Electronic Supplementary Information

Conversion of a molecular signal into visual color based on the permeation of nanoparticles through a biomolecule-recognition gating membrane

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Experimental

A porous, high-density polyethylene membrane (maximum pore size: 0.15 µm, thickness: 27 μm, porosity: 50%) was kindly supplied by the Asahi Chemical Co. Ltd. *N*-isopropylacrylamide kindly supplied Kohjin was by Co., Ltd. α -Methoxy- ω -mercapto-poly(ethylene glycol) (PEG-SH; Mn = 2100) was purchased from NOF Corporation (Japan). All other reagents were purchased from Wako Pure Chemical Industries, Ltd. (Japan), and used without further purification.

The substrate was treated with argon plasma at a pressure of 10 Pa. The plasma treatment power and time were 30 W and 1 min, respectively. The plasma-treated membrane was exposed to air for 60 s to generate a peroxide group on its pore surface. Then, the substrate containing the peroxide group was immersed in an extensively degassed (frozen and thawed) aqueous solution of 2.5 wt% NIPAM and 0.5 wt% biotin monomer, with 5 wt% sodium dodecyl benzene sulfonate as a surfactant. Active radical sites on the pore surface were formed by thermal cleavage of the peroxide group in the solution at 80 °C, and a graft polymerization reaction started from the initiator radical. SEM (S-5200; Hitachi, Ltd., Japan) measurement was performed by Center for Advanced Materials Analysis (Suzukakedai), Technical Department, Tokyo Institute of technology).

AuNPs were synthesized as reported in the literature.¹ A HAuCl₄ solution, prepared by diluting 210 μ L of 0.24 M aqueous HAuCl₄ solution with 55 mL water, was brought to boiling. Under vigorous stirring, 5 mL of 38.8 mM aqueous trisodium citrate solution was added quickly to the HAuCl₄ solution. During the reaction, the color of the solution changed to ruby-red. After 5.5 min (from the addition of the citrate solution), heating was removed and the solution was air-cooled, while stirring.

PEGylated AuNPs were synthesized as reported in the literature.² Under vigorous stirring, 170 μ L of 0.1 wt% aqueous PEG-SH solution was added quickly to 15 mL of a solution of the synthesized AuNPs. The reaction was continued for 30 min. Particle diameters of the AuNPs and PEGylated AuNPs were measured by DLS (Nano-S90; Malvern Instruments Ltd, United Kingdom) and TEM (H-7000; Hitachi Ltd, Japan).

The filtration area was 3.5 cm^2 when membranes were set in a permeation cell. Photographs of the membrane and the permeation experiment setup are shown in Fig. S1. The volumes of the permeated AuNPs or PEGylated AuNPs solutions were 1.0 mL. The nanoparticle concentrations of the AuNPs and PEGylated AuNPs solutions for the substrate were 1×10^{-8} – 1×10^{-10} moles of nanoparticles/L. The nanoparticle concentrations for the biomolecule-recognition gating membrane were about 1.7×10^{-9} moles of nanoparticles/L. Flow rate of nanoparticles solutions was 0.5 mL/h. Absorbance of the permeated solutions at 519 nm was measured with a UV-Vis spectrophotometer (U-3310; Hitachi Ltd, Japan).





Fig. S1 Photograph of the membrane and the experiment setup; (Left) membrane used in the permeation experiment, (Right) permeation experiment using syringe pump.

References

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