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Fabrication of Polyphenylsulfone Nanocomposite Membranes with SiO_2 Nanoparticles Used in Pharmaceutical Industry

KAMEL EARAR[1], AURELIANA CARAIANE[2]*, ADRIAN BEZNEA[1], ALINA MIHAELA CALIN[1], NICOLAE SARBU[1], ION CIUCA[3], CARMEN TIUTIUCA[1]*, ALINA - RAMONA DIMOFTE[1], MAGDA ECATERINA ANTOHE[4], GABI TOPOR[1]
[1]Dunarea de Jos University of Galati, Faculty of Medicine and Pharmacy, 35 Al. I. Cuza Str., 800010, Galati, Romania
[2]Ovidius University of Contanta, Faculty of Dental Medicine, 7 Ilarie Voronca Str., 900178, Constanta, Romania
[3]University Politehnica of Bucharest, Materials Science and Engineering Faculty, 313 Splaiul Independentei, 060042, Bucharest, Romania
[4]Grigore T. Popa University of Medicine and Pharmacy, Faculty of Dental Medicine, 16 Universitatii Str., 700115, Iasi, Romania

Abstract: *SiO_2 nanoparticle were used in aPolyphenylsulfone (PPSU) matrix to obtain nanofiltration membranes used in the pharmaceutical sector to remove pollutants from the water processes. In this study was investigated the influence of SiO_2 nanoparticles on the PPSU membranes performance at different concentration of polymer and at six different concentrations of SiO_2. Adding SiO_2 like additive in the PPSU membrane matrix, the permeability increases due to the higher porosity. Increasing the polymer concentration, the pores are smaller and the permeation properties are decreasing. The affinity for water of membrane surface is higher when nanoparticles are added in the polymer matrix. Adding 0.3 wt.% SiO_2 the permeation properties are increasing with more than 10% in comparison with membranes without nanoparticles.*

Keywords: *membranes, SiO_2 nanoparticles, pharmaceutical*

1. Introduction

In the pharmaceutical industry water is used for a variety of processes like washing of solid cake, extraction of different substances or to wash the equipment. The waste water from the pharmaceutical and drugs industry has a wide variety of pollutants which are very dangerous for humans and environment. The treatment of pharmaceutical waste water is realized from many methods, from aeration, flocculation-coagulation, biological degradation to the filtration process. In the filtration processes the most use technique is nanofiltration due to the low pressure needed and high rejection rate. The main problem in the filtration processes in general are the membrane properties in view of life cycle, permeability and rejection capacity. In view to improve the membranes properties many studies were made to establish the optimal condition of fabrication [1-5], the polymer [6-9] and the additive influence [10-14]. In general, researches are focused on the use of nanoparticles like additive in the membrane structure, or on the membrane surface. The optimum nanoparticles concentration is challenge due to the variety of the nanoparticles type, size and concentration [15-18]. In this paper, SiO_2 nanoparticles were used in a PPSU matrix membrane at different concentration. The influence of the SiO_2 nanoparticles on the membrane properties [19-22] is less studied in comparison with others type on nanoparticles. Was studied the influence of the polymer and nanoparticles concentration on the permeation properties.

2. Materials and methods

2.1. Materials

Polyphenylsulfone (Figure 1) is a high performance polymer with a good chemical and heat resistance used for different application like automotive, aerospace but and for membranes used in waste water treatment.

**email: drcaraiane@yahoo.com; tiutiuca_carmen@yahoo.com*

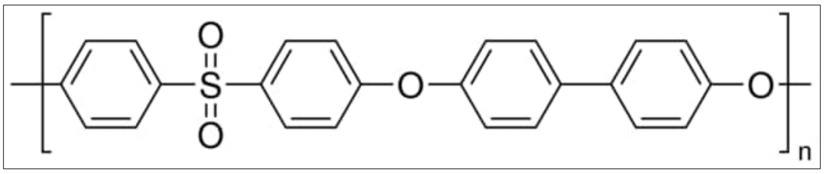

Figure 1. Polyphenylsulfone

SiO_2 nanoparticles are used on a large scale in biomedical research due to their stability and low toxicity. SiO_2 nanoparticles have a density of 2.4 g/cm^3 and a molar mass of 59.96 g/mol.

2.2. Preparation of nanocomposite membrane

Membranes were obtained by immersion precipitation method (Figure 2).

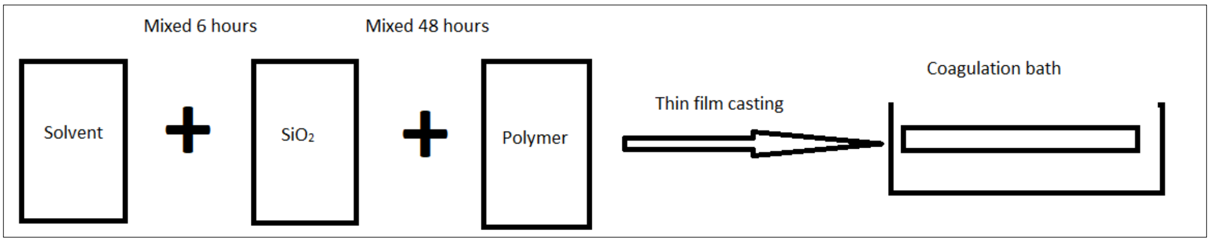

Figure 2. Membranes preparation

SiO_2 nanoparticles were added in the solvent and mixed for 6h. The polymer was gradually added and mixed for 4h. Resulted composite solution was casted on a support layer and immersed in deionized water.

All the membranes were obtained by adding nanoparticles in the solvent and mixed for 4hat room temperature. The polymer was added gradually and mixed for 24h to obtain a homogeneous solution.

3. Results and discussions

3.1. Permeability

In Figure 3 in presented the permeability evolution at different concentration of PPSU.

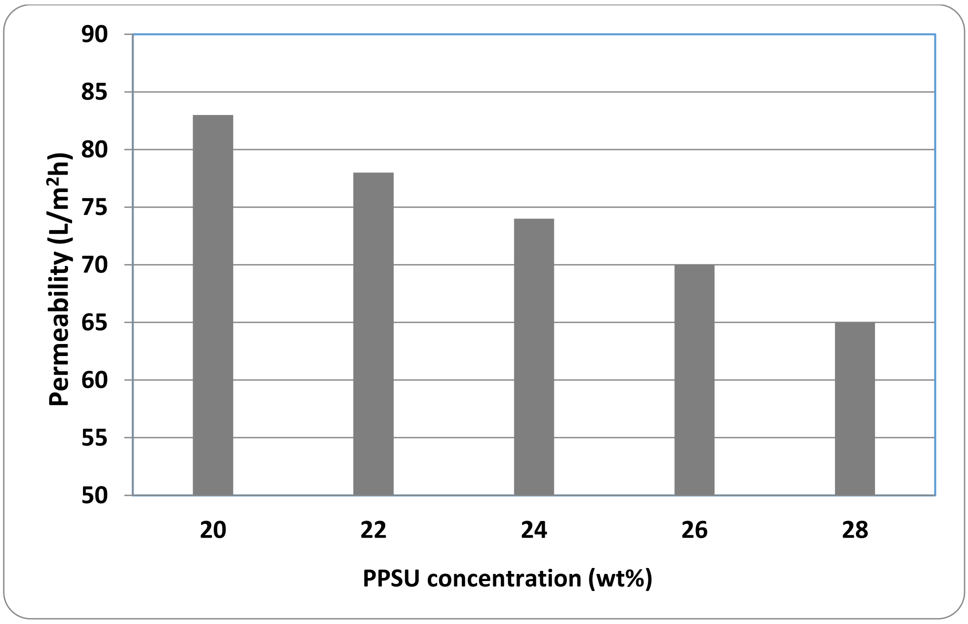

Figure 3. Permeability at different PPSU concentration

Increasing the polymer concentration, the porosity and the pore size are decreasing. Increasing the polymer concentration from 20 wt.% to 28 wt.% the permeability decrease with more than 13%, from 83 L/m^{2}h to 65 L/m^{2}h. Adding nanoparticles in the membrane with 20 wt.% polymer (Figure 4) the permeability increases even at small concentration of SiO_2. This aspect show that the nanoparticles increase the porosity of membranes without increasing and the pore size.

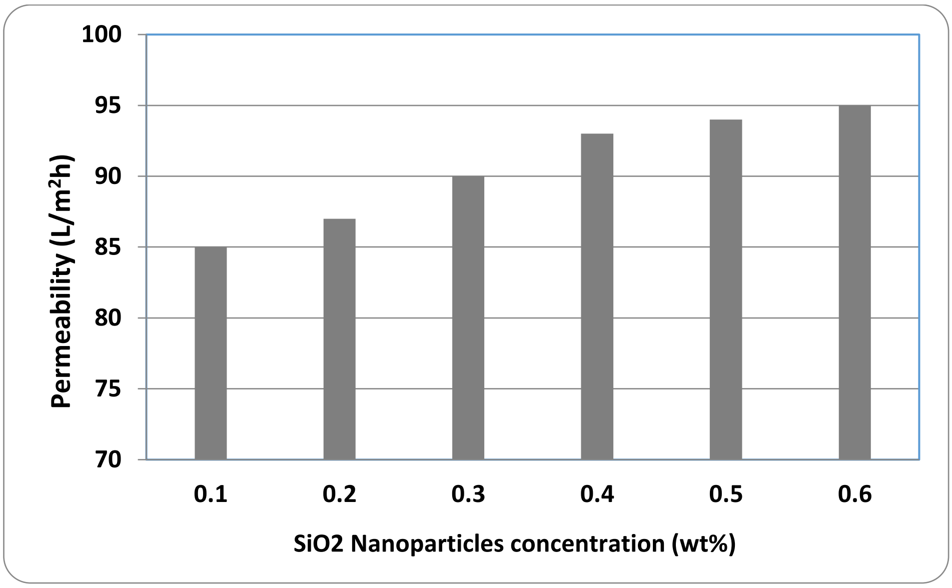

Figure 4. Pure water permeability of 20% PPSU membranes at different SiO_2 concentration

Adding 0.1 wt.% SiO_2 nanoparticles the permeability increase from 83 to 85 L/m^{2}h. For higher SiO_2 nanoparticles concentration the permeability is increasing more, reaching 95 L/m^{2}h for membranes with 0.6 SiO_2 concentration. The nanoparticles concentration has an important influence on the permeation properties, due to the modification of membrane structures. Increasing the concentration the porosity is higher and the permeation properties are increasing.

Adding 0.3 wt.% SiO_2 nanoparticles (Figure 5) the permeability is improved for every polymer concentration.

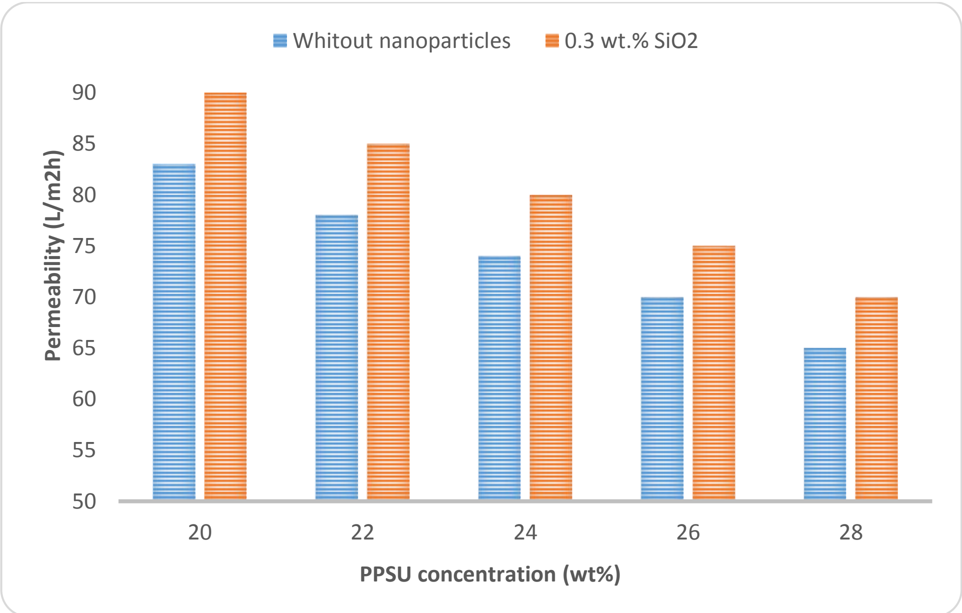

Figure 5. Permeability at different PPSU concentration and 0.3 wt% SiO_2

In Figure 5 is presented the influence of 0.3 wt.% SiO_2, which improve with more than 10% permeability for all types of membranes, showing that the influence of nanoparticles is the same regardless of the polymer concentration.

3.2. Pure water flux

To establish the permeation properties, all the membranes were tested at different pressure (Figure 6) for 50 mL of water, and at a constat pressure (Figure 7) for 300 mL of water.

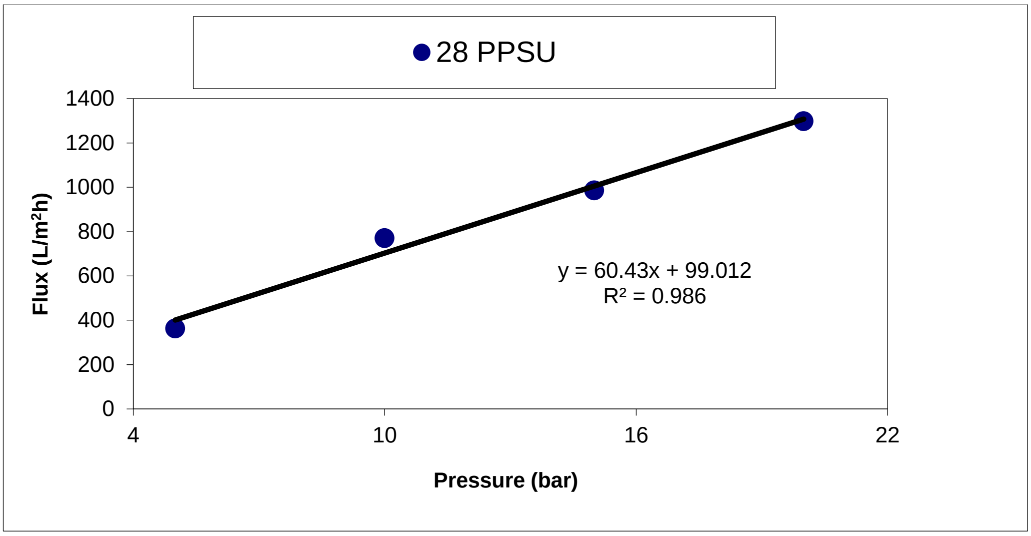

Figure 6. Flux for membranes at 28 wt% PPSU

In Figure 6 is presented the water flux for a membrane with a 28 wt.% PPSU without nanoparticles, at pressures between 6 and 20 bars.

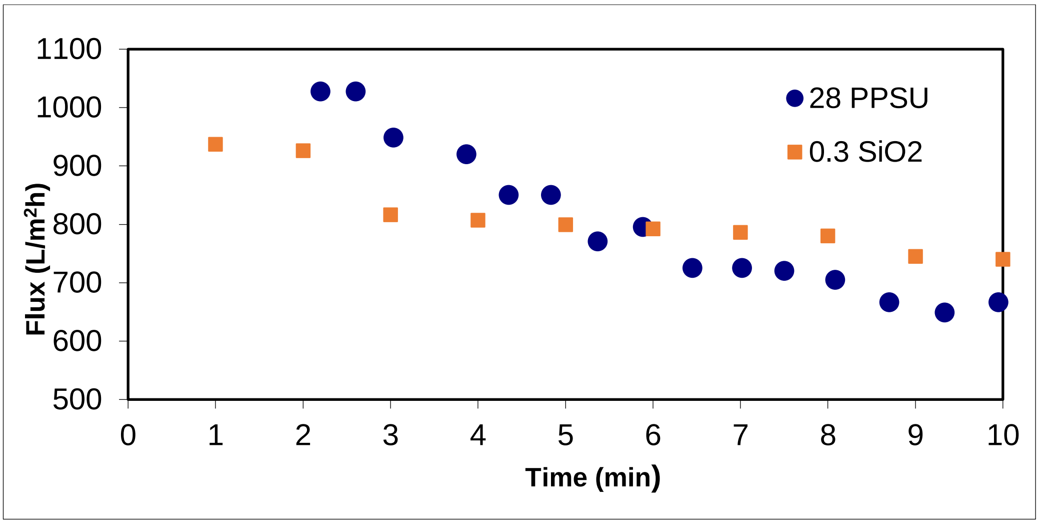

Figure 7. Flux for membranes at 28 wt% PPSU with 0.3wt% SiO_2

In Figure 7 is presented the comparison between water flux of a membrane with 28 wt.% PPSU without nanoparticles and one with 0.3 wt.% SiO_2 nanoparticles. Adding nanoparticles, the membrane stability is increasing and the water flux, after the membrane compaction, is higher. This effect of nanoparticles on membranes properties is due to the reducing the macropores which give more stability and reduce the precompactation value. In the same time, increasing the porosity the permeation is higher after precompactation period.

3.3. Hydrophilicity

The membrane surface affinity for water is increasing by adding nanoparticles.

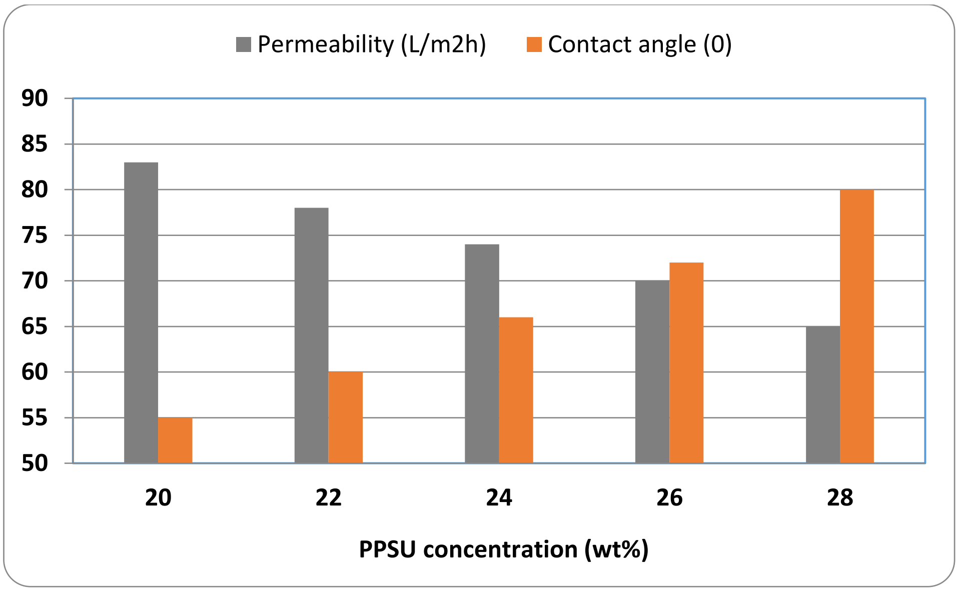

Figure 8. Permeability versus contact angle for membranes at different concentration of PPSU

In Figure 8 is presented the comparison between evolution of permeability and contact angle for membranes at different concentration of polymer. Increasing the polymer concentration permeability is decreasing and the contact angle is increasing.

Adding nanoparticles the affinity for water is increasing for every type of membrane.

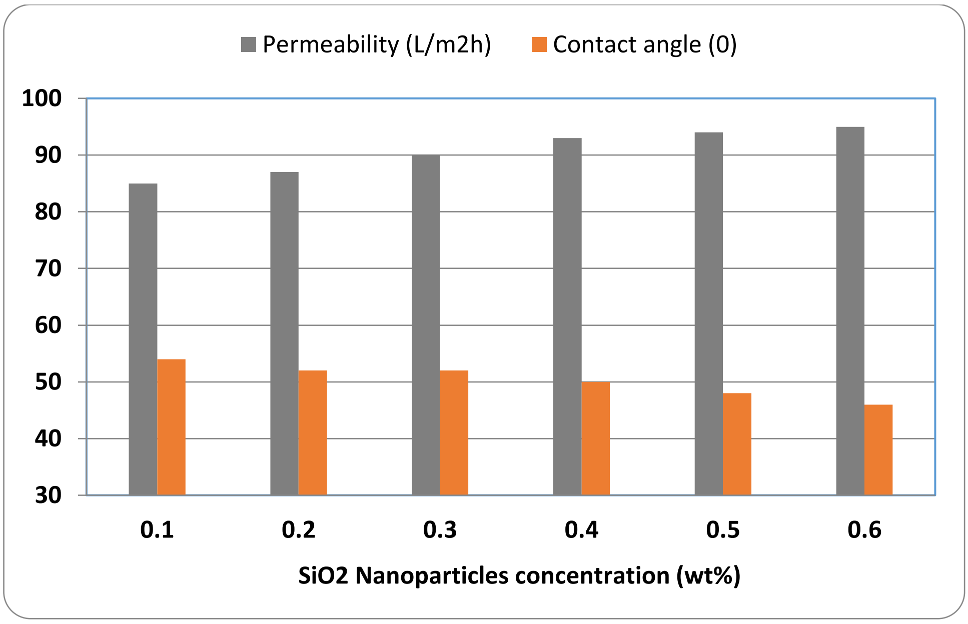

Figure 9. Permeability versus contact angle for membranes at different concentration of SiO_2

In Figure 9 is presented the evolution of permeability for different concentration of nanoparticles and the contact angle for every type of membranes. Increasing the SiO_2 concentration the contact angle is decreasing due to the surface modification of membranes and the permeability is increasing.

4. Conclusions

In this study the influence of PSSU concentration on the permeation properties was studied. Increasing the polymer concentration the permeability and the water flux is decreasing and this effect in general leads to a better rejection capacity but with mor pressure needed. Adding SiO_2 nanoparticles the permeation properties and the membrane surface affinity for water are increasing. The concentration of nanoparticles have an important impact on the membrane permeability, increasing the SiO_2 concentration from 0.1 to 0.6 wt.%, the permeability is increasing. This effect is due to the membrane structures which is changed when nanoparticles are added. The porosity of membranes increase when nanoparticles are added in the polymeric structure and the pores are uniformly distributed.

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