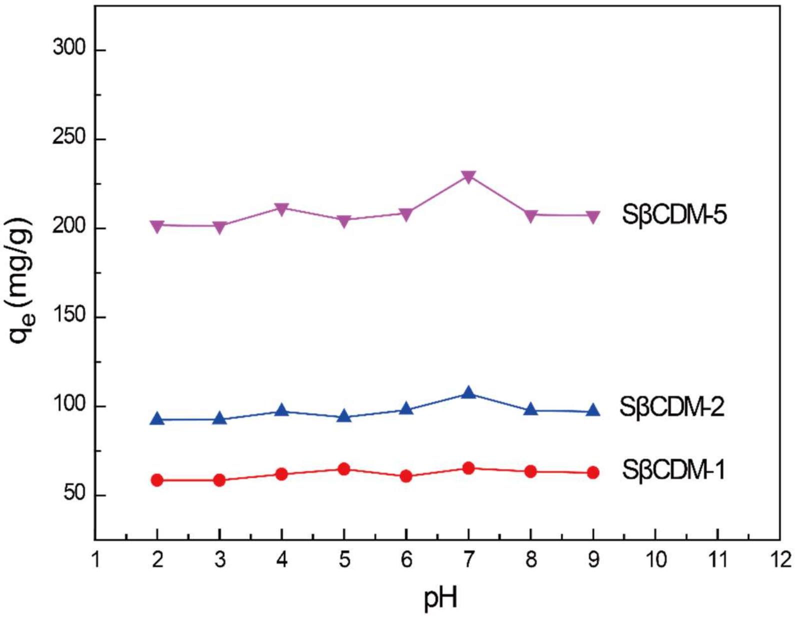

Fig. S7 Effect of pH on U(VI) uptakes of SβCDM-1, SβCDM-2 and SβCDM-5.

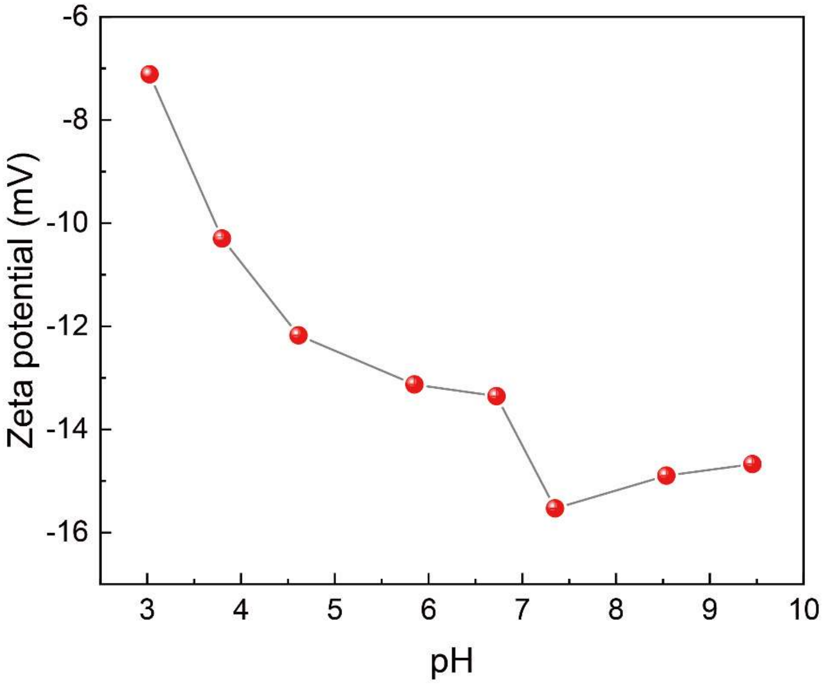

Fig. S8 Zeta potential of SβCDM at different pH.

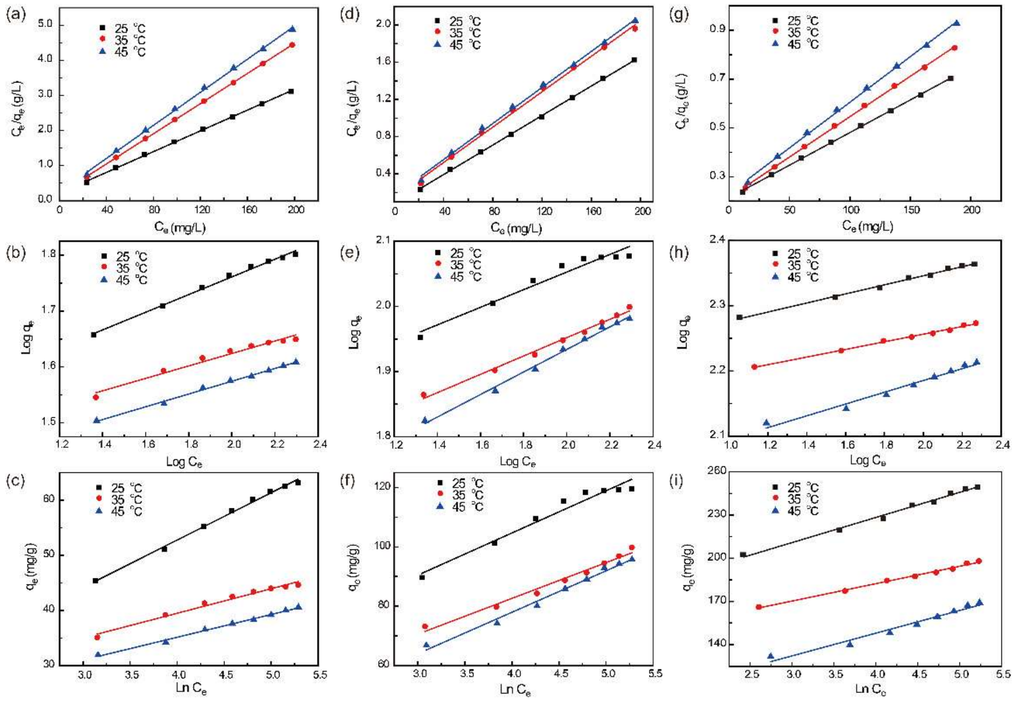

Fig. S9 (a) Langmuir isotherms, (b) Freundlich isotherms and (c) Temkin isotherms for U(VI) onto SβCDM-1 at 25°C, 35°C and 45°C. (d) Langmuir isotherms, (e) Freundlich isotherms and (f) Temkin isotherms for U(VI) onto SβCDM-2 at 25°C, 35°C and 45°C. (g) Langmuir isotherms, (h) Freundlich isotherms and (i) Temkin isotherms for U(VI) onto SβCDM-5 at 25°C, 35°C and 45°C.

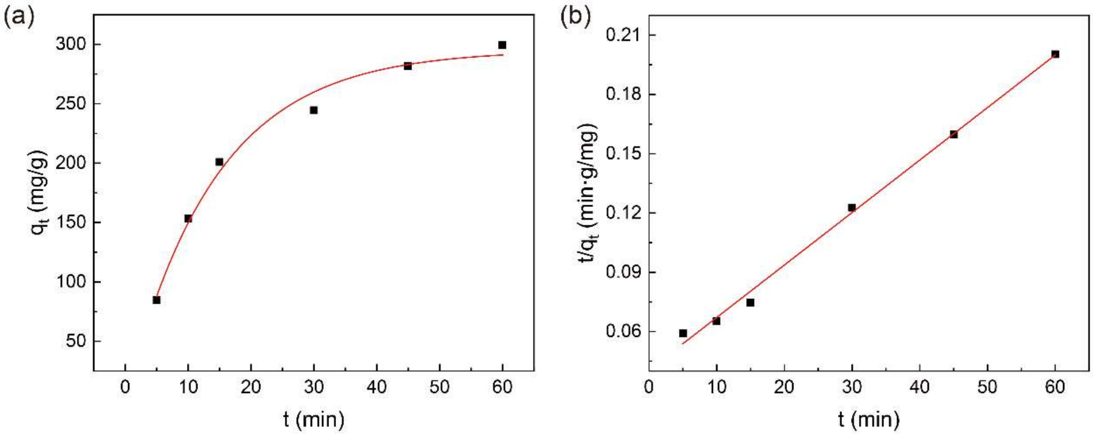

Fig. S10 (a) Pseudo-first-order kinetic model and (b) pseudo-second-order kinetic model fit for the adsorption of U(VI) onto SβCDM.

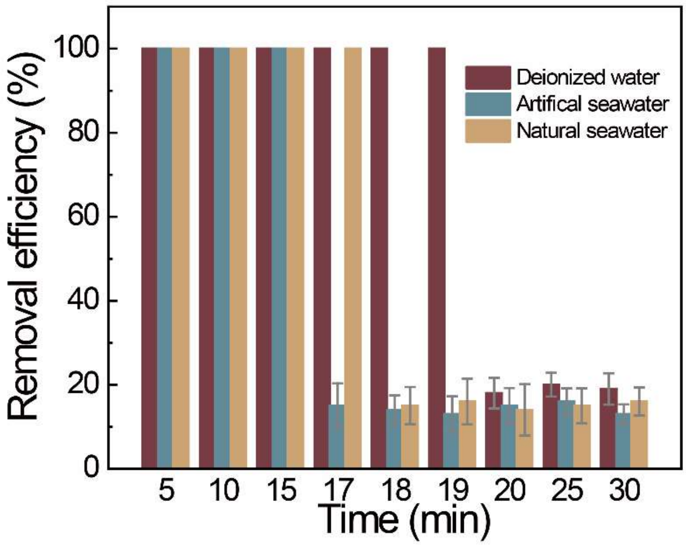

Fig. S11 Removal efficiency of U(VI) at different times in a dynamic system in deionized water, artificial seawater and natural seawater.

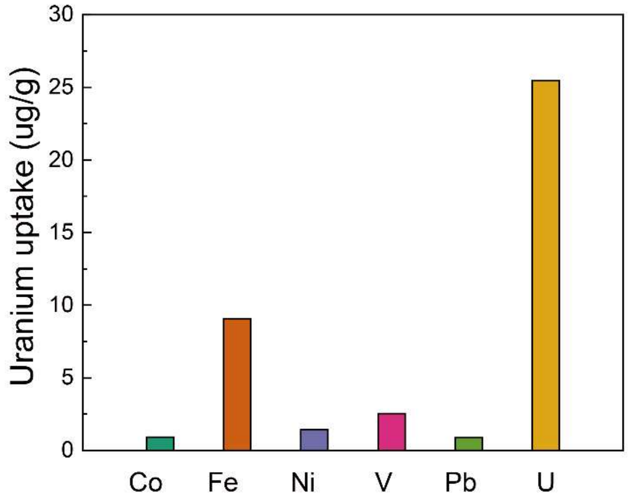

Fig. S12 Average adsorption capacities (ug/g) of Co, Fe, Ni, V, Pb and U for SβCDM during d with natural seawater for 8 days.

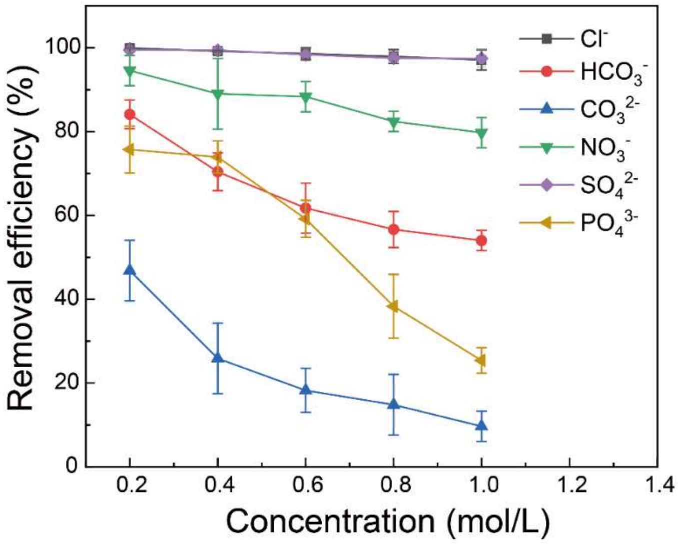

Fig. S13 Effect of different anions and their concentrations on removal efficiency of U(VI) in 100 mg/L uranium solution.

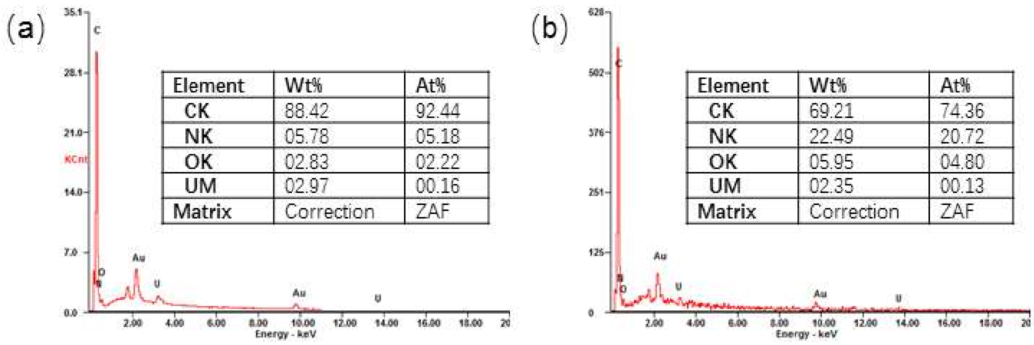

Fig. S14 EDS data of SβCDM and SβCDM-R10 adsorbed U(VI).

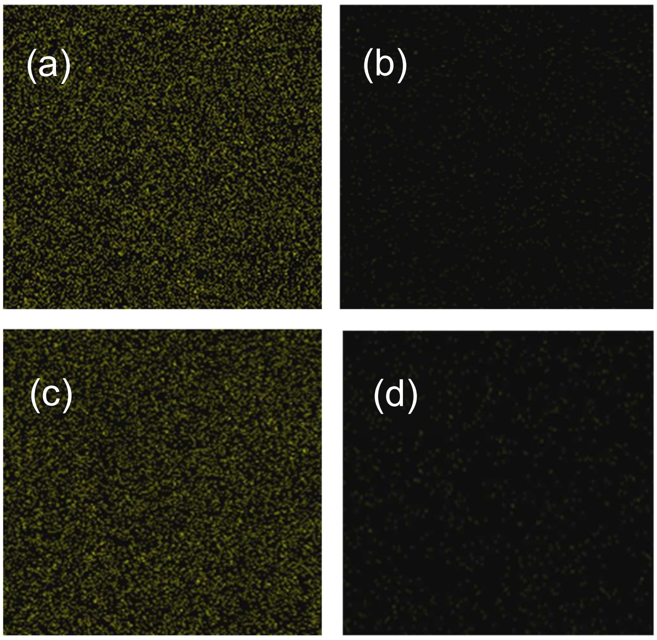

Fig. S15 U distribution mapping of (a) SβCDM-U, (b) desorbed SβCDM-U, (g) SβCDM-R10 with U and (h) desorbed SβCDM-R10.

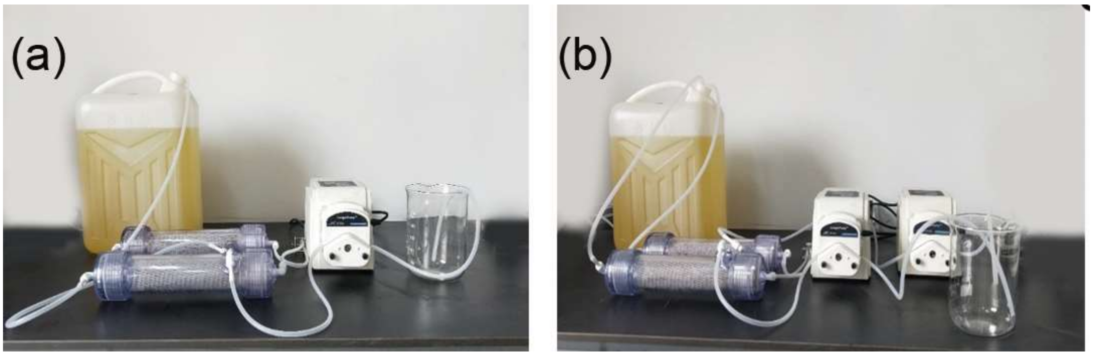

Fig. S16 (a) Series connection and (b) parallel connections of hollow fiber SβCDM modules.

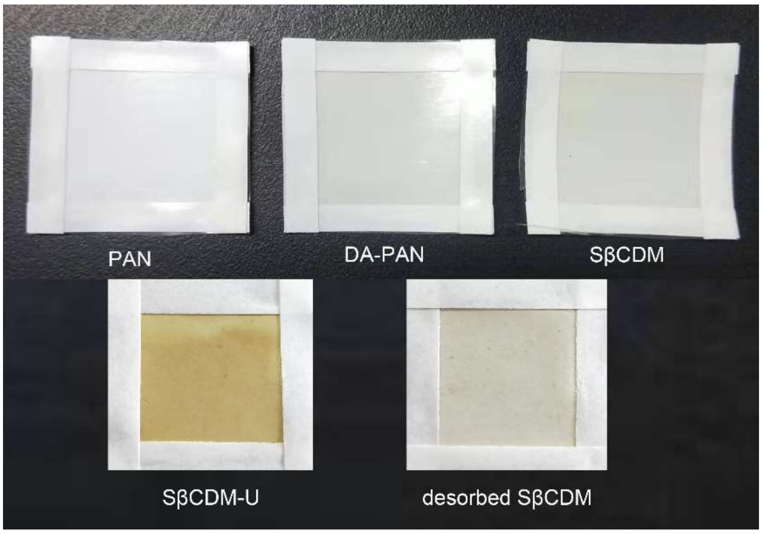

Fig. S17 Photos of different membranes.

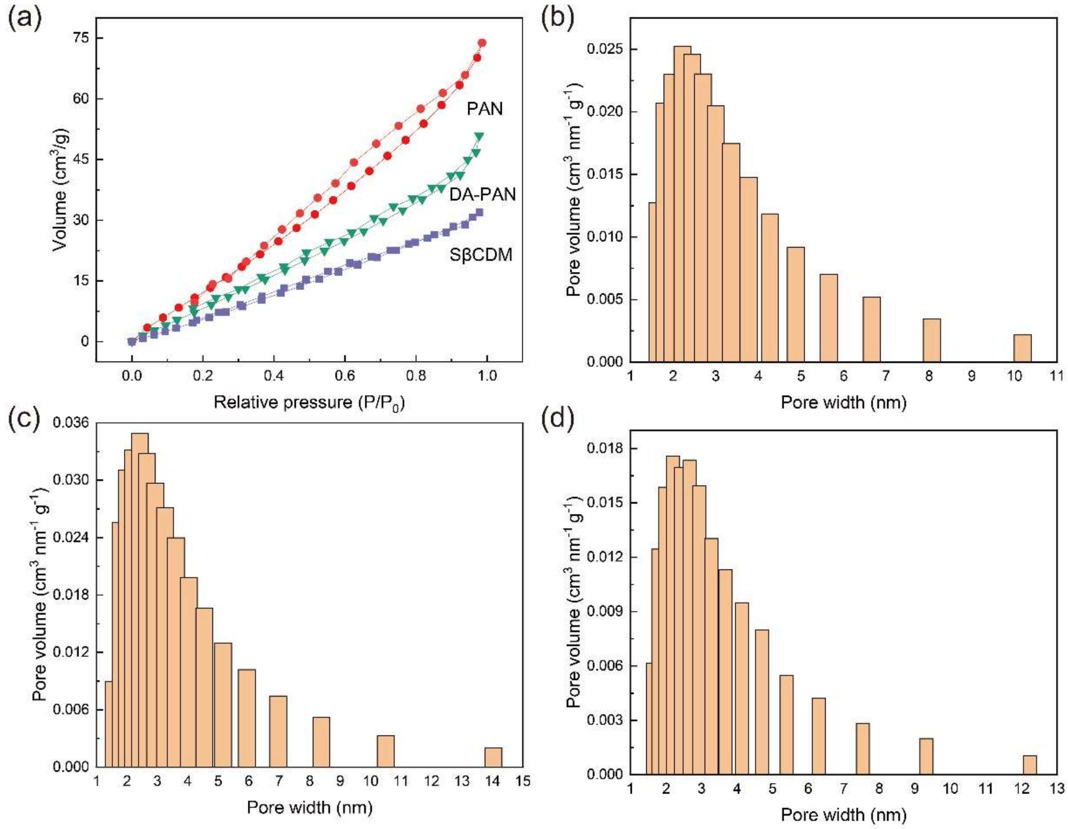

Fig. S18 (a) The N_2 adsorption/desorption isotherms. Pore size distributions of (b) PAN, (c) DA-PAN and (b)SβCDM.

Table S1. Roughness of SβCDMs.

membranes	**Rq (nm)**
SβCDM-1	14.9
SβCDM-2	15.5
SβCDM-5	16.8

Table S2. Adsorption isotherm parameters obtained from the Langmuir, Freundlich and Temkin models in the adsorption of U(VI) onto SβCDMs.

	Isotherms	Parameters	Temperature		
			25 °C	**35 °C**	**45 °C**
SβCDM	Langmuir	q_{max} (mg/g)	378.8	304.9	270.3
		K_L (g/mg)	0.1277	0.1572	0.0919
		R^2	0.9996	0.9995	0.9986
	Freundlich	$1/n$	0.08986	0.07154	0.1064
		K_f ((mg/g) L/mg$^{1/n}$)	10.59	10.07	8.735
		R^2	0.9926	0.9929	0.9866
	Temkin	a	224.6	212.0	146.3
		b	23.29	16.11	21.06
		R^2	0.9899	0.9930	0.9625
SβCDM-5	Langmuir	q_{max} (mg/g)	227.3	215.4	182.0
		K_L (g/mg)	0.0089	0.0067	0.0068
		R^2	0.9980	0.9958	0.9947
	Freundlich	K_f ((mg/g) L/mg$^{1/n}$)	2.205	2.049	1.931
		$1/n$	0.1335	0.1398	0.1423
		R^2	0.9808	0.9842	0.9710
	Temkin	a	98.08	78.92	67.20
		b	28.65	26.27	23.79
		R^2	0.9757	0.9691	0.9517
SβCDM-2	Langmuir	q_{max} (mg/g)	114.3	91.25	88.86
		K_L (g/mg)	0.0107	0.0071	0.0060
		R^2	0.9995	0.9965	0.9517
	Freundlich	$1/n$	0.1351	0.1407	0.1729
		K_f ((mg/g) L/mg$^{1/n}$)	1.616	1.445	1.331
		R^2	0.9463	0.9898	0.9923
	Temkin	a	47.81	34.45	22.06

		b	14.22	12.05	13.97
		R^2	0.9804	0.9905	0.9940
SβCDM-1	Langmuir	q_{max} (mg/g)	61.04	41.37	37.94
		K_L (g/mg)	0.0071	0.0119	0.0093
		R^2	0.9992	0.9999	0.9989
	Freundlich	K_f ((mg/g) L/mg$^{1/n}$)	1.153	1.104	1.044
		$1/n$	0.1583	0.1115	0.1145
		R^2	0.9917	0.9656	0.9952
	Temkin	a	18.41	21.65	18.59
		b	8.591	4.459	4.134
		R^2	0.9952	0.9769	0.9935

Table S3. Porous structure parameters of PAN, DA-PAN and SβCDM

Adsorbent	S_{BET} **(m²/g)**	V_{tot} **(cm³/g)**	D_p **(nm)**
PAN	88.094	0.114	5.187
DA-PAN	66.292	0.079	4.748
SβCDM	51.979	0.049	3.804

S_{BET} : BET surface area; V_{tot}: Total pore volume; D_p: Average pore size.

Preparation of artificial seawater

Artificial seawater was prepared according to the Mocledon artificial seawater [1], the constituent parts and their concentration were shown in Table S4.

Table S4. Constituent parts in Mocledon artificial seawater.

Constituent parts	Concentration (g/L)
NaCl	26.73
$MgCl_2$	2.26
$MgSO_4$	3.25
$CaCl_2$	1.15
$NaHCO_3$	0.20
KCl	0.72
NaBr	0.0580
H_3BO_3	0.0580
Na_2SiO_3	0.0035
$KAl(SO_4)_2 \cdot 12H_2O$	0.0230
$LiNO_3$	0.0013
$NH_4H_2PO_4$	0.0040

Table S5. Elements in natural seawater.

Elements	**Concentration (mg/L)**
K	7.4×10^{2}
Na	8.2×10^{3}
Ca	3.4×10^{2}
Mg	1.0×10^{2}
Fe	6.4×10^{-3}
Ni	1.8×10^{-2}
Co	8.4×10^{-4}
V	2.8×10^{-3}
U	3.5×10^{-3}

Table S6. EXAFS Parameters of SβCDM-U at k_3-Weighted L_3 Edge.

	shell	CN	R (Å)	σ^2	ΔE_0 (eV)	R-factor
SβCDM-U	U-O_{ax}	1.9	1.78	0.002	7.38	0.031
	U-O_{eq}	4.8	2.31	0.011		

Table S7. Calculated Gibbs free energies for complex formation in a water environment.

Metal cation	**Aqua complex**	**Calculated Volum (Å^3)**
Li^+	$[Li(H_2O)_4]^+$	104.5
Na^+	$[Na(H_2O)_4]^+$	112.1
K^+	$[K(H_2O)_6]^+$	162.8
Rb^+	$[Rb(H_2O)_6]^{2+}$	168.7
Mg^{2+}	$[Mg(H_2O)_6]^{2+}$	144.2
Ca^{2+}	$[Ca(OH)(H_2O)_7]^+$	196.5
Sr^{2+}	$[Sr(OH)(H_2O)_7]^+$	204.0
Ba^{2+}	$[Ba(H_2O)_8]^{2+}$	218.7
UO_2^{2+}	$[UO_2\ (H_2O)_4]^{2+}$	147.0

Table S8. The composition of hydrated metal ions in aqueous solution.

Aqua complex	ΔG^{Aqua} (Kcal/mol)
SCE-$[Li(H_2O)_4]^+$	-55.33
SCE-$[Na(H_2O)_4]^+$	-55.58
SCE-$[K(H_2O)_6]^+$	-47.35
SCE-$[Rb(H_2O)_6]^{2+}$	-42.37
SCE-$[Mg(H_2O)_6]^{2+}$	-78.56
SCE-$[Ca(OH)(H_2O)_7]^+$	-54.40
SCE-$[Sr(OH)(H_2O)_7]^+$	-60.31
SCE-$[Ba(H_2O)_8]^{2+}$	-75.99
SCE-$[UO_2\ (H_2O)_4]^{2+}$	-265.00

Table S9. Adsorption operation conditions of reported studies on adsorbents for U(VI) in Fig. 11d.

Adsorbents	**Operation conditions**
GONRs/CTS	M = 15 mg, pH = 5.0, C_0 = 50 mg·L^{-1}, t = 24 h.
OMS-2 nanowires	C[U(VI)/Eu(III)]$_{initial}$ = 20 mg·L^{-1}, I = 0.01 M KNO_3 and T = 293 K.
CS-CNTs	C_0 = 15-100 mg L^{-1}; SD (sorbent dosage) = 0.5 g L^{-1}; pH 4.0; T = 298 K
CS-Fe	T = 298 K, $C_{U(VI), initial}$ = 30 mg/L, Sorbent dosage (SD) = 0.4 g/L
PCTM@PDA@ZIF-8	20 mg·L^{-1}, [m/V] = 0.075 g/L

Reference

[1] H. Yue, C. Ling, T. Yang, X. Chen, Y. Chen, H. Deng, Q. Wu, J. Chen, G.-Q. Chen, A seawater-based open and continuous process for polyhydroxyalkanoates production by recombinant Halomonas campaniensis LS21 grown in mixed substrates, Biotechnology for Biofuels, 7 (2014).