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Manufacturing of Three-way Catalyst Membrane Particulate Filter and Porosity Measurement using Electron Microscopy Image Analysis

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A Three-way Catalyst (TWC)-particles membrane was manufactured on a conventional filter substrate to obtain a 100% initial-filtration efficiency for particulate matter and a low pressure-drop membrane particulate filter as shown in figure 1. Agglomerated nitrogen dispersant TWC-particles were deposited on the bare filter substrate as a membrane layer. A 2-dimensional porosity measurement method was presented to measure the porosity of the cross-sectional area of the membrane through electron microscopy image analysis. A parametric analysis was conducted in the membrane manufacturing process by introducing three different particle sizes under three different superficial velocity conditions (i.e., 5, 25 and 50 mm/s). In the manufacturing process, different agglomerated particle sizes can be produced by diluting the catalyst slurry which is originally composed of 20 wt% of 20~30 nm sized primary TWC-particles. Mean particle sizes produced from different TWC-particles concentration of (20, 5 and 0.5 wt%) were measured as (1.2, 0.93 and 0.5 um) respectively. According to SEM micrographs of cross-sectional view of the fabricated membrane on a bare filter substrate, the TWC-particles were deposited at the entrance of the pores of the filter as a membrane layer under lower superficial velocity (i.e., 5 mm/s) by introducing any particle sizes. Due to the deposition of the TWC-particles in the pores of the filter, the drastic pressure-drop increases were exponentially increased with respect to the deposited weight up to the inflection points of the S-curves at which the bridge formation process were completed. The fabricated membrane was infiltrated by epoxy resin to measure the porosity at the cross-sectional area of the membrane. Morphology of cross-sectional view of TWC-particles were revealed as much the same morphology as the surface view of agglomerated spherical TWC-particle. It was confirmed that homogeneously agglomerated spherical TWC-particles were successfully manufactured under low superficial velocity condition (i.e., 5 mm/s) in the manufacturing process.

Porosity measurement was initiated with the FE-SEM micrographs by depicting on each particle by utilizing Image-J image processing program. Due to the slightly partial separation of thin resin around the borderline of the particles, some particles were not absolute circular shapes. Therefore, it was essential to measure the cross-sectional particles sizes as inscribed circle area in order to exclude the separated resin area. The porosity of the membrane can be determined by the ratio of total area of TWC-particles and the measured area as described in the equation below.

$$Porosity = \left(1 - \frac{Total\ area\ of\ TWC\ particles}{Measured\ area}\right)$$

According to the measurement result, an average porosity of mean particle diameter 1.2 microns under superficial velocity 5 mm/s was measured as approximately 64% as described in figure 2. A similar porosity was obtained when increasing the superficial velocity even 10 times higher (i.e., 50 mm/s). Besides, the porosity was not much different by comparing different particle size under the same superficial velocity condition. According to the porosity and particle size, the permeability of the TWC-particle membrane layer becomes larger as the particle size increases. Therefore, it is preferable that TWC-particles with a mean diameter of 1.2 um (deviation width of approximately 0.3 um) should be introduced into the conventional substrate under the condition of a low superficial velocity to obtain a TWC-particles membrane filter with a low pressure drop.

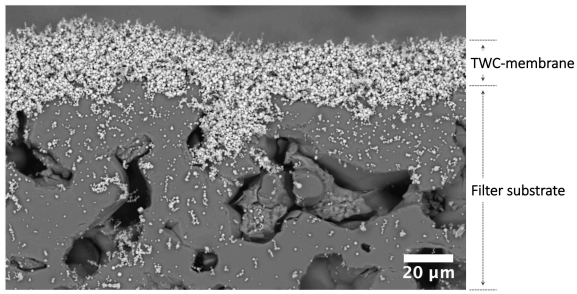

Fig. 1 A Three-way Catalyst (TWC)-particles membrane filter

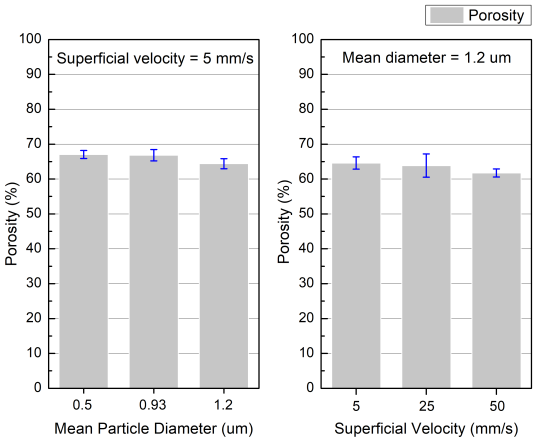

Fig. 2 Summary of porosity of TWC-membrane