Hemocompatibility Enhancement of Silicon Nanopore Membranes (SNM) using Optimized Deposition of Thin-Film Poly(Sulfobetaine Methacrylate) (pSBMA)

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Background:

The precision geometry and manufacturability of SNM is fundamentally enabling for the development of an implantable bioartificial kidney. To enhance long-term hemocompatibility, we optimized the deposition of sub-5nm thick pSBMA, a zwitterionic polymer to provide an anti-thrombogenic non-pore-occluding surface coating on SNM. This work details the optimization parameters for pSBMA deposition and presents hemocompatibility results under static and flow conditions.

Methods:

By varying the starting reagent concentrations, 2,2'-bipyridyl (BPY) and copper (II) bromide ($CuBr_2$) from 0 to 0.3 M, and 0 to 0.4 M, respectively, and polymerization time (PT) from 10 to 60 min, we optimized for sub-5 nm pSBMA coating and minimal protein adsorption (fibrinogen and albumin). Coating thickness was determined by ellipsometry. Hydraulic permeability was measured for SNMs before and after coating. Fibrinogen adsorption was determined by enzyme-linked immunosorbent assays after 2 hour incubation and FITC-labeled bovine serum albumin adsorption was examined by fluorescent microscopy after 1 hour incubation. pSBMA-coated silicon (Si) was compared to bare-Si after 2 hour fresh heparinized human blood flow (20 ml/min and 73.3/s wall shear rate). Platelet activation (CD62) (immunohistochemistry) and cell attachment (scanning electron microscopy) on surface were analyzed.

Results:

The optimized protocol (0.3 M BPY and 0.01 M $CuBr_2$ with 15 min PT) produces a ~4.6 nm thin-film pSBMA coating that significantly reduced protein adsorption compared to bare-Si. For static conditions and relative to bare-Si, albumin adsorption was reduced by 52%, while fibrinogen adsorption was reduced by 64%. Under flow conditions, there was a qualitative decrease in both platelet activation and cell adhesion. This study shows that pSBMA performance can enhance SNM hemocompatibility in both static protein solutions and under blood flow conditions.

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