Supporting Information

Long Time and Distance Self-Propelling of PVC Sphere on Water Surface with Embed ZnO Micro-/Nano-Structured Hollow Sphere

Lei Wang, [a] *Lujia Yu,* [a] *Liting Yi,* [a] *Bin Yuan,* [a] *Yongping Hou*[b], Xiangfu Meng*[c] and Jing Liu*[a]*

a. Beijing Key Lab of Cryobiomedical Engineering and Key Lab of Cryogenics, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100190, China

b. Key Laboratory of Bio-Inspired Smart Interfacial Science and Technology of Ministry of Education, School of Chemistry and Environment, Beihang University, Beijing,100191, P. R. China.

c. Department of Chemistry, Capital Normal University, Beijing 100048, China

*E-mail: houyongping09@buaa.edu.cn, xfmeng@cnu.edu.cn, jliu@mail.ipc.ac.cn

Experimental Section

Preparation of ZnO MNHS. The MNHS was fabricated by integrating the methods of enhanced crystal growth and combustion. Polymethyl methacrylate (PMMA) micro spheres with diameter ranging from 10 μm to 120 μm were purchased from Solvay China Ltd. The crystal seed solution was prepared by dissolving 2 g $Zn(Ac)_2•2H_2O$ and 0.6 g monoethanolamine (purchased from Shanghai Zhenpin Chemical Co., Ltd., China) in 20 mL ethylene glycol monomethyl ether (purchased from Zhongshan Xinxin Chemical Co., Ltd., China). The growth liquid was prepared as follows: 0.3 g hexamethylene tetramine (purchased from Beijing Lanyi Chemical Co., Ltd., China) and 0.62 g $Zn(NO_3)_2•6H_2O$ (purchased from Beijing Lanyi Chemical Co., Ltd., China) were mixed into 100 mL deionized water and then the liquid was stirred to be transparent. PMMA micro spheres were mixed with the growth seed with mass ratio 6:1 and dried at 80 ^oC for 1 hour. After that, the modified micro spheres (5 g) were moved into Teflon reactor (100 mL) with 100 mL growth liquid. The reactor was removed into an oven for reacting at 95^oC for 1-16 h. After that, the micro-/nano-structured spheres could be obtained. Moved the spheres into the muffle furnace and kept them at 600 ^oC for 50 min. The PMMA is burnt off and the MNHS was realized finally.

Preparation of PVC solution. The macromolecule chains of polymer in solution shows chaos state, it contains much cohesive energy density. The PVC solution can solidify when it contacts with water and the macromolecule chains of PVC will polymerize and release heat. Most of the heat is generated by the solidification of the polymer from the solution, which is induced by the different cohesive energy density. The larger cohesive energy density of polymer will release more heat in the solidification process, for example, the cohesive energy density of PVC, polyethylene (PE), polystyrene (PS), Polymethyl Methacrylate (PMMA) and polyvinyl acetate (PVAc) are 381, 260, 272, 247 and 368 J/cm^3, respectively. So, the PVC show the largest cohesive energy density, which induces the PVC particle can run the longest time and distance

on water surface. The PVC solution was prepared as follows: 4 g PVC (average polymerization degree was around 300, purchased from Lanyi Chemical Co., Ltd., China) and 100 ml dimethylformamide (DMF) were mixed and stirred with a magnetic stirrer for 2 h. After that, mixed MNHS particles into the solution and stirred for getting uniform dispersion solution. The Taiji and Dragon shapes were fabricated by cutting Teflon board and fed (dipped) by PM1 solution and then fast motion behaviour was observed (without MNHS, the Taiji and Dragon can will run in chaos state).

Motion of PVC sphere. Deposited a droplet of PVC solution onto the water surface in a circular petri dish (with diameter of 10 cm), the PVC solution became solidified and moved fast under the effect of heat and surface tension gradient. The PVC particle will get centripetal force in the circular petri dish. In other vessels (not circular), the PVC particle will move without orbit.

Characterization. SEM images of the topography of PVC particles were observed by Environmental Scanning Electron Microscopy (ESEM, Quanta FEG 250, FEI, USA) under a voltage of 5-15 kV. The motion was recorded through thermal infrared Camera (FLIR SC620, FLIR Systems Inc, USA). The recording speed is 30 pictures per second.

Supplementary Figure Legend: Figure S1-S3

Figure S1:

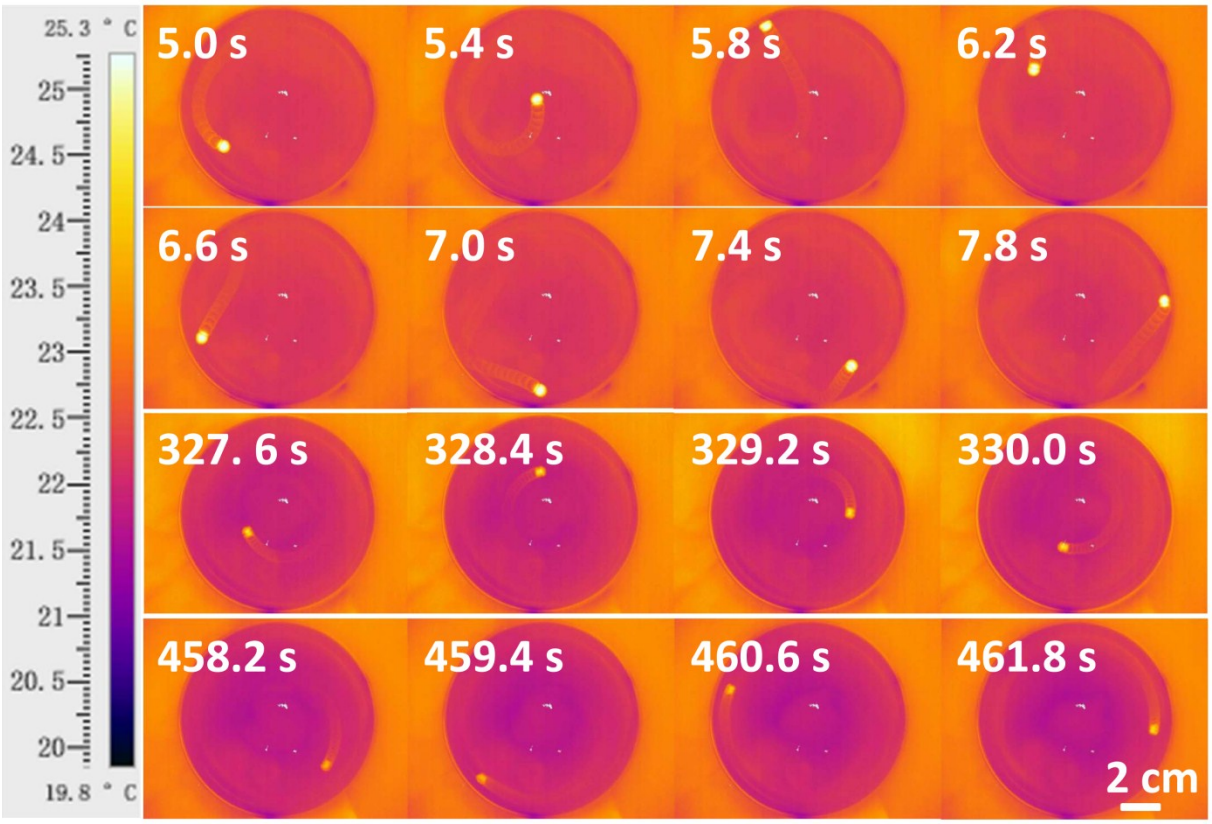

Figure S1. The PVC motion without MNHS. The PVC particle runs with high speed and crashes the wall. After 458.2 s, the particle runs into the first orbit (smaller one) due to its high speed.

Figure S2:

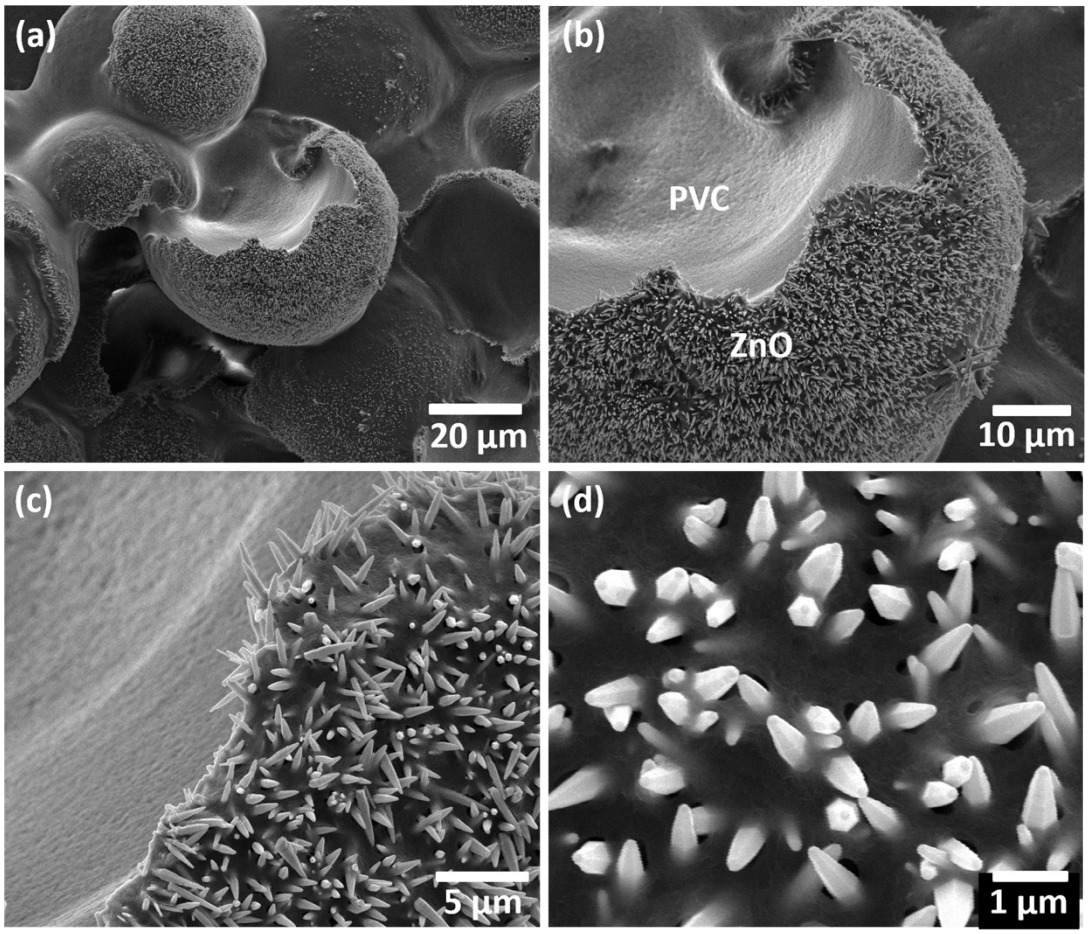

Figure S2. The SEM observation of the MNHS before self-propelling of PVC sphere stops. PVC solidifies inside the sphere (a). The magnified view of (a) is shown in (b) and (c). The nano-rods are submerged by PVC layer.

Figure S3

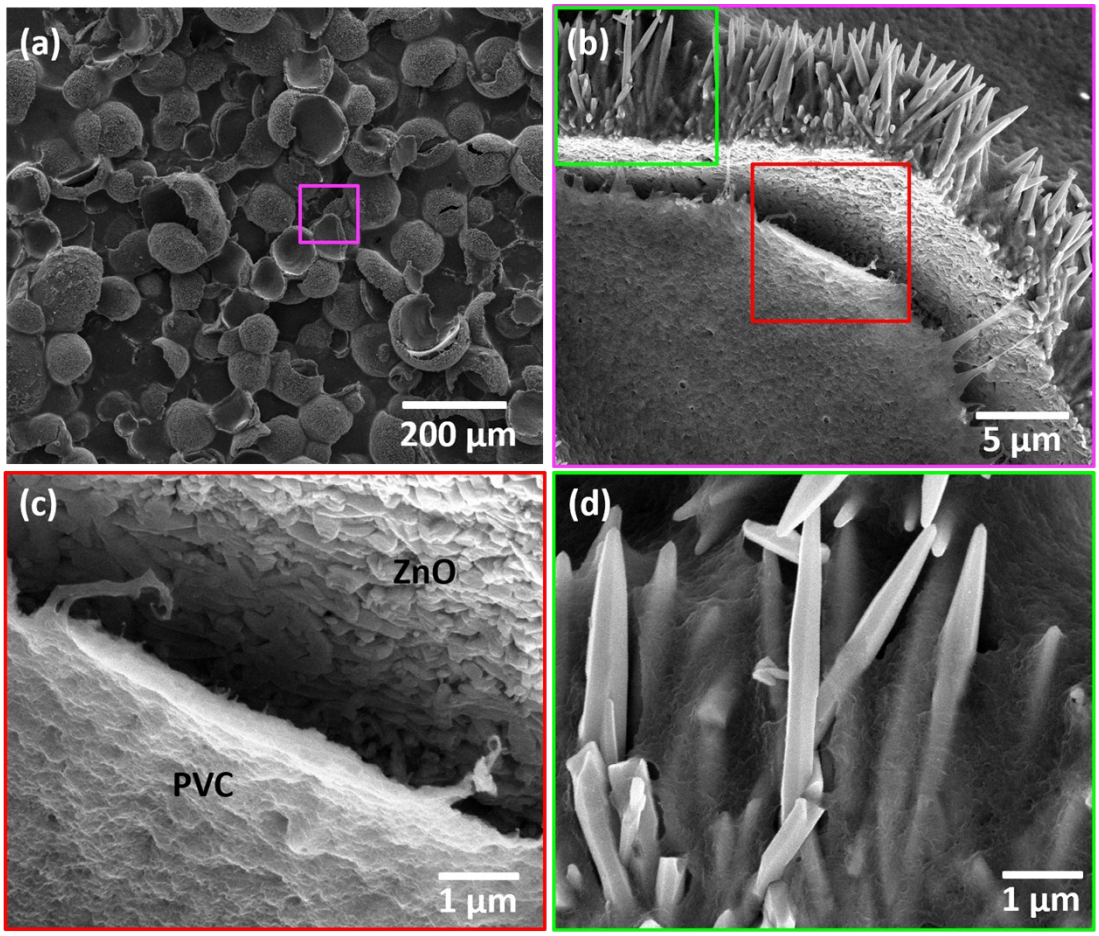

Figure S3. The SEM observation of the MNHS (inside the PVC) after self-propelling of PVC sphere stops. The MNHSs are broken in the release process (a). PVC layer forms inside of the sphere (b, c). The nano-rods are submerged inside the PVC layer (d).