Supplementary Material

A Novel Artificial Hemoglobin Carrier Based on Heulandite-Calcium Mesoporous Aluminosilicate Particles

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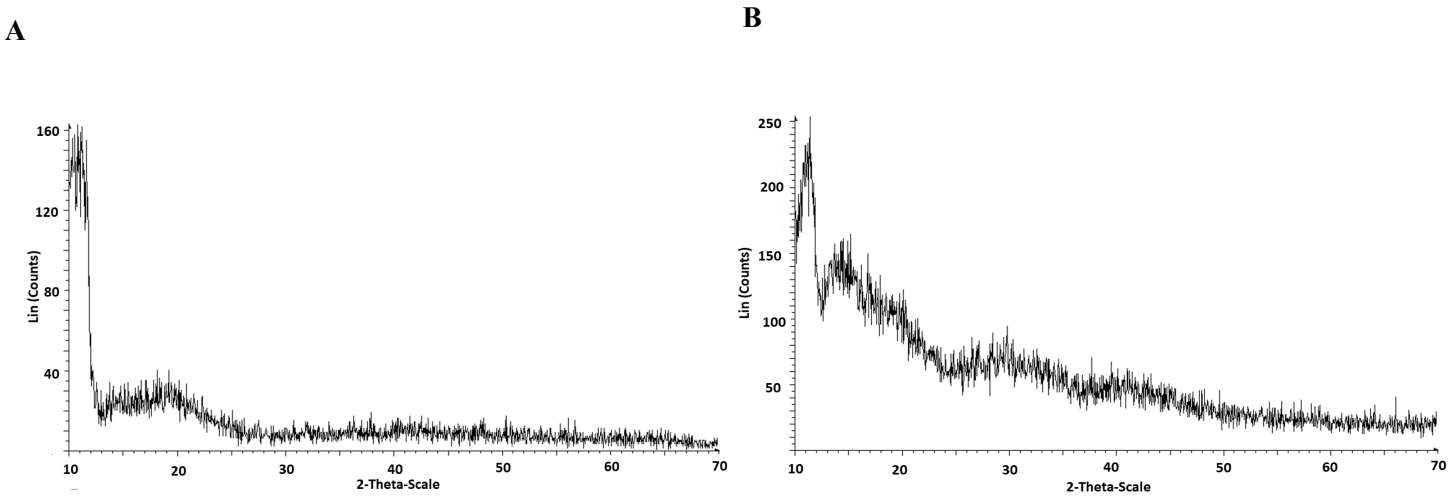

Figure S1. X-ray diffraction patterns of empty liposomes (LB) (**A**) and liposome-encapsulated MSPs (LB-MSPs)(**B**).

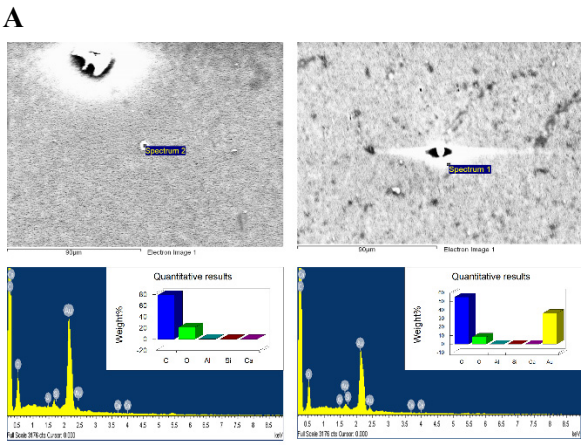

Figure S2. Field emission SEM energy dispersive spectroscopy analysis of empty liposomes (**A**) and liposome-encapsulated MSPs (**B**).

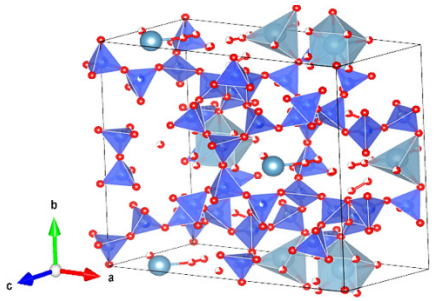

Figure S3. Crystal structure of heulandite-Ca, visualized using the VESTA software, with atom coordinates from the American Mineralogist Crystal Structure Database (VESTA, n.d.).

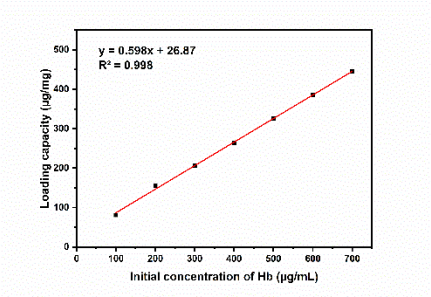

Figure S4. Hemoglobin-loading capacity for MSPs at low-loading concentrations, using a plate reader (Safire 2; Tecan; absorbance, 405 nm; 400-700 µg/mL).

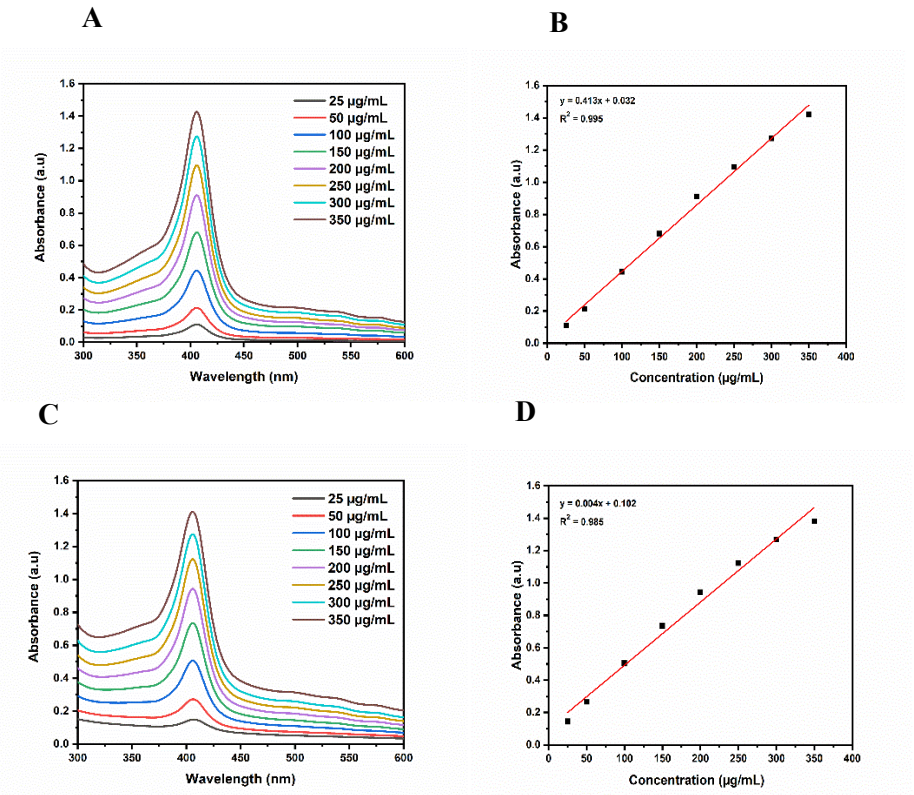

Figure S5. (A, C) UV-VIS absorbance spectra of Hb (25-350 µg/mL; 1 mM PB as control) (**A**) and Hb-loaded MSPs (25-350 µg/mL; 250 µg/mL MSPs in 1 mM PB as

control) (**C**). (**B, D**) Standard curves for absorbance (405 nm) of Hb (**B**) and Hb-loaded MSPs (**D**).

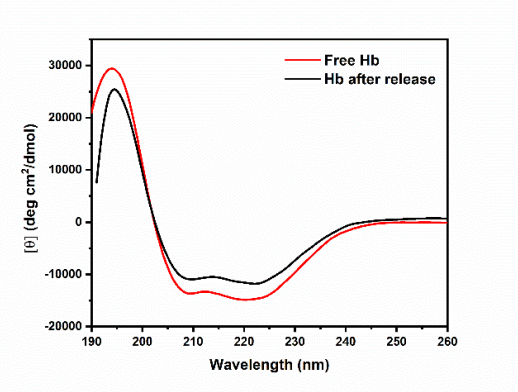

Figure S6. Far-UV circular dichroism spectra of free Hb and Hb after release from Hb-loaded MSPs.

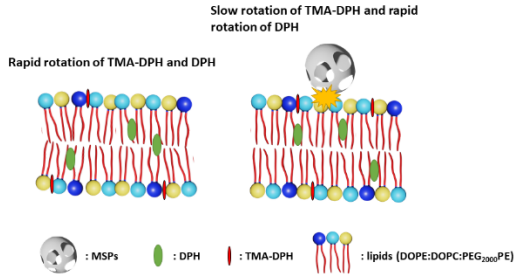

Figure S7. Schematic illustration of the MSP–liposome membrane interactions. DPH, 1,6-diphenylhexatriene; TMA-DPH, DPH trimethylammonium derivative; DOPE, 1,2-dioleoyl-*sn*-glycero-3-phosphoethanolamine; DOPC, 1,2-dioleoyl-*sn*-glycero-3-phosphocholine; PEG, polyethylene glycol.

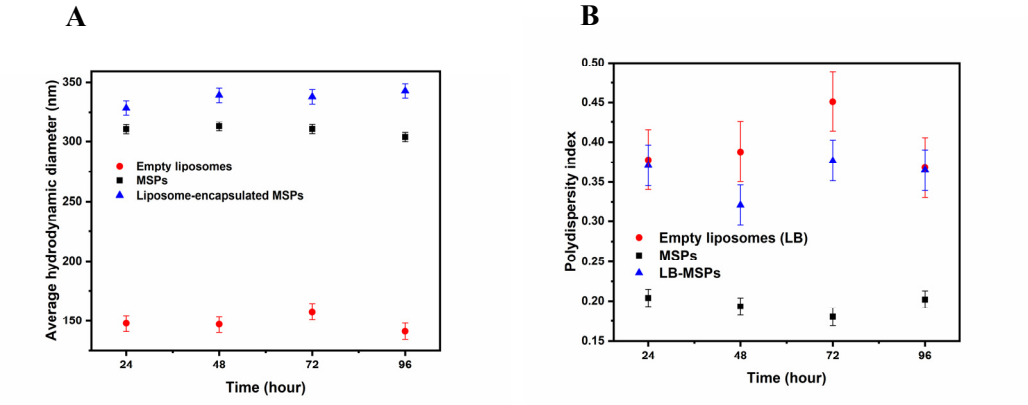

Fig. S8. (A) Size stability of LB, MSPs and LB-MSPs); (B) Coresponding PDI values.

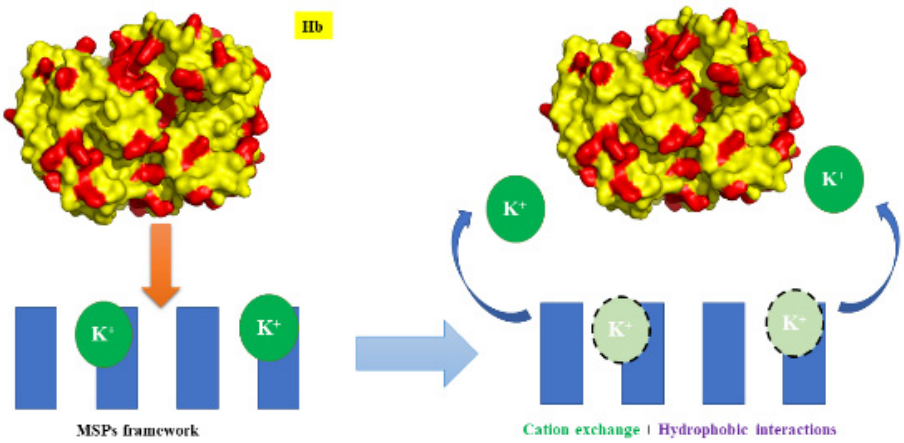

Figure S9. Schematic diagram of adsorption of hemoglobin (Protein) onto natural zeolite (heulandite-Ca). The hydrophobic surface of hemoglobin was modeled with the PyMOL software, version 2.4.1. Yellow, Hb backbone; red, Hb positively charged amino acids (i.e., Arg, His, Lys).

Table S1. Summary of hemoglobin effects upon interaction with tetraethyl orthosilicate (TEOS)-based particles and heulandite-Ca MSPs.

Analysis technique	**Particle type**	
	TEOS-based particles	**Heulandite-Ca MSPs**
Fourier transform infrared spectroscopy	Structural changes induced	Partial denaturation and successful binding
Fluorescence spectroscopy	Degradation induced	Partial denaturation and successful binding
Circular dichroism	Displacement and denaturation	Partial denaturation
UV-Vis spectroscopy	Iron release induced at low particle concentrations	Iron release induced at high particle concentrations (≥100 µg/mL)
Peroxidase-like activity	Preserved redox activity of bound hemoglobin	Higher redox activity of bound hemoglobin

Cytotoxicity	Cytotoxic at low concentrations (≥10 µg/mL)	No cytotoxicity up to ≥100 µg/mL