DEVELOPMENT OF CERAMIC MEMBRANE FOR WASTEWATER FILTRATION

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Abstract - Ceramic membrane receive great attention recently due to high porosity, high chemical, thermal and mechanical stability which able to operate at extreme operating conditions. The aim of this study is to produce multilayer ceramic membrane (MLCM) and investigate the effect of titanium dioxide (TiO_2) concentration to the properties of membrane and filtration ability under gravity flow. Porous ceramic support was prepared using polymeric sponge technique, while aluminum oxide (Al_2O_3) intermediate layer and TiO_2top layer was prepare by dip coating technique. Different concentration of TiO_2 was used ranging from 5 wt. % to 20 wt. % in the preparation of top layer. Samples were sintered at 1000°C to produce MLCM. The properties of MLCM such as density and porosity were determine by using Archimedes Principle, while morphology was observed using Scanning Electron Microscope (SEM). The efficiency of MLCM was tested using filtration test. It shows that the density of porous ceramics increase with the increasing of the concentration of TiO_2 and inversely proportional with the porosity. Filtration process shows clearer effluent was produced with increasing concentration of TiO_2. The best concentration of TiO_2 was 20 wt.% which produced good quality of effluent after the filtration process.

Keywords - Porous ceramic, Multilayerceramic membrane, Filtration, Titanium dioxide

I. INTRODUCTION

Wastewater treatment become more complicated recently due to multiple type of pollutant discharge to water mainstreams. Beside conventional wastewater treatment plant, membrane technology become an alternative choice to treat this kind of wastewater. Ceramic membranes receive great attention over polymeric membrane due to high chemical, thermal and mechanical stability which able to operate at extreme operating conditions [1,2]. Other than that, ceramic membrane display several advantages including it is easy in controlling the pore size, higher durability and efficiency. The effectiveness of the membrane is influenced by its structural properties for separation during the filtration process and it can be controlled during the fabrication of the membrane. The surface of the membrane which in contact with the fluid has an active layer which determine the porosity of the membrane. The active layer is full of holes from different diameters in order to allow the desired molecules to pass through the membrane. Various technique was reported used in preparation of porous ceramic support such as polymeric sponge method, pore forming agent, foaming agent[3-5]. Among them are, polymer replication method which produce high porosity, high pore connectivity and greater pore size of porous ceramic [6]. Ceramic membrane can be prepared in single or multiple layers depend on the applications. In multilayers ceramic membrane (MLCM), porous support normally used to improve performance of membrane due to its excellence mechanical and chemical properties. There are various type of ceramic materials has been employed as ceramic membrane such as alumina (Al_2O_3), zirconia (ZrO_2), titanium dioxide (TiO_2) and silicon dioxide (SiO_2)[7-9].Titanium dioxide normally used as top layer due to its photocatalytic activity, chemical stability and high water flux [10]. Photocatalytic degradation is important in removing the organic pollutant, the efficiency of purification of water membrane can be increased by coupling the separation process with photocatalytic activity.In this study multilayer ceramic membrane (MLCM) will be produce using porous ceramic support, alumina interlayer and TiO_2as a top layer. The effect of titanium dioxide (TiO_2) concentration to the properties of membrane and filtration ability under gravity flow will be investigated.

II. EXPERIMENTAL

2.1 Preparation of porous ceramic support

Porous ceramic support was prepared using polymer sponge replication method as describe in our previous paper [11]. Polymeric sponge was cut into desire size and porcelain slurry was prepared at 50% solid content using deionized water media. Polymeric sponge were immersed in the slurry, the squeeze until there are no bubbles formations was observed. Impregnated porcelain slurry in polymer sponge then dried on a flat wood board. Sample were flipped twice daily to get a homogenous drying on both sided. Sample than left at room temperature for a two day before dry in oven at 100 °C for one day before sintered at 1000 °C in a furnace to produce porous ceramic support. The heating rate was fixed at 5 °C /min with two hours.

2.2 Preparation of intermediate layer

Aluminium oxide (Al_2O_3) was used as intermediate layer. 30% solid content of alumina slurry was prepared by adding 30g of Al_2O_3 into 70ml of solution

containing binder and dispersant and mixed thoroughly using mechanical stirrer to form a slurry. Porous ceramic support then dip in alumina slurry for 1 minute and left at room temperature for one day for drying. Sample then sinter again at 1000°C to produced solid alumina layer on top of porous support.

2.3 Preparation of Multi-layered Ceramic Membrane

In order to complete MLCM structure, titanium dioxide (TiO_2) was used as top layer to produce photocatalytic active layer.TiO_2 powder ranging from 5 to 20 wt.% was mixed with binder and dispersant to form a deflocculated suspension. Again porous ceramic support with alumina layer on the top was dip into titanium dioxide slurry for 1 minute to produce top layer. Sample then dried at room temperature before dry in oven at 100 °C and followed by the sintering process at the temperature of 1000 °C to produce MLCM.

2.1 MLCM characterization

MLCM was characterized using Archimedes Principle to determine the amount of porosity and density while fracture surface of MLCM was observed using SEM. The efficiency of MLCM was tested using filtration test under gravity flow. Artificial wastewater was prepare by adding 20g of porcelain powder into 80ml deionized water and mixed thoroughly using mechanical stirrer to form muddy wastewater. The filtration process was set for 30 minutes, the amount of water filtered as well as clarity of water was observed and compared.

III. RESULTS AND DISCUSSION

3.1 Physical observation

Good MLCM sample which comprise of TiO_2 top layer, Al_2O_3 intermediate layer on porous ceramic support was produced as shown in Fig. 1. No cracks was observed during fabrication and final sample of MLCM after sintering. This is due to lower sintering temperature (1000°C) which prevent the formation of glassy phase on porcelain, and enhanced coating of Al_2O_3 intermediate layer and TiO_2 top layer on to porous ceramic support.

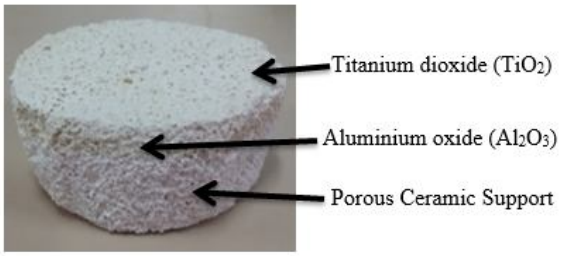


Fig.1. Multilayer ceramic membrane comprise of TiO_2, Al_2O_3 and porous ceramic support

3.2 Density and Porosity of MLCM

Density and porosity of MLCM was determined by using Archimedes principle. Figure 2(a) shows the density of the porous ceramic membrane was increase with increasing theconcentration of titanium dioxide (TiO_2) and vice versa for porosity (Fig. 2(b)). Density was increase from 0.75 to 0.97 g/cm^3 while porosity was decrease from 66 to 56% with increment of TiO_2 from 5 to 20 wt.%. This is due to increment of TiO_2 contents which is produce compact and less pores structure,thus lead to the increasing of density. As density increase, the amount of porosity decrease [11].

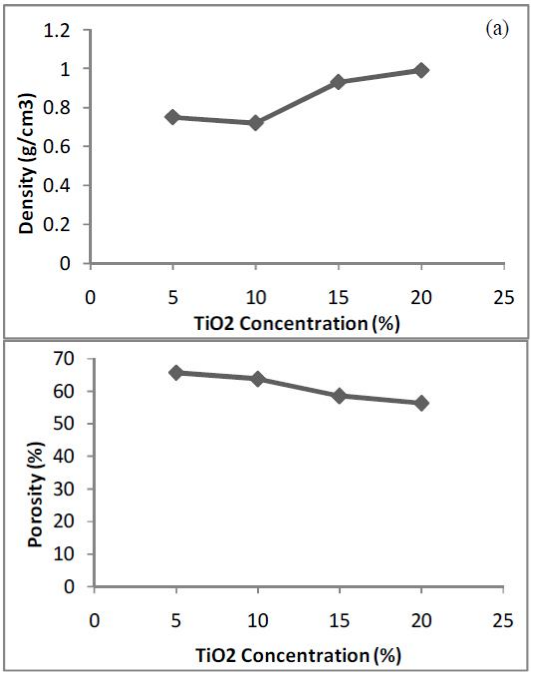
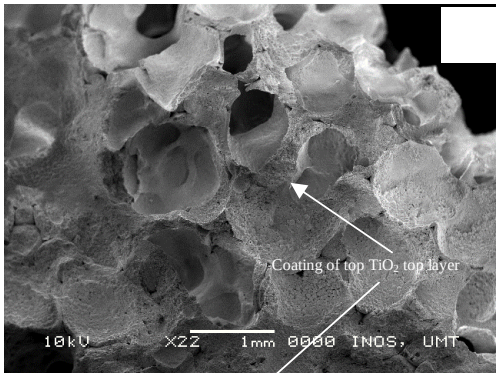
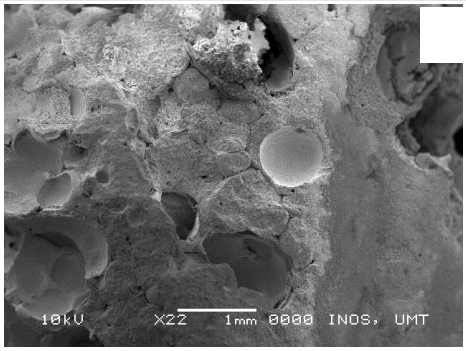


Fig.2. Density (a) and porosity (b) of MLCM

3.3 Morphology of MLCM

Figure 3 (a) shows a fracture surface of MLCM for 5 wt.% and 20 wt.% of TiO_2observed using SEM through magnification of 22x. It is clearly seen that sample with the lowest concentration TiO_2 (5 wt.%) consist of large pores and less compact compared structure compared to higher ones (20 wt.%.). It is clearly seen the coating of TiO_2 increase with increasing the concentration of TiO_2. However, it is very hard to differentiate between the layers of Al_2O_3 and TiO_2 top layer. It was believe that this layers was embedded in the porous structure of ceramic supports. Since that, the density of the porous ceramics was increased while porosity will be decreasing due to the compactpore structure as shown in Fig. 3(b).





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Fig.3. Microstructure of MLCM fracture surface; (a) 5 and (b) 20 wt.% of TiO_2

3.4 Filtration test

The ability of wastewater to pass through the MLCM under gravity flow was determined using artificial wastewater contains suspended particles. It is clearly seen that wastewater can pass through all sample under gravity flow. It was due to greater pores size of ceramic support which produced by polymer replication technique. The concentrations of $TiO_2$was greatly influenced the quality of filtrate. As the concentration of TiO_2 increase, clearer effluent was obtained as shown in Figure 4. The quantity of effluent also decreaseddue to efficient filtration by thicker layer of TiO_2 which filtered the suspended solids.

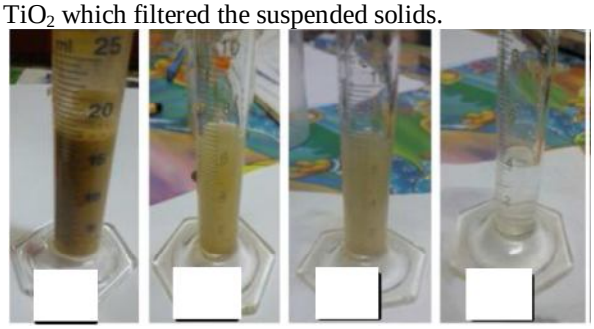


Fig. 4 Effluent after 30 minute filtration: (a) 5, (b) 10, (c) 15 and (d) 20 wt.% of TiO_2

The volume of effluent obtained after filtration process was decrease from 18 ml to 4 ml with increasing concentration of TiO_2 from 5 wt.% to 20 wt.% as shows in Figure 5. This is due to formation of compact structure as the concentration of TiO_2 increases. Sample became more compact thus, the particles cannot pass through the layers easily.

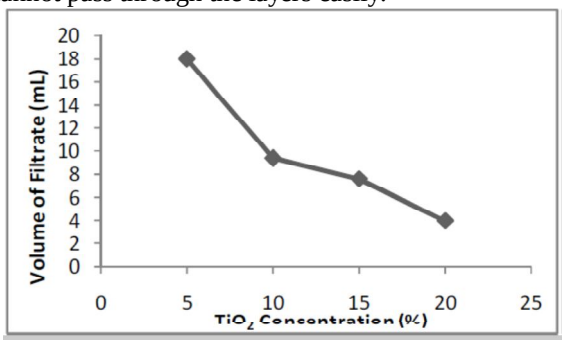


Fig. 5 Volume of effluent after 30 minutes filtration under gravity flow

CONCLUSIONS

MLCM was successfully produced and characterized, and major conclusions are as follows:

1. Increased in concentration of TiO_2will increased the density of MLCM and vice versa for porosity.
2. The best concentration of TiO_2 was 20 wt.% which produce clearer effluent due to the ability of MLCM in separating the suspended particles.

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