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Fabrication of a Clay Microfiltration Membrane for Air Filtration

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ABSTRACT

In this study, ceramic membranes designed for bacteria removal through filtration have been fabricated using ceramic materials. These membranes consist of a macro-porous support and a thin separation layer. Tubular and flat supports were prepared from quartz sand and calcite using extrusion and roll pressing methods, respectively. The slip casting technique was employed to deposit the clay layer onto these supports. Comprehensive analyses of morphology, microstructures, pore characteristics, and permeability were carried out. The study included an examination of morphology, microstructures, pore characteristics, and permeability. The experimental results indicate that the total porosity and average pore size of the porous ceramic supports, when sintered at 1150°C, are approximately 53% and 5μm, respectively. As for the clay layer, after firing at 580°C, it exhibited a thickness of approximately 50 μm, and the water permeability was estimated to be around 1050 L/h·m²·bar. Finally, the optimized membranes were tested for air sterilization. The filtration results demonstrate the efficiency of the clay-deposited membranes in removing bacteria, resulting in the air being completely free of microorganisms.

Keywords: Ceramic; Membrane; Filtration; Bacteria removal; Clay

1 Introduction

Membrane separation is a versatile technique that uses selectively permeable barriers to separate components in a mixture based on differences in size, charge, or molecular properties. These membranes are crucial for air and water sterilization, effectively preventing the transmission of harmful microorganisms and contaminants. In air purification systems, membranes trap and remove airborne pathogens, allergens, and pollutants, making them indispensable in fields like microbiology, pharmacy, and medicine. For instance, in microbiology labs, sterile air prevents contamination of cultures, experiments, and delicate equipment, safeguarding research and diagnostic procedures' integrity. This approach is advantageous because it ensures a clean, pathogen-free atmosphere without using harsh chemicals or high temperatures that might harm sensitive equipment and samples [1, 2]. Moreover, these membranes can be fabricated from a wide range of materials, including polymers, ceramics, and metals, and they are available in various shapes and configurations. The utilization of ceramic membranes offers numerous advantages, such as exceptional thermal and chemical stability, resistance to high pressure, long service life, and effective fouling resistance [3]. In this study, we crafted ceramic membranes tailored for both air and water filtration, using raw ceramic materials. These membranes consist of a macro-porous support and a separation layer.

2 Experimental procedures

2.1 Supports preparation

Supports were prepared by blending quartz sand and calcite powders in a weight ratio of 75:25, with methylcellulose serving as a binder. Tubular configurations were fashioned using the extrusion method, while flat configurations were prepared through roll pressing. Following room temperature drying, the supports underwent sintering at 1150°C for 1 hour.

2.2 Membranes preparation

The slip casting method was employed to prepare the clay layer. The slip was derived by blending 15 wt% clay powder, 30 wt% aqueous solution of hydroxyethyl cellulose, and 55 wt% distilled water. Subsequently, it was applied onto the support using the slip casting technique. The deposition process took approximately

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2 minutes. Following that, the membrane underwent room temperature drying before being sintered at 580°C for 1 hour.

3 Results and discussion

Ceramic supports must possess a high porosity ratio, a narrow pore size range, and greater mechanical strength. Additionally, they should exhibit high performance in treating the chemical nature of filtered water. The regularity of the porous texture in the prepared supports is achieved through the dissociation of calcium carbonate into CaO and CO_2 gas under sintering conditions. The path taken by the released CO_2 gas creates the porous texture of the ceramic membrane, contributing to membrane porosity during the sintering process. The pore size distribution curve of the specimen sintered at 1150°C is depicted in Fig. 1a. As evident from the figure, the majority of pores had a diameter smaller than 10 µm, ranging from 2 to 10 µm, with an average pore size of about 5 µm. Furthermore, the pore size distribution of the membrane supports shows a single (mono) modal distribution, as illustrated in Fig.1a. This clearly indicates that the samples have a uniform pore size distribution. The water flow in the multilayer system is typically measured, and the results are presented as a function of time and mean applied pressure, as depicted in Fig. 1b. As anticipated, the water flux increases with higher applied pressure, and a stable flux is achieved after a few minutes. The average water permeability is approximately 1050l.h^{-1}.m^{-2}.bar^{-1}.

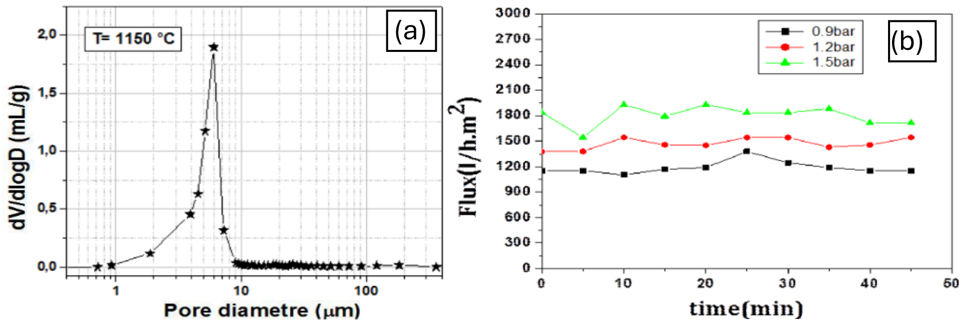

Figure1: a) Pore size distribution of membrane support sintered at 1150°C.
b) Distilled water flux versus time, at 3 working pressures, for ceramic membrane.

4 Conclusions

This study focuses on fabricating multilayer ceramic membranes. The top layer, composed of clay, was prepared using the slip casting technique, while tubular supports were created through the extrusion method. Optimal support performance is achieved at a firing temperature of approximately 1150 °C. Under these conditions, crucial parameters such as porosity ratio, average pore size, flexural strength, and permeability show favorable values, measuring around 53%, 5 µm, 20 MPa, and 4000 lh^{-1}m^{-2}bar^{-1}, respectively. Furthermore, filtration results demonstrate the effectiveness of clay-deposited membranes in removing bacteria, ensuring that the air remains entirely free of microorganisms. This signifies a significant advancement in the application of these membranes for enhancing air quality.

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