Supplemental Information

1. PNIPAm hydrogel fabrication

N-Isopropylacrylamide (NIPAm) monomer and N,N'-Methylenebis (acrylamide) (BIS) crosslinker were dissolved in deionized water. The mixture was stirred for 15 min to obtain a homogeneous dispersion of the magnetite nanoparticles. The radical initiator Ammonium Persulfate (APS) (0.1 wt% of mixture) and accelerator Tetramethylethylenediamine (TEMED) (2.25 wt% of mixture) were then added and mixed to initiate the redox reaction. After mixing, the solution was injected into a cylindrical mold that was 7 mm in diameter and allowed to stand overnight at room temperature to achieve the desired cylindrical PNIPAm hydrogels. The diameters of hydrogel particles were ~1 cm at the swollen state. After swollen, the gel cylinder was cut into specimens of 5 cm and stored in de-ionized water.

The chemicals, including NIPAm monomer, BIS cross-linker, TEMED, APS were obtained from Sigma Aldrich (St. Louis, MI).

2. Controlling of hydrogel crosslink density

The hydrogel's crosslink density was controlled by varying both the concentration of NIPAm and BIS in polymerization. To ensure the homogeneity of hydrogel network, we choose the reference concentration as $C_{NIPAm} = 700\ mM$ and $C_{BIS} = 8.62\ mM$ according to Okajima et al.[1] We then vary these two quantities while keeping C_{NIPAm}/C_{BIS} constant to obtain hydrogels with different crosslink densities. The gel's crosslink density was measured by measuring its swelling ratio at the swollen equilibrium state at room temperature ($298\ K$). The measured value is then plugged into eq.1 to determine the crosslink density. Table S1 summarizes the parameters regarding the gel fabrication.

Table S1 Summary of hydrogel fabrication parameters and corresponding swelling ration and crosslink density

C_{NIPAm} (mM)	C_{BIS} (mM)	Swelling ratio	Crosslink density (mM)
400	4.93	42	50.3
700	8.62	27.6	103.02
1000	12.31	21.4	158.46
1400	17.24	16.9	236.33

3. Set up for hydrogel blistering experiment

The experimental set up for hydrogel blistering experiment is shown in Fig. S1. A water bath is first heated on a hot plate to the targeting temperature. After the temperature becomes stable, the dyed hydrogel particle is immersed in the water bath. To track the change in hydrogel's volume and the surface morphology, we used three cameras (one from top and two from side views) to take pictures at every 5 seconds. The hydrogel's swelling ratio is then calculated from the volume of the gel which is measured via image processing using ImageJ. The blister density is computed as the number of blisters per initial surface area (at the swollen state).

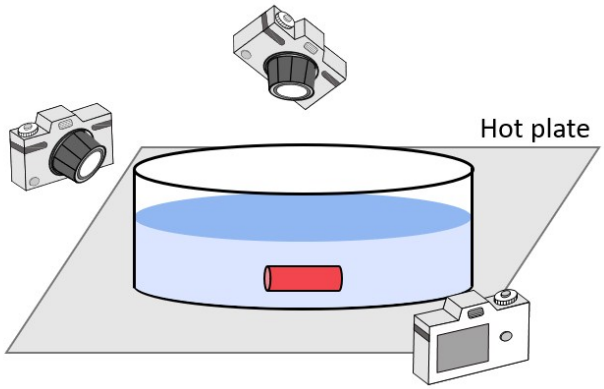

Figure S1. Schematic of experiment set up. The dyed hydrogel particle is immersed in a hot water bath. The change in hydrogel size and surface morphology are recorded by three cameras.