Electronic Supplementary Material (ESI) for Materials Horizons.

Supporting Information

Non-Newtonian fluid gating membranes with acoustically responsive and self-protective gas transport control

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Contents

1. Supplementary Methods

Transmembrane pressure measurements: The non-Newtonian fluid gating membranes (NFGMs) were sealed in between two polymethyl methacrylate (PMMA) sheets. An inlet tube and an outlet tube were set on the two sides of the composite membrane. The transmembrane behavior of the non-Newtonian fluid gating membranes was determined by measuring the transmembrane pressure during the flow of gas and liquid. Air was used as the transport gas. The transmembrane pressure was measured by wet/wet current output differential pressure transmitters (PX154-025DI and PX273-020DI) from OMEGA Engineering Inc. (Stamford, CT, USA). A Harvard Apparatus PHD ULTRATM Syringe Pump was used for the flow of gas. Without specification, a constant flow rate mode was selected with a flow rate of 0.1 mL/min. To characterize the self-protective property of confined cornstarch suspension, the pressure of 1 kPa, 1.5 kPa, 2.5 kPa, 5 kPa, and 20 kPa in the constant pressure mode was applied.

Microscopic observation of confined cornstarch particles: A Polydimethylsiloxane (PDMS) membrane with a pore size of 100 μm was placed on a glass slide, and 10 μL of 38% cornstarch suspension was infused into the pore. The agglomeration, contact, and distribution changes of cornstarch particles in the confined space under the on/off state of the acoustic field were observed under an optical microscope (TH4-200, Olympus, Japan).

Testing of cornstarch suspensions properties: Viscosity and shear stress of cornstarch suspensions at different shear rates were measured using a viscometer (DV2T, Brookfield, USA). The viscosity of non-colloidal and colloidal suspensions under the acoustic wave was measured under the shear rate of 2 s^{-1}. The thermal change of the cornstarch suspension under the action of ultrasound was measured by a FLIR A325c infrared thermal imager, and the distance between the ultrasonic horn probe and the upper surface of the NFGM was kept at 16 mm. A digital camera (Nikon D750) was used to take photos and record videos.

2. Supplementary Figures: Figures S1-S6

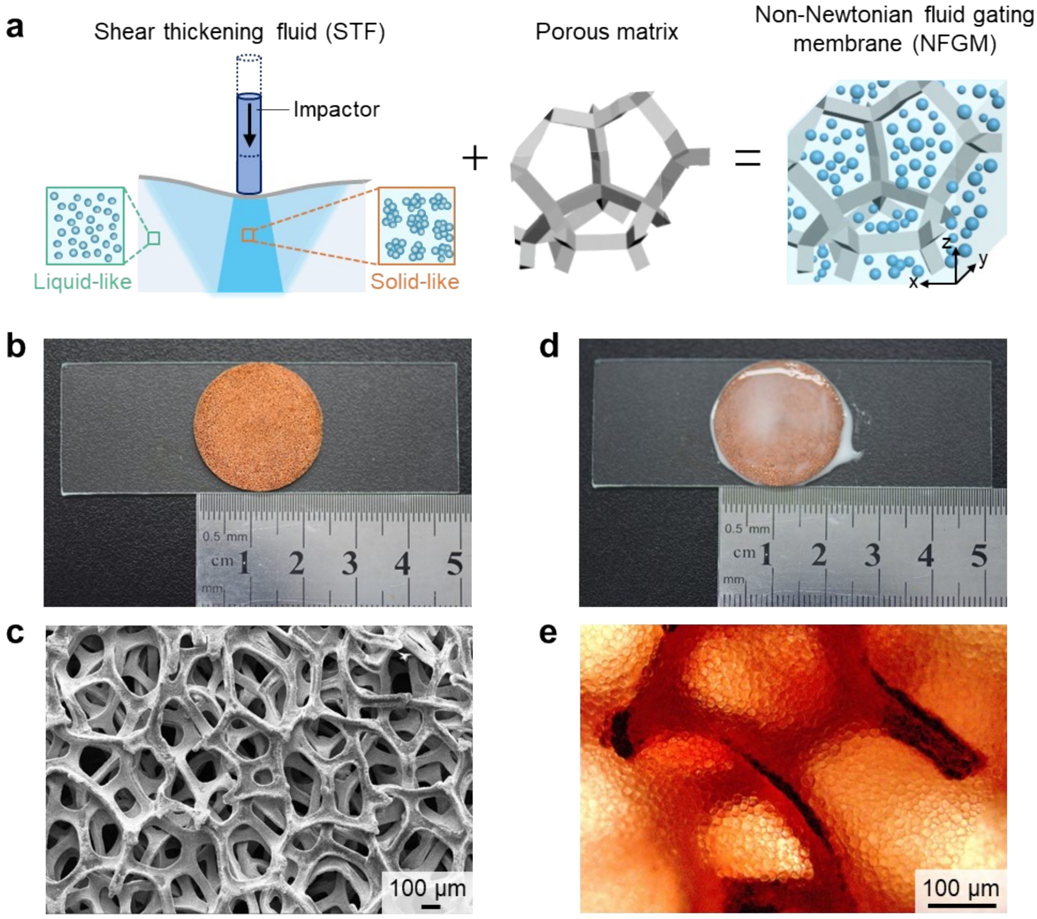

Fig. S1. The establishment of a non-Newtonian fluid gating membrane (NFGM). (a) A diagram showing the concept of NFGM. (b) Image of the porous network (Cu foam with a pore size of 50 μm). (c) SEM image of the Cu foam. (d) The NFGM is formed by impregnating the cornstarch suspension in the copper porous network. (e) Microscopic image of cornstarch suspension confined in Cu foam.

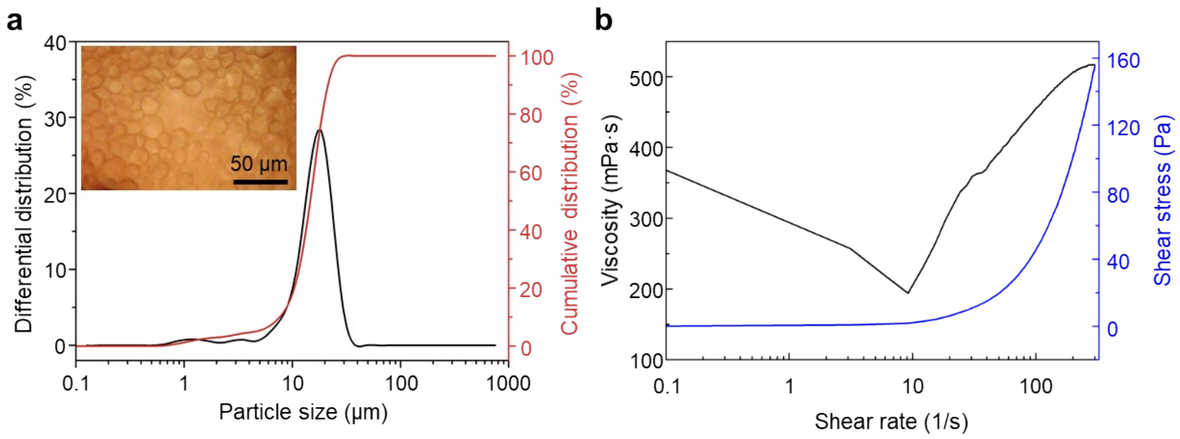

Fig. S2. The morphology and particle size distribution of cornstarch. (a) The differential distribution and cumulative of cornstarch particles. Inset: An microscopic image of cornstarch particles. (b) Viscosity and shear stress as a function of the shear rate for cornstarch suspension with a weight percentage of 38%.

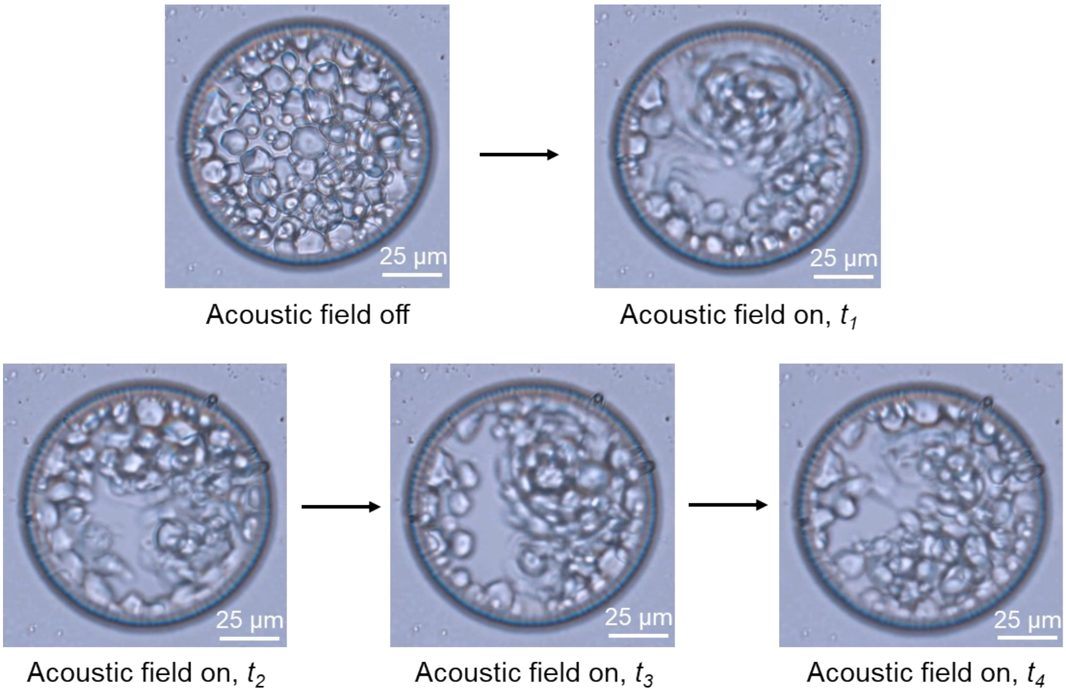

Fig. S3. The acoustic field-induced dynamic configurations of cornstarch suspension confined in a PDMS pore (pore size of 100 μm).

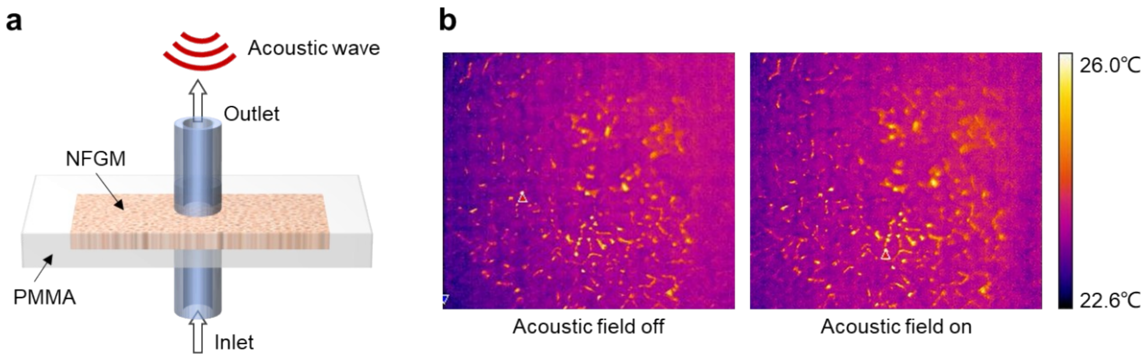

Fig. S4. (a) The schematic of the gas transport device in response to the acoustic field. (b) The infrared thermal images on cornstarch suspension with the acoustic field on and off.

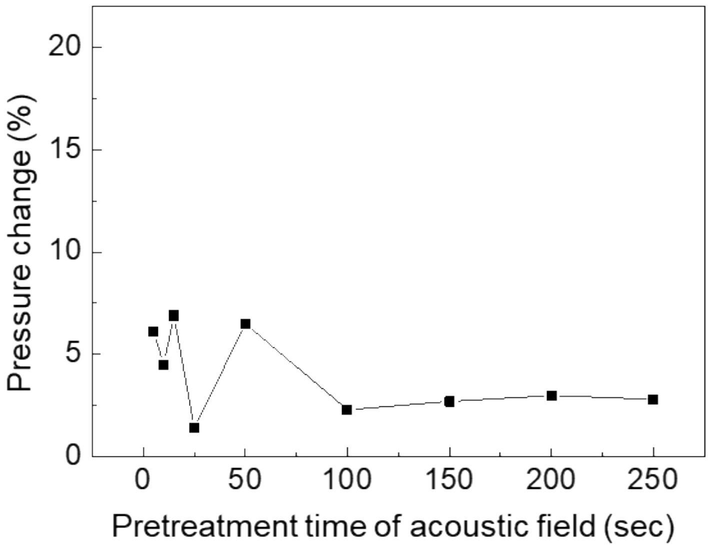

Fig. S5. Effect of acoustic field pretreatment time on the pressure change of glycerol/water solution as a gating liquid.

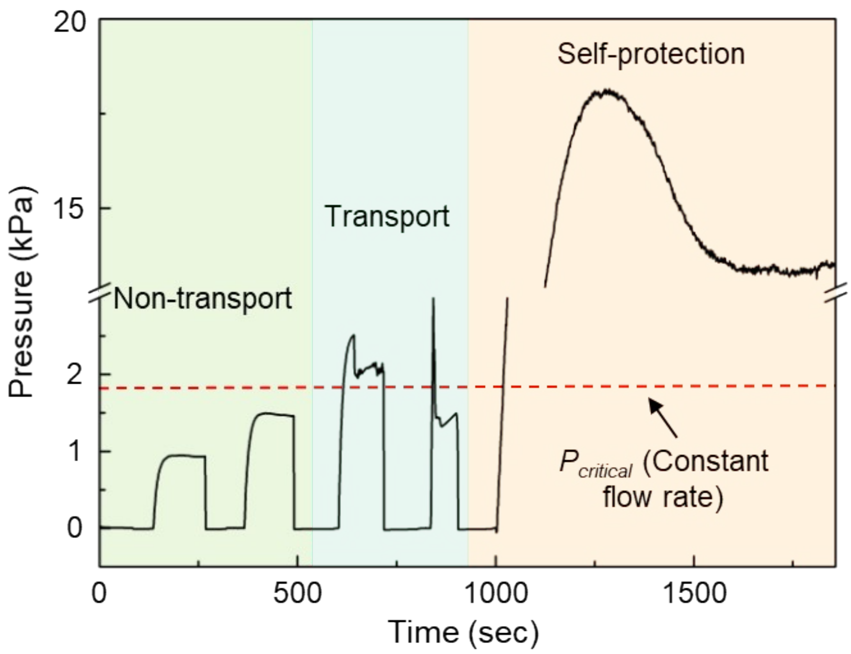

Fig. S6. Pressure regulation for gas transport control in a dynamic process. The pressure of 1 kPa, 1.5 kPa, 2.5 kPa, 5 kPa, and 20 kPa in the constant pressure mode was applied.

3. Supplementary Movies

Movie S1: Cornstarch particles distribution without and with acoustic field

The cornstarch particles confined in the pore are initially randomly distributed. With the applied acoustic field, the particles aggregate and roll in the pore due to the radiation force of the acoustic field.

Movie S2: Self-protective behaviour of the NFGM

When the applied pressure was slowly increased to slightly higher than the critical pressure, the gas was transported stably. When the applied pressure was suddenly increased to a level far above the critical pressure, due to the thickening effect of the cornstarch suspension under the action of rapid gas shear, the shear-jammed state was automatically created to resist flow, showing a self-protective behaviour.