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Electronic Supplementary Information (ESI)

Effective removal of particulate matters from air by using zeolite-coated filters

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1. Materials

Sodium silicate and sodium aluminate were purchased from Sigma-Aldrich and Junsei Chemical Co., respectively. Sodium hydroxide (NaOH, 99%), potassium hydroxide (KOH, 99%), and toluene (C_7H_8, 99.5%) were acquired from OCI Co. Cotton (5 cm x 5 cm x 0.25 mm), heavy cotton (5 cm x 5 cm x 0.34 mm), polyester (5 cm x 5 cm x 0.26 mm) and incense (24 cm, length × 1.5 mm OD) samples were purchased from local shops. Y zeolite samples, in hydrogen form, with various SiO_2/Al_2O_3 ratios (such as CBV780 (SiO_2/Al_2O_3: 80), CBV720 (SiO_2/Al_2O_3: 30) and CBV 400 (SiO_2/Al_2O_3: 5.1)) were supplied by Zeolyst International.

2. Synthesis of NaX zeolite

NaX zeolite was synthesized based on a procedure reported earlier.[1] Three solutions (named A, B and C) were prepared as follows: For solution A, 22.37 g of sodium aluminate was dissolved in 30 g of deionized water. Solution B was prepared by dissolving 31.1 g of NaOH and 21.5 g of KOH in 70 g of deionized water. Subsequently, the solution B was added to the solution A, and mixed until homogeneous solution was obtained. Solution C was obtained by dissolving 46.0 g of sodium silicate in 72 g of deionized water. The solution C was mixed with previously obtained solution (A + B) and mixed thoroughly. Mixed solution was further stirred for an additional 10 minutes before ageing for 3 h at 70 ^{o}C. Finally, the solution was placed in an oven at 95 ^{o}C and maintained for 2 h for crystallization. After the syntheses of zeolite for a pre-determined time, the heated mixture was naturally cooled to room temperature. Solid product containing the intended X zeolite was separated from mother liquor via filtration, washed several times with water and ion-exchanged (3 times) with NaOH aq. solution (0.01 M). Finally, the zeolite was washed with ample water, dried for 12 at 130 ℃

with a vacuum oven, and stored for further uses. NaY zeolite samples were obtained from HY zeolites via a similar procedure (in 3 times) that was applied for NaX zeolite.

3. Zeolites coating onto substrates

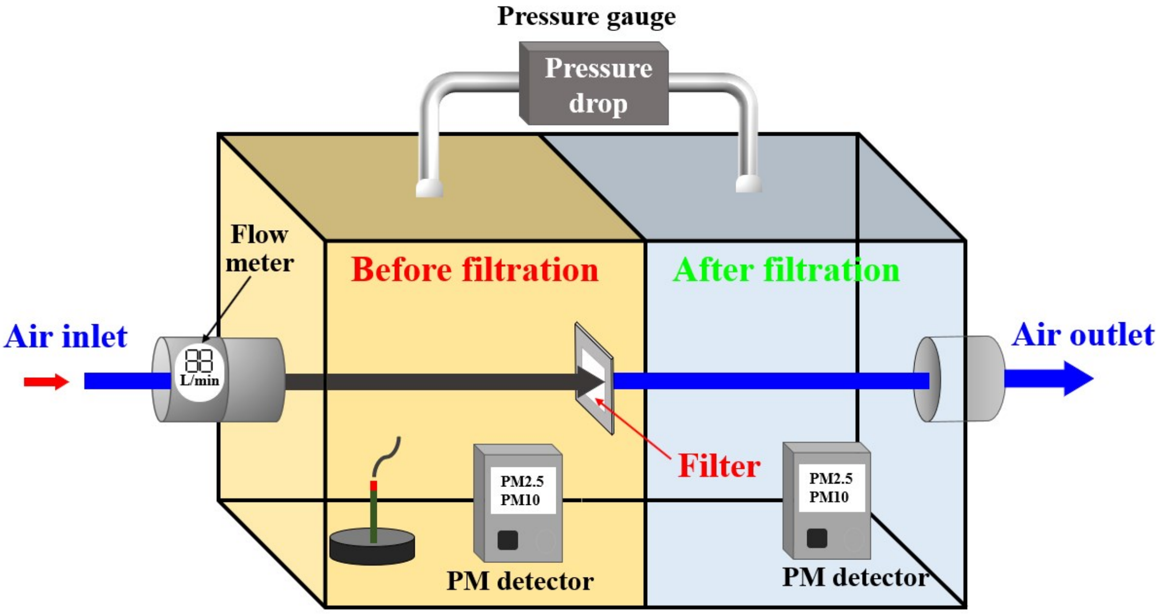
Pretreated fabric specimen was put into a solution containing 0.01 mmol of (3-chloropropyl)trimethoxysilane (CPTMS) and toluene (200 ml). The fabric-containing solution was maintained at 100 °C for 2 h in order to introduce CPTMS into the substrate via a reaction between –OH group of a substrate and methoxy group of CPTMS (Scheme 1, top). After maintaining for 2 h, the reactor (containing CPTMS-loaded substrate) was cooled down to room temperature, and a prepared zeolite sample (Na-form, 0.2 g) was added to the reactor, and further heated for 48 h at 80 °C under magnetic stirring to coat the zeolite on the substrate (Scheme 1, bottom). The reactor (containing substrate-coated with a zeolite) was cooled down to room temperature. The substrate, coated with a zeolite, was recovered by filtration, washed with ethanol several times, and finally dried with a conventional oven for 12 h at 100 °C. MOFs coating on cotton substrate was done similarly.

4. Characterization

Powder X-ray diffraction patterns of zeolites and substrates (with or without zeolites/MOFs coating) were obtained with a diffractometer (D2 Phaser, Bruker, Cu Kα radiation). Nitrogen adsorption isotherms of zeolites were acquired at 77 K using a surface and porosity analyzer (Tristar II 3020, Micromeritics). Before measurements, the samples were evacuated for 12 h at 150 °C. Surface area of zeolites was calculated by using the Brunauer-Emmett-Teller (BET) equation.

5. Evaluation of PM removal

PM removal experiments, including checking the removal efficiency and pressure drop with various filters, were carried out with a homemade measurement system.[2] The device was composed of two chambers (divided by an acryl plate with or without a hole). PMs were generated inside of the left chamber by burning of incenses. After the PM concentration was stabilized to an intended level, a filter was rapidly set on the middle of the chambers, and the PM-containing air was flown continuously to the right chamber by air feeding. Thus, air (contaminated with PMs in constant concentration) was supplied from the left chamber to the right chamber with a face velocity of 0.2 m s^{-1} (flow rate of air: 11 L/min, and window size of filter for airflow: 3 x 3 cm^2). Concentrations of PM2.5 and PM10, in both the left and right chambers, were measured with independent commercial PM meters (CEM, DT-9681). The removal efficiency of PM (or the degree of reduction in PM concentrations after passing through the filter) was calculated by comparing the PM concentrations in the two chambers. The pressure drop was measured with a differential pressure gauge (ULFA Tech Corporation, PDT series), during the air flow or PM capture. Scheme S1 shows the



Scheme S1. Schematic diagram of an equipment to evaluate the performances of filters in removing PM from air.

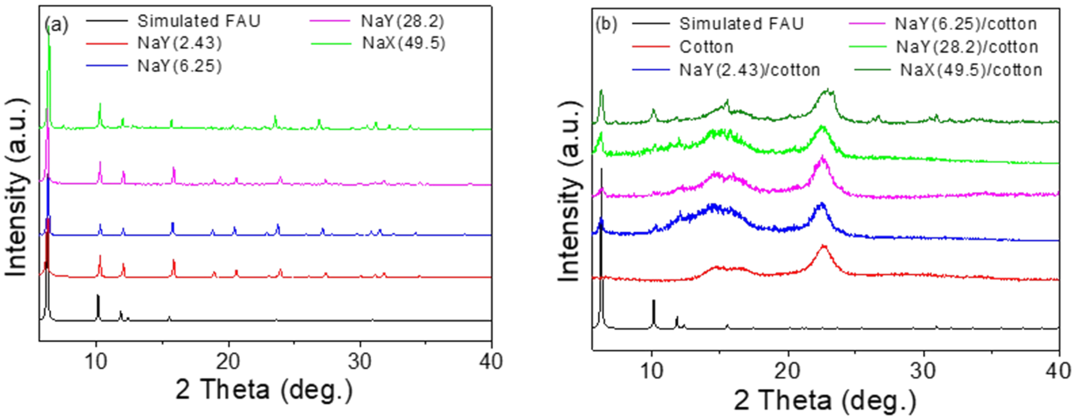


Fig. S1. XRD patterns of (a) zeolites and (b) cotton and zeolites-coated cotton. Calculated pattern of FAU zeolite is also shown for reference.

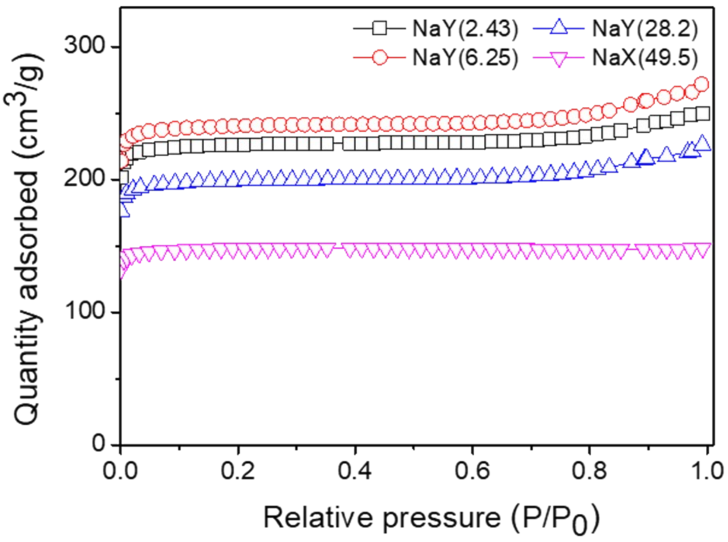


Fig. S2. Nitrogen adsorption isotherms of zeolites that coated onto cotton for PM removal.

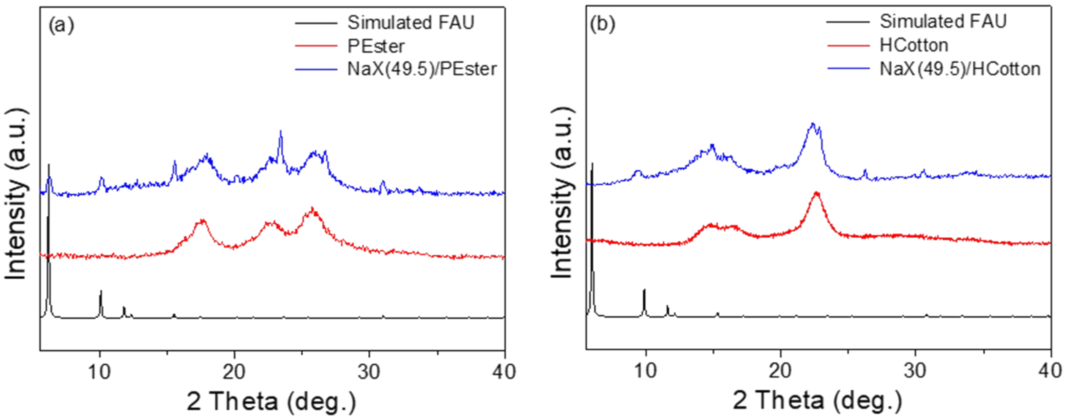


Fig. S3. XRD patterns of substrates (polyester and heavy cotton) and NaX(49.5)-coated substrates. Calculated pattern of FAU zeolite is also shown for reference.

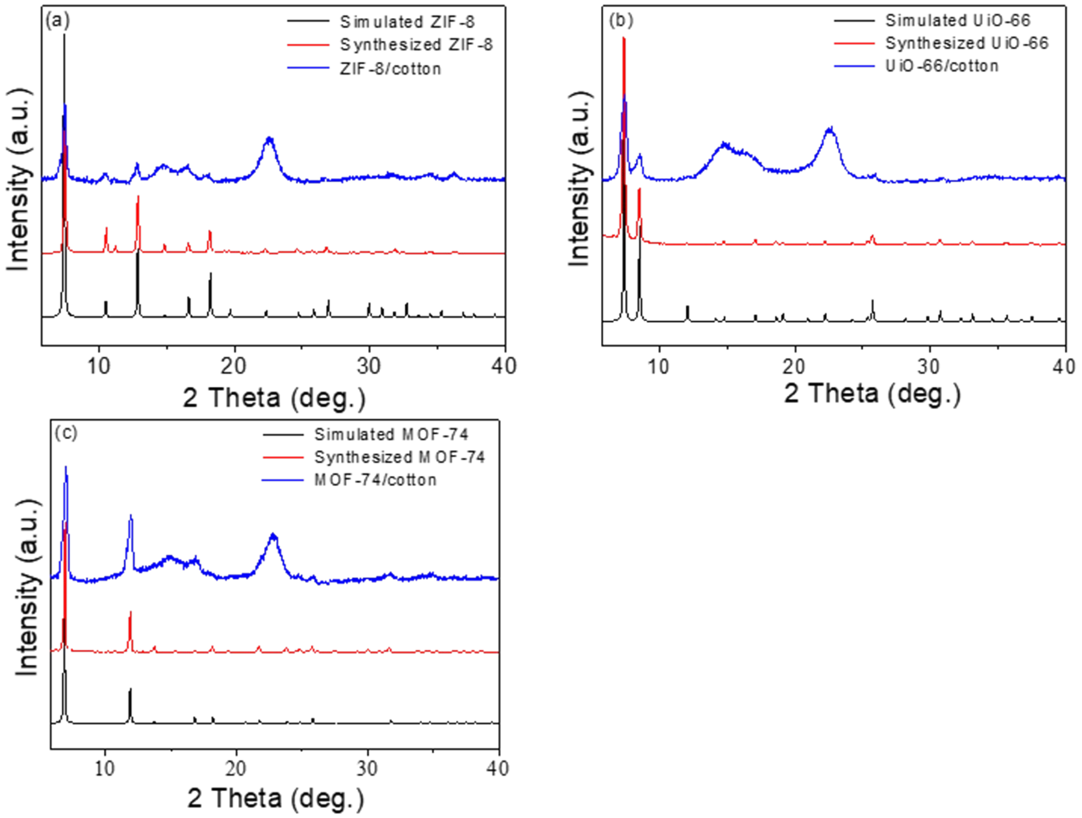


Fig. S4. XRD patterns of (a) ZIF-8 and ZIF-8 coated cotton; (b) UiO-66 and UiO-66 coated cotton; (c) MOF-74 and MOF-74 coated cotton. Calculated patterns of each MOF are also shown for reference.

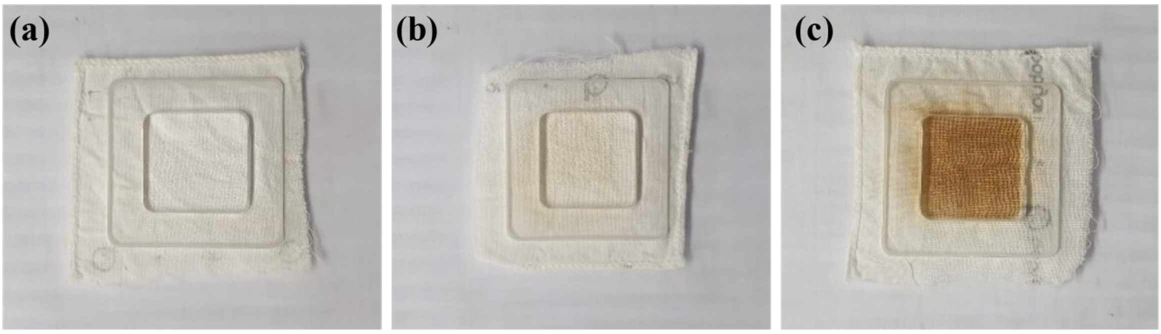


Fig. S5. Photos to show the change of color of NaX(49.5)/cotton filter with increasing operation time. From left to right, the time was (a) 0 (before use), (b) 1 and (c) 12 h.

[1] S. Mintova and N. Barrier (Editors), *Verified Synthesis of Zeolitic Materials,* 3rd revised Ed., pp 218-220. The Synthesis Commission of the International Zeolite Association, 2016.

[2] D. K. Yoo and S. H. Jhung, *ACS Appl. Mater. Interfaces,* 2019, 11, 47649−47657.