Asymmetric Cellulose Acetate Dialysis Membranes: Synthesis, Characterization, and Performance

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ABSTRACT: Cellulose acetate (CA) is highly comparable to other synthetic polymer materials and is effective in the hemodialysis process. In this work, asymmetric CA membranes were synthesized with the phase-inversion method. CA with a molecular weight of 52,000, poly(ethylene glycol) (PEG) with a molecular weight of 400, and 1-methyl-2-pyrrolidone (NMP) were used as the polymer, additive, and solvent, respectively. The effects of the CA and PEG concentrations and coagulation bath temperature (CBT) on the morphology, pure water permeability (PWP), insulin/human serum albumin (HSA) transmission, and finally thermal and chemical stability of the prepared membranes were determined and investigated. In general, increasing the PEG concentration and CBT and reducing the CA concentration resulted in increased PWP and insulin/HSA transmission. Also, these variations facilitated the formation of macrovoids in the membrane sublayer. On the other hand, increasing the PEG and CA concentrations and reducing CBT resulted in increased thermal and chemical stability of the prepared membranes. Also, ratios of 15.5/10/74.5 and 17.5/10/72.5 (w/w) for the CA/PEG/NMP casting solutions and their immersion into coagulation baths with CBTs of 0 and 25°C, respectively, resulted in the preparation of membranes that had not only optimum sieving properties and higher PWP but also thermal and chemical stability better than that of conventional CA hemodialysis membranes. J Appl Polym Sci 116: 2251–2259, 2010

Key words: membranes; phase separation; dialysis

INTRODUCTION

With the advent of membrane technology, separation, concentration, and purification have become industrially viable unit operations because of the high separation efficiency, low energy use of the operation, spatial requirements, simplicity of the operation with modern compact modules, and so forth.[1] During the past century, medical applications of membranes have been developed along with industrial applications. W. J. Kolf demonstrated the first successful artificial kidney in the Netherlands in 1945. It took almost 20 years to refine the technology for use on a large scale, but these developments were completed by the early 1960s. Since then, the use of membranes in artificial organs has become a major life-saving procedure. Nowadays, more than 800,000 people are sustained by artificial kidneys.[2,3] The total world sales of dialysis membranes in 1994 have been estimated at $1400 million (US dollars), and they account for about 40% of the total predicted membrane sales (worth $4000 million). Until the year 2000, hemodialysis treatment cost around $140, and this promised about $20,000 of profit per year per patient.[4]

Various polymers have been used for the preparation of hemodialysis membranes. Basically, these polymeric materials should have the following:

1. Excellent biocompatibility, which is equivalent to low platelet adhesion,[5] low clot formation, which results in a reduction of the dosage of the anticoagulant required during hemodialysis,[7,8] low activation of leukocytes,[2,5,6] more protection for patients against oxidative stress,[8] and a high blocking efficiency versus harmful substances contained in the dialysate.[9,10]
2. Low cost.
3. Fiber-spinning ability.
4. Appropriate morphology.[4,11]

Also, the membranes should have appropriate sieving properties. In other words, hemodialysis membranes should facilitate the passage of uremic toxins of low and moderate molecular weights (MWs) such as urea [weight-average molecular weight (M_w) = 60 g/mol], uric acid, creatinine (M_w = 130 g/mol), insulin (M_w = 5700 g/mol), and β_2-microglobulin (M_w = 11,800 g/mol) and simultaneously reject proteins such as human serum albumin (HSA; M_w = 66,000 g/mol) and bigger particles.[12,13]

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