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Influence of the Electric Potential Applied on Hollow Fiber (HF) Membrane and Surface Morphology

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Abstract*: *The present work is focused on the study of the effect of electric field on HF membrane surface morphology in acidic medium and comparing it with alkaline results. Two different dimensions of HF polysulfone (PS) membranes were used. Membranes (A) and (B) have the same composition and different dimensions. Membrane (A) dimensions, including outside diameter (Do), inside diameter (Di) and wall thickness (t), are 356, 172, & 92 µm respectively, and membrane (B) dimensions are 409, 223, and 93 µm. HF membranes were treated electrochemically at different electric potential range from 2 to 10 V in both mediums. The results showed that the HE membrane dimensions are highly influenced by applied electric potential in both mediums. SEM analysis confirmed the contraction and expansion of HF thickness according to the value of potential applied (2 -10 V). Maximum decrease of all dimensions DO, DI and thickness were 10%, 13%, and 5% respectively in the acidic medium when compared with the alkaline medium which showed a decreasing about 13%, 15%, and 11%, respectively obtained at 5-volt treatment.

Keywords*: *Hollow fiber membrane, electric potential, morphology, acidic and alkaline medium

I. INTRODUCTION

Normally, HF membranes are fabricated by wet spinning techniques followed by a series of physical and chemical post-treatment. Physical methods for tuning of membrane porosity and mechanical properties deserve special attention due to simplicity, quick processing time and cost performance [1-8]. Physical post-treatment method generally includes, but not limited to, heat treatment, microwave intervention, UV, ultrasonic and recently electrochemical methods [9-16]. The latter deserves wide attention and excessive special endeavors due to low cost in addition to its frequency characteristics.

In the previous work, we presented the findings of the effect of electric potential on HF membrane morphology and composition [17]. These findings enable tuning of the fiber morphology using electric current with a specific limit concluded at our earlier investigations. In this work, we extend our work to the effect of moderate electric potential on HF morphology at acidic conditions. The objective is to explore the differences at different pH conditions and enable a higher level of the precise according to the intended application.

II. MATERIALS AND METHOD

A. Materials

Two different dimensions of HF polysulfone (PS) membranes and the same compositions were used. Membrane (A) dimensions, including outside diameter, inside diameter and wall thickness, are 356, 172, & 92 µm respectively, and membrane (B) dimensions are 409, 223, and 93 µm. Sodium acetate (anhydrous, 99% assay) and acetic acid glacial (99.7% assay) were bought from (Alpha chemika, India).

B. Treatment method

HF membranes were treated electrochemically in an electrochemical cell at different electric potential range from 2 to 10 V and one-hour treatment. The electrochemical cell contains; two electrodes of stainless steel and graphite materials and electrolytic solution with 0.1 M. Two mediums were used the wherein alkaline medium at pH =3.5 and alkaline medium in pH=8.5. Time variation from 15 to 60 minutes also studied at 5 V in alkaline medium and 10 V in acidic medium.

III. CHARACTERIZATION OF HF MEMBRANE

Scanning electron microscopy (SEM) equipment

HF membranes structure details were investigated using (JEOL JCM-6000 apparatus).

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The inner, outer diameters and thickness of membranes were examined by cutting HF membranes to cross-sectional samples using a sharp blade and exposed to sputter device for 0.5 min to coat the samples with golden layer and fixed with a paper clip and put inside the stage holder.

IV. RESULT AND DISCUSSION

A. Effect of electric field on HF membrane morphology in alkaline medium

Scanning electron microscope (SEM) images show that with increase current and the potential voltage applied more than 2.5 volts, more cracks are formed on the membrane surface. Cracks formation probably due to the aggressive attack of ions towards the sensitive surface of HF membrane leads to the distortion and cracking of the surface. Mobility and movement of ions on electrolyte solution increased with increasing electric current and voltage applied. Deformation of surface and cracks were obviously observed in 10 V of electric potential. Membrane contraction in all dimensions observed in 5 V of electrochemical treatment for both membrane types A and B as described before [17].

Effect of time on membrane surface has been studied. SEM images of membrane treatment at 5 V in the alkaline medium for 15, 30, 45, 60 min showed that cracks and deformation began to be formed after 15 min on the membrane surface. So, cracking and deformation of the surface is electric potential dependent. 15 min treatment showed no cracking.

Fig. (1) shows the effect of time on the membrane outer surface in using electric potential 5 V.

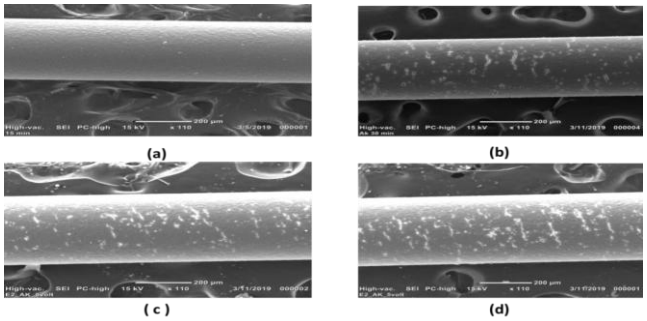
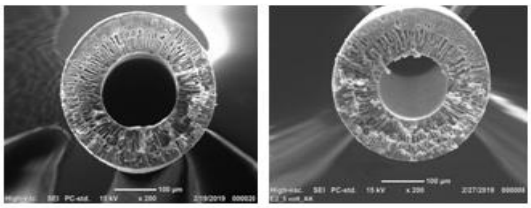


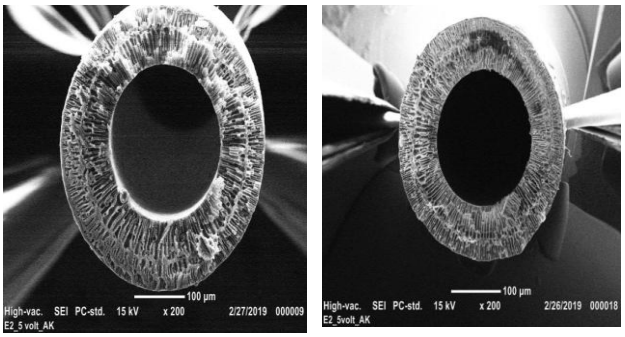
Fig. 1: Time effect on the membrane outer surface in 5 volt treatment in alkaline medium(a) 15, (b) 30, (c) 45, and (d) 60 min

Comparison of Average dimensions of raw (A) and raw (B) untreated and treated at 5 V from SEM data as shown in Figure (2) and (3).



Raw (A)	Electric potential (5 V)
DO=356µm	DO=343µm
DI=172µm	DI=164µm
t= 92µm	t= 90µm

Fig. 2: Comparison of average dimensions of (a) untreated membrane, and (b) Electric potential 5 V in alkaline medium.



Raw (B)	Electric potential (5V)
DO=409µm	DO=356µm
DI=223µm	DI=190µm
t= 93µm	t= 83µm

Fig. 3: Comparison of average dimensions of (a) untreated membrane raw (B) and (b) Electric potential 5 V in alkaline medium

B. Effect of electric field on HF membrane morphology in acidic medium

Like SEM images in alkaline medium, cracks were appeared on the HF membrane surface with increasing of current and voltage applied above 2.5 V in an acidic medium at pH=3.5 and for duration time 1 h. Deformation and cracks have begun to have appeared at 5 V and greatly appeared at 10 V with increasing of current; more ionization of sodium acetate occurred and movement of ions increased. Figure (4) shows the cracks formed on the HF membrane surface at different voltage applied in acidic medium.

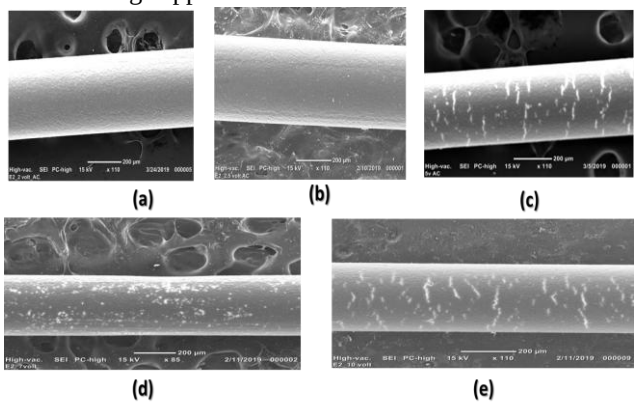


Fig. 4: Electrically treated membrane surface at different voltage in acidic medium pH=3.5 (a) 2 V(b) 2.5 V(c) 5 V(d) 7.5 V and (e) 10 V

Effect of time on membrane surface has been studied. SEM images of membrane treatment at 10 V in an acidic medium for 15, 30, 45, 60 min showed that cracks and deformation began to be formed after 15 min on the membrane surface.

SEM results in an acidic medium are compatible with results of alkaline medium treatment Figure (5) shows the time effect on the membrane outer surface in 10-volt treatment in acidic medium.

Also, cracking and deformation were instantiated that it depends mainly on applied electric potential, regardless of pH of the medium and the time.

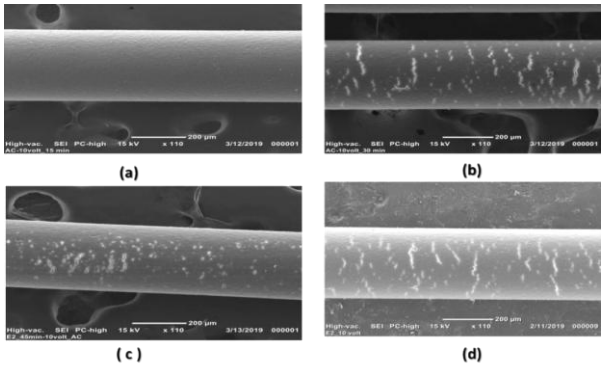


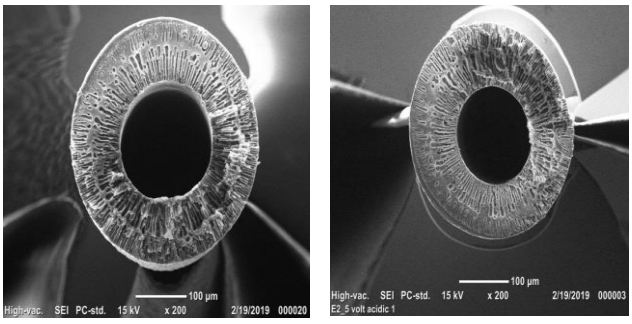
Fig. 5: Time effect on the membrane outer surface in 10 volt treatment in acidic medium (a) 15, (b) 30, (c) 45, and (d) 60 min

SEM imaged showed that electric field forces could change membrane dimensions (Do, DI, and thickness). Table (I) shows the percentage change of dimensions of raw (A) and raw (B) membranes after treatment in the acidic medium at different voltages. Membrane contraction in all dimensions observed in 5 V of electrochemical treatment for both membrane types.

Table I: Percentage change of dimensions in membranes A and B after treatment in acidic medium

Percentage change of dimensions			
Electric potential (V)	**Δ DO (%)**	**Δ DI (%)**	**Δ t (%)**
Membrane raw A			
2	-3	-1	-4
2.5	-3	3	-9
5	-4	-7	-1
7.5	-2	-3	0
10	-2	-3	-1
Membrane raw B			
2	-5	-4	-6
2.5	-11	-13	10
5	-10	-13	-5
7.5	-7	-10	-3
10	-7	-6	-9

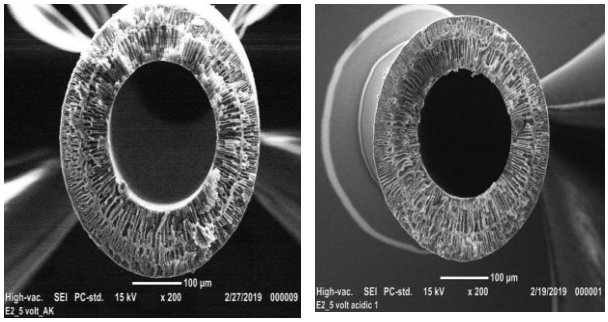
Comparison of average dimensions of membranes (A) and (B) untreated and treated at 5 V from SEM data as shown in Figure (6) and (7).



Raw (A)
DO=356µm
DI=172µm
t= 92µm

Electric potential (5 V)
DO=341µm
DI=160µm
t= 91µm

Fig. 6: Comparison of average dimensions of (a) untreated membrane raw (A), and (b) Electric potential 5 V treated.



Raw (B)
DO=409µm
DI=223µm
t= 93µm

Electric potential (5 V)
DO=370µm
DI=195µm
t= 88µm

Fig. 7: Comparison of average dimensions of (a) untreated membrane raw (B), and (b) 5Vtreatment

V. CONCLUSION

This work focused on the electrochemical treatment impacts on Polysulfone (PS) HF membrane surface morphology. This study was carried out in both acidic medium and alkaline medium. The results indicated the ability of the electric field to change the membrane surface morphology, where the membrane dimensions can be compacted or expanded as confirmed by SEM analysis in both mediums. Maximum decrease of all dimensions DO, DI and thickness were 10%, 13%, and 5%, respectively in acidic medium while, the alkaline medium showed decreasing 13%, 15%, and 11%, respectively obtained at 5-volt treatment. Although, the electric potential has a positive effect on the activation of HE membrane surface, it may cause cracks on the membrane surface over than 2.5 V.

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Nourhan A. Shawky is currently working at National Research Centre as a research assistant in chemical engineering department. Her research interests include hollow fiber (HF) preparation, characterization and data simulation. She was graduated as engineer and she is preparing for M.Sc. thesis in chemical and petrochemical engineering at Suez University. In addition she is currently working in (HF) project in National Research Centre.