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MIN-JEONG LEE[1,2], HYEON-JU KIM[1], MANHO PARK[3], JUNG-YEUL YUN[1*]

FABRICATION AND PORE PROPERTIES OF SUS316L MEMBRANE WITH DOUBLE-LAYERED PORE STRUCTURES BY WET POWDER SPRAYING

In this study, a SUS316L membrane having double layered pore structures was fabricated, and the pore characteristics were analyzed after coating with a spherical powder and a flake-shaped powder on a disk-shaped SUS316L support using a wet powder spraying process. The thickness of the coated layer was checked using an optical microscope, and air permeability was measured using a capillary flow porometer. When the coating amount was similar, the fine porous layer prepared using flake powder was thicker and showed higher porosity. In the case of a similar thickness, the case of using flake powder was half of the amount of spherical powder used. Therefore, it was confirmed that it is possible to manufacture a metal membrane having a high filter efficiency even with a small coating amount when using the flake powder.

Keywords: Wet powder spraying process; Double-layered pore structures; Powder shape; Spherical; Flake

1. Introduction

Porous metal membranes can be widely applied to many industrial areas, including in semiconductor manufacturing, the medical field, the oil and gas industry, and food. They possess shape stability, good fatigue, high-temperature durability, thermal shock resistance, chemical stability for acids and solvents, good filter performance, and good back pressure flow [1,2]. Methods of manufacturing a porous metal membrane include semi-solid foaming, gas expansion, Metal hollow spheres (MHS) sintering, space holder technique, slurry coating, among other methods [3-7]. As the shape, pore size, and relative density of pores that are characteristic factors of the porous metal vary in accordance with the manufacturing method, the manufacturing method is selected according to the purpose of use. In order for a metal membrane to be used as a filter material, a high flow rate and a low pressure drop are required. There have been attempts to manufacture a gas filter having a double pore structure that includes coarse pores and micro pores by using a metal powder that can be used at high temperatures and that has excellent corrosion resistance.

In this study, a filter having a double pore structure was manufactured by coating a fine pore layer on the surface of a porous substrate having coarse pores using wet powder spraying (WPS) which is a promising method for producing graded porous structures. The WPS involves the technique of spraying a metal powder slurry onto a support using a spray gun. The process parameters include the size of the spray nozzle, the distance between the nozzle tip and the support, the width of the spray beam, and the spray pressure. If fine metal powder slurry is coated on a support with coarse pores, a filter having graded pore structures can be fabricated [8]. Research has been conducted on a manufacturing process having a graded porous structure by coating ceramic or metal powder using WPS, but research on metal powder shape, particularly flake shape, has not been conducted.

This research aimed to manufacture a metal membrane having high filtration efficiency and low pressure drop by additionally coating spherical or flake-shaped metal powder on a disk-shaped metal substrate to manufacture a membrane having a double pore structure. The prepared double pore structure membrane allowed analysis of the pore structure and coating efficiency of the microlayer according to the difference in powder shape.

2. Experimental

Fig. 1. Shows a flow-chart for the fabrication of a SUS316L membrane with double-layered pore structures using WPS. In this

1 KOREA INSTITUTE OF MATERIALS SCIENCE (KIMS), METAL POWDER DEPARTMENT, CHANGWON 51508, REPUBLIC OF KOREA
2 PUSAN NATIONAL UNIVERSITY DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING, REPUBLIC OF KOREA
3 R&D CENTER, ASFLOW CO. LTD, SUWON, REPUBLIC OF KOREA

* Corresponding author: yjy1706@kims.re.kr

study, an experiment was undertaken by coating a metal powder on a disk-shaped support for the fabrication of a double-layered pore structure having a fine pore structure on the surface of the metal porous substrate by WPS. First, a disk-type substrate was produced by uniaxial pressing of SUS316L powder with an average powder size of 70-80 μm. In order to examine how the pore characteristics of the double-layered pore structures formed according to the shape of the metal powder were different, WPS was performed using spherical and flake-shaped powders. The spherical-shaped powder had an average powder size of 8 μm. The flake-shaped powder had an average powder diameter of 42 μm and a thickness of 1 μm. The powder morphologies are shown in Fig. 2. The metal powder slurry was prepared by mixing a metal powder-solvent-binder solution before the WPS stage, and then prepared metal powder slurry was coated on a disk-shaped support by WPS. Ethyl alcohol was used as the solvent and (hydroxypropyl)methyl cellulose 2 wt.%, 98 wt.% distilled water were used as the binder solution. The slurry mixing ratio was 20 vol.% for the powder, 50 vol.% for the solvent, and 30 vol.% for the binder solution. Among the WPS experimental variables, the nozzle size was 0.8 mm, and the distance between the nozzle tip and the substrate was 150 mm, which was a fixed variable. The coating time was varied for making a similar coating amount and coating thickness. The fabricated membrane was dried in air for 30 minutes and sintered in a vacuum at 950°C for 1 hour

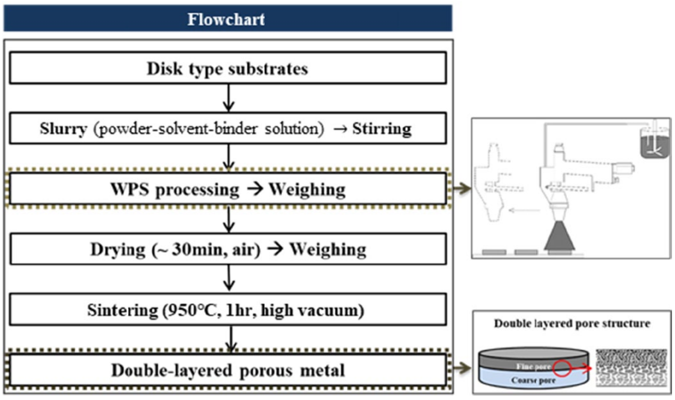

Fig. 1. Flow chart for double-layered porous metal using wet powder spraying

to fabricate a SUS316L membrane with double layered pore structures. The prepared membrane cross-sectional morphology was observed by using an optical microscope (TME-BD, Nikon, Japan). The porosity was analyzed via image analysis software. Air permeability measurements were performed using a capillary flow porometer (CFP1200AEL, PMI, USA) at room tempertature.

3. Results and discussion

Fig. 3 shows the cross section of the fabricated double-layered pore structure. It can be observed that the double layered pore structures were well fabricated with the support having a large pore structure and the coated layer having a small pore structure. In addition, it could be confirmed that the coated layer was flat and evenly coated on the support by the WPS process.

TABLE 1 shows the values for the coating amount, coating thickness, and porosity. These values were obtained based on the optical microscopy results. In TABLE 1, columns (a) and (b) display the properties of a membrane coating layer fabricated using spherical powder, and column (c) lists the properties of a coating layer of a membrane fabricated using flake powder. When (a) and (c) are compared, a characteristic of a coating layer fabricated with a similar coating amount according to a powder shape may be compared, and when (b) and (c) are compared, a characteristic of a coating layer fabricated with a similar coating thickness according to the powder shape may be compared.

When a comparison between Figs. 3. (a) and (c) is made with a similar coating amount, in the case of fabrication with spherical power, the coating thickness was 70 μm, and in the case of fabrication with flake powder, the coating thickness was 139 μm. These results showed that the thickness of coated layer using flake powder was about twice as thick as when using spherical powder. When comparing porosity, the porosity was more than 15% higher when using flake powder than when using spherical powder.

The comparison of Table 1 columns (b) and (c) for similar coating thickness shows that 0.146 g was used when using flake powder, while 0.341 g was used when using spherical powder. Therefore, the double-layered pore structure membranes fabri-

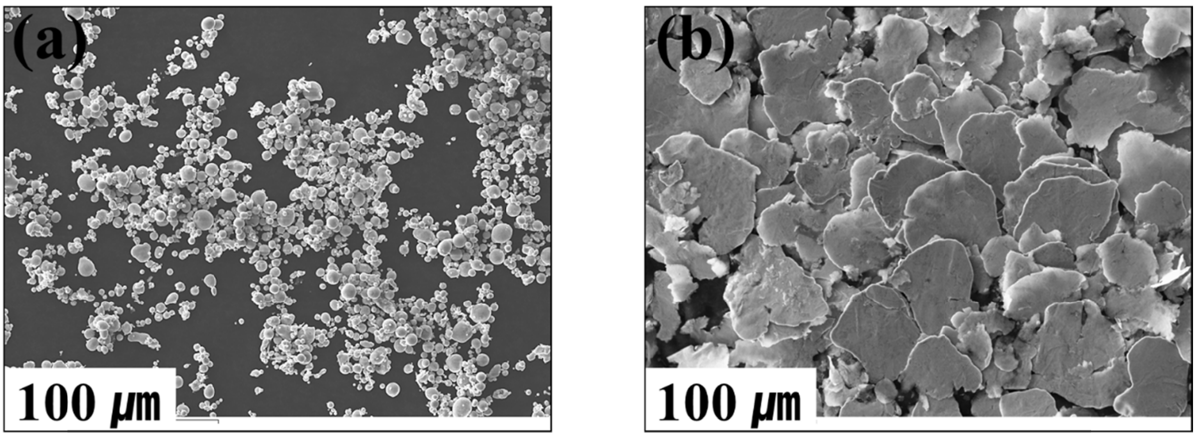

Fig. 2. Scanning electron microscope image of the SUS316L powder morphology (a) spherical shape and (b) flake shape

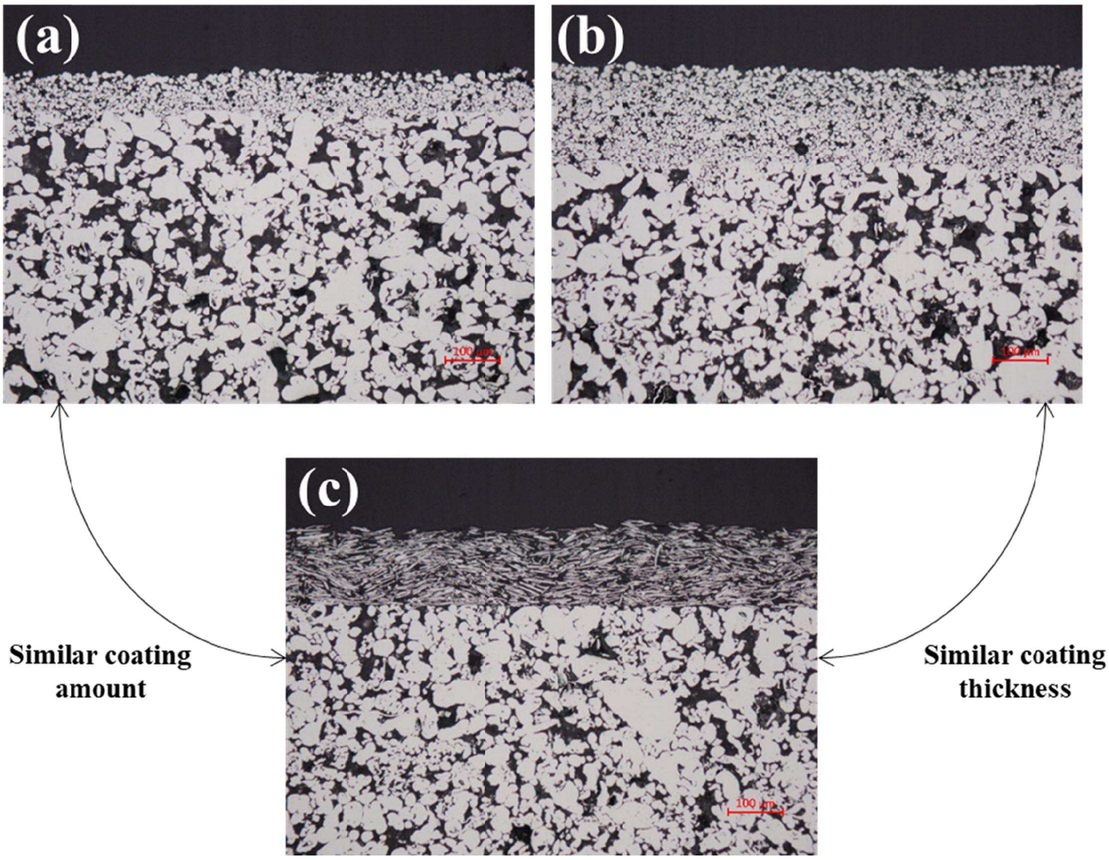

Fig. 3. Optical microscope image of cross section according to powder shape (a), (b) spherical and (c) flake

TABLE 1

Coated layer properties of double layered pore structure fabricated by wet powder spraying

	(a)	(b)	(c)
Powder shape	Spherical	Spherical	Flake
Coating amount (g)	0.129	0.341	0.146
Coating thickness (μm)	70	165	139
Porosity (%)	32	35	48

cated with flake powder can be coated with the same thickness in an amount of approximately 1/3 as compared to that fabricated with spherical powder. As a results of measuring the porosity, the porosity of the double layer made of flake powder was about 13% higher.

Fig. 4 shows the permeability according to the powder shape when the coating amount and the coating thickness are similar. It can also be seen in the figure that the support having coarse pores is more permeable than the double pore structure. Also, regardless of the coating amount and the coating thicknesses, it was confirmed that the membrane fabricated with flake powder exhibited a higher permeability than the one fabricated with spherical powder.

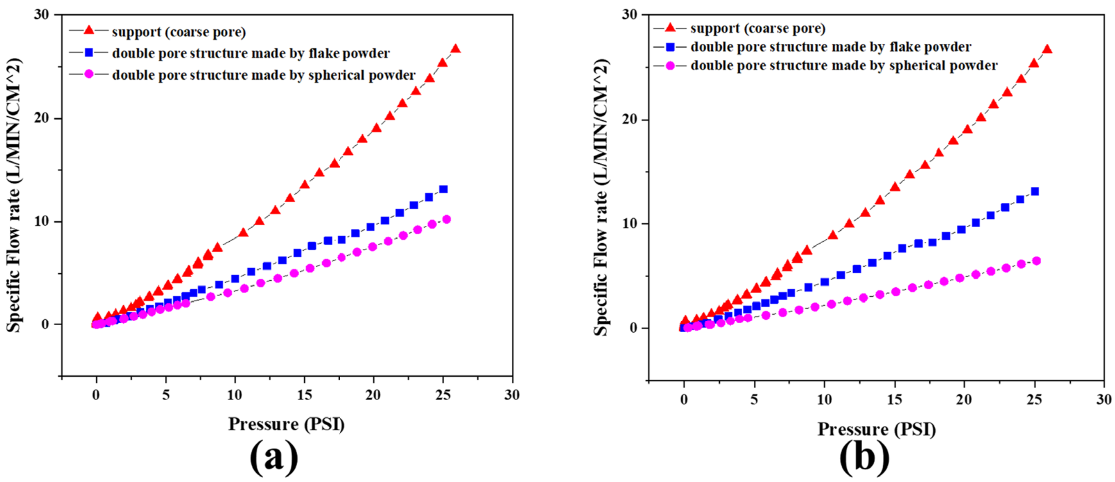

Fig. 4. Experimental result of permeability (a) similar coating amount, (b) similar coating thickness

In general, as the thickness of a porous body increases, air permeability decreases. However, in the case of membranes with a similar coating amount (Fig. 4(a)), it can be seen that the membranes fabricated with flake powder have better air permeability even though the coating layer is twice as thick. In addition, when fabricating a membrane using flake powder, a coating layer with a similar thickness can be prepared using only 1/3 of the amount of spherical powder used, but it can nevertheless be seen that, it has better air permeability. This phenomenon is considered to be because the pore size and porosity of the membrane fabricated by the flake-shaped powder are larger than that of the spherical powder, and the pores formed in the coated layer are connected to each other.

From these results, it was confirmed that manufacturing a membrane having a double pore structure by using a WPS process using flake-shaped powder is more advantageous than using spherical powder.

4. Conclusions

In this study, an SUS316L membrane with a double-layered pore structure was fabricated a WPS process and the pore properties were analyzed according to the powder shape used spherical powder and flake powder. When comparing similar coating amounts, the thickness of the coating layer using the flake powder was thicker and had a higher porosity than when using the spherical powder. When the coating layers were of similar thicknesses, the amount of powder used was smaller with flake powder than when spherical powder was used, and the porosity was higher in flake powder than in spherical powder. When analyzing permeability, the permeability of the support was higher than that of the double layered pore structure, and regardless of the amount of coating and thickness, the membrane made of flake powder had a higher permeability than the membrane made of spherical powder. In general, the thicker the coating thickness, the lower the permeability; however, the membrane fabricated with flake powder had better permeability despite the thicker coating layer than the membrane fabricated with spherical powder. In addition, even when manufacturing a coating layer having a similar thickness, the amount of flake powder used can be reduced by one-third compared with the spherical powder. Therefore, it was confirmed that the fabrication of membrane having a double-layered pore structure using flake powder was advantageous during the WPS process.

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