Ag-nanogels blended polymeric membranes with antifouling, hemocompatible and bactericidal capabilities

Yi Xia,[a,1] Chong Cheng,[a,1,*] Rui Wang, [a] Chuanxiong Nie,[a] Jie Deng,[a] and Changsheng Zhao[a,b,*]

[a] College of Polymer Science and Engineering, State Key Laboratory of Polymer Materials Engineering, Sichuan University, Chengdu 610065, China

[b] National Engineering Research Center for Biomaterials, Sichuan University, Chengdu 610064, China

1 These two authors contribute equally to this work.

* Corresponding author. Tel: +86-28-85400453, Fax: +86-28-85405402, E-mail: (C. Cheng) sagecheng@163.com or chong.cheng@fu-berlin.de, (C.S. Zhao) zhaochsh70@163.com or zhaochsh70@scu.edu.cn

Supplementary Information

Materials

Micro BCA™ Protein Assay Reagent kits were from PIERCE. Beef extract and calf serums were of analytical grade and purchased from Kebite bio-reagent, Chengdu. Other reagents were obtained from Aladdin reagent Co. Ltd. (China) with analytical grade and used as received unless otherwise stated. Prothrombin time (PT), activated partial thromboplastin time (APTT) and thrombin time (TT) agents (Dade Actin Activated Cephaloplastin Reagent, Siemens) were incubated 10 min before use. All the aqueous solutions were prepared with de-ionized water (DI water). Polyethersulfone (PES, Ultrason E6020P, BASF).

Water contact angle method

The hydrophilicity of the membrane surface was characterized on the basis of static

contact angle measurement using a contact angle goniometer (DSA100, KRUSS GmbH, Germany) equipped with a video capture. A piece of 1×1 cm^2 membrane was attached on a glass slide and mounted on the goniometer. For the static contact angle measurements, a total of 3 μL double distilled water was dropped on the airside surface of the membrane at room temperature. The static contact angle was measured after 10 s, and the dynamic contact angle was measured at different drop ages. At least five measurements were averaged to get a reliable value.

Protein adsorption method

Protein adsorption experiments were carried out with BSA solution and BFG solution under the static condition, respectively. Firstly, a pieace of 1×1 cm^2 membrane was immersed in PBS (containing BSA or BFG with the concentration of 1 mg/mL) solution and incubated at 37 °C for 1 hour; then the membrane was rinsed slightly with PBS and DI water. Then the membrane was transferred into a washing solution (containing 2 % sodium dodecyl sulfate (SDS) and 0.05 M NaOH) at 37 °C; and then shaken for 2 hours to remove the adsorbed BSA or BFG protein. The above adsorption and desorption times were pre-determined based on preliminary experiments. The protein concentration in the washing solution was used to calculate the adsorbed protein amounts and determined by using the Micro BCATM Protein Assay Reagent Kit (PIERCE). More than 95 % of the adsorbed protein could be eluted into the SDS solution.

Antifouling test method

Ultrafiltration of BSA solution through the membranes was carried out to study the dynamic antifouling property, and a dead-end ultrafiltration cell with an effective membrane area of 3.9 cm^2 was used. BSA solution was prepared by dissolving BSA in PBS (pH=7.4) with a concentration of 1.0 mg/mL. For the ultrafiltration experiment, the membrane was firstly pre-compacted by DI water at a pressure of 0.07 MPa for 20 min to obtain a steady flux. Then, the water flux and PBS flux were measured in order. The measurement lasted for 30 min, and the data were recorded

every 5 min. After the filtration of PBS solution for 30 min, the feed solution was switched to 1.0 mg/mL of the BSA solution. For the BSA solution ultrafiltration experiment, the same method was used, and the data were recorded every 5 min. After the filtration of protein solution, the membrane was washed with PBS for 1 h, and then the PBS flux was measured again.

Platelet adhesion method

Healthy fresh human blood (male, 26 years old) was collected using vacuum tubes containing sodium citrate as an anti-coagulant; the concentration of sodium citrate was 3.8 wt. %, and the ratio of the anticoagulant to blood was 10:90 vol. %. The blood was centrifuged at 1500 r.p.m. for 15 min to obtain platelet-rich plasma (PRP) or at 4000 r.p.m. for 15 min to obtain platelet-poor plasma (PPP).

For platelet adhesion experiments, the PES and modified PES membranes were immersed in PBS and equilibrated at 37 °C for 1 h. Then, the PBS was removed and 1 mL of fresh PRP was introduced. The membranes were incubated with PRP at 37 °C for 2 h. Then, the PRP was decanted off and the membranes were rinsed three times with PBS. Finally, the membranes were treated with 2.5 wt. % glutaraldehyde in PBS at 4 °C for 1 day. The samples were washed with PBS, subjected to a drying process by passing them through a series of graded alcohol–PBS solutions (30, 50, 70, 80, 90, 95 and 100%) and isoamyl acetate–alcohol solutions (30, 50, 70, 80, 90, 95 and 100%). Platelet adhesion was observed using a FE-SEM (JSM-7500F, JEOL, Japan). The number of adherent platelets on the membranes was calculated from five SEM pictures at 500 × magnification from different places on the same membrane.

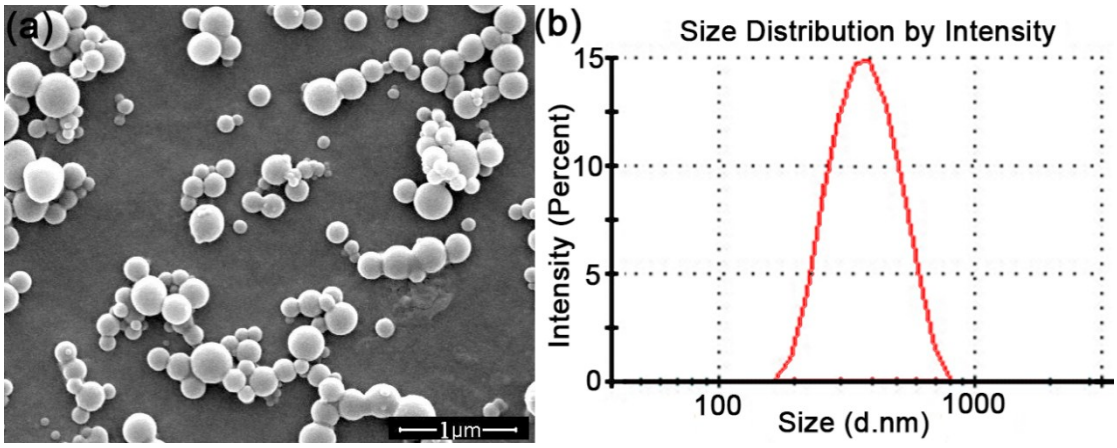

Figure S1 (a) SEM image for PEGMA-MAA nanogels; (b) Size distribution of the obtained PEGMA-MAA nanogels.

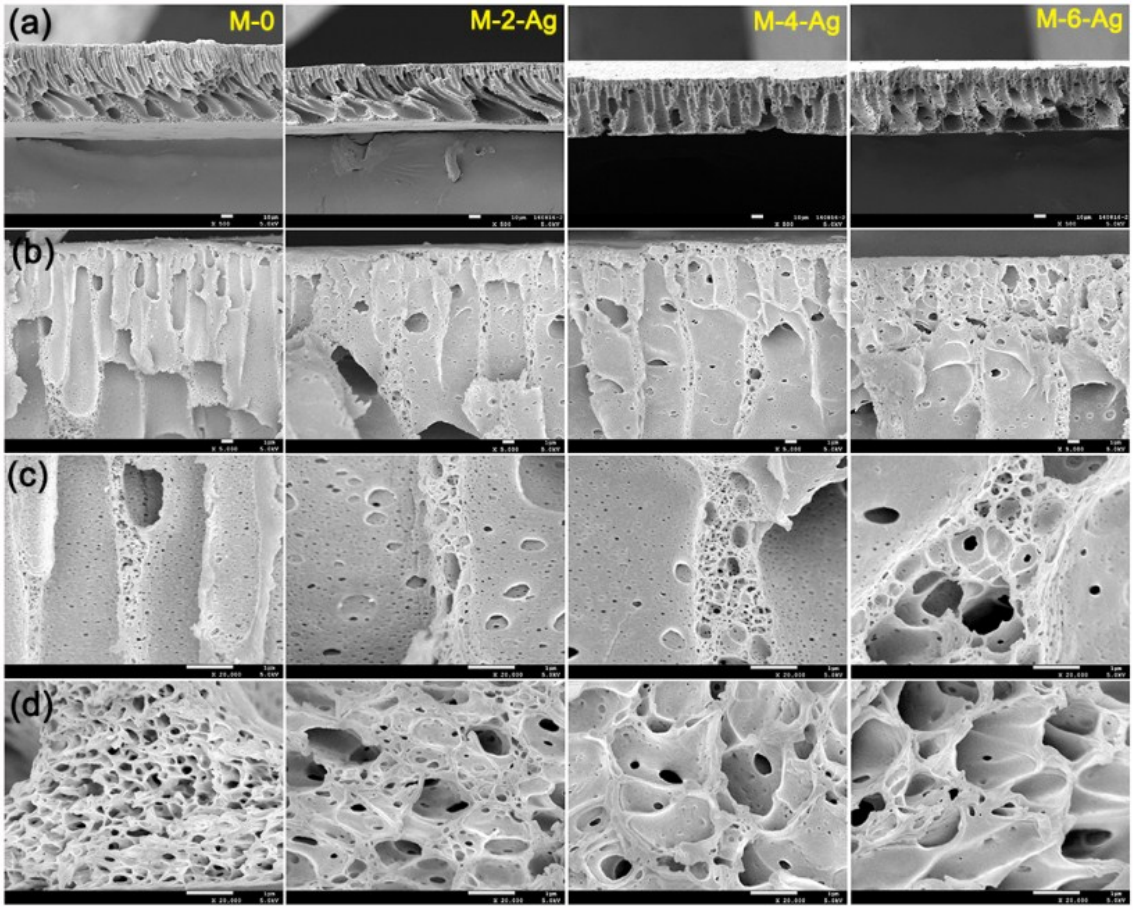

Figure S2. SEM images of the cross-section view of the membranes M-0, M-2-Ag, M-4-Ag and M-6-Ag，The scale bar for (a) is 10 μm (500×), (b) is 1 μm (5000×), (c) and (d) are 1 μm (20000×).(b) The image for is the amplified image of top skin layer,

(c) is the amplified image of finger-like structure in the center, and (d) is amplified image the bottom.

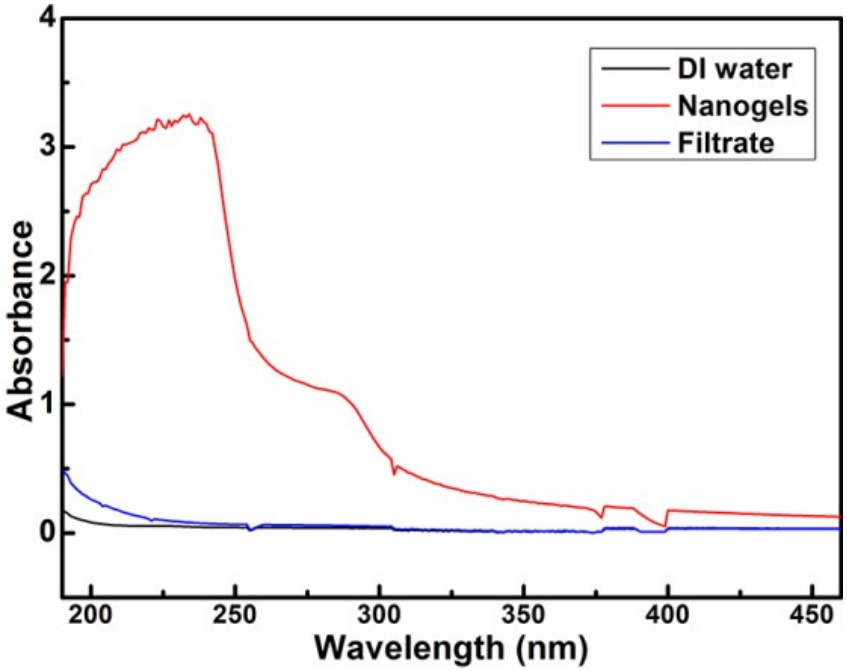

Figure S3. The UV-Vis spectra for PEGMA-MAA nanogels solutions and filtrates from the nanogels blended membrane (M-6).