NOTE

Adsorption of Ammonia Gas with Cation-Exchange Resins and Sulfur Dioxide Gas with Anion-Exchange Resins

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Currently, it is assumed that traces of inorganic gas such as ammonia gas[1,2] or sulfur dioxide gas affect the yield of products in the semiconductor industrial field. Ammonia gas[3] is used inside the clean rooms of such factories. Sulfur dioxide gas[4] flows into the clean rooms from the outside atmosphere. To remove these gases, so-called chemical filters are used.

In the course of our investigation of chemical filters, we found that ion-exchange resins work in the gas phase as well as in the liquid phase. For ammonia gas, cation-exchange resins work well. On the other hand, for sulfur dioxide gas, anion-exchange resins work well. Ion-exchange resins may remove basic gases and acidic gases from the air.

EXPERIMENTAL

Materials

Polyurethane foam, which is the support of the chemical filter used in this experiment, was commercially available from the Inoac Corp., Nagoya, Japan (malt filter). A commercially available acrylic emulsion adhesive, Boncoat R-3310 (Dainippon Ink and Chemicals, Incorporated, Tokyo, Japan), affixed the adsorbents to the support. Commercially available cation-exchange resins (Diaion PKH228L) and anion-exchange resins (Diaion RCP160H) were from the Mitsubishi Chemical Corp., Tokyo, Japan.

Production of Chemical Filters

Conventional Chemical Filter for Ammonia Gas. Polyurethane foam (8 mesh, 100 × 100 × 20 mm thickness) was

dipped with the adhesive. The excess of the adhesive was removed to pass through a roll. Phosphoric acid-impregnated activated carbon beads (Kureha Chemical Industry Co., Ltd., Tokyo, Japan), with an average diameter of 0.6 mm, were dropped over the foam. An excess of the beads was removed by vibration.

Cation-exchange Resins Filter. This filter was made in the same way as described above except that Diaion PKH228L, with an average diameter of 0.6 mm, was used instead of phosphoric acid-impregnated activated carbon beads. Diaion PKH228L was half-dried by an air flow at room temperature.

Conventional Chemical Filter for Sulfur Dioxide Gas. This filter was also made in the same way as described above except potassium carbonate-impregnated activated carbon beads (Kureha Chemical Industry Co., Ltd.), with an average diameter of 0.6 mm, were used instead of phosphoric acid-impregnated activated carbon beads.

Anion-exchange Resins Filter. This filter was also made in the same way as described above except Diaion RCP160H, with an average diameter of 0.6 mm, was used instead of phosphoric acid-impregnated activated carbon beads. Diaion RCP160H was half-dried by an air flow at room temperature.

Evaluation of Filter

Equipment. Ammonia and sulfur dioxide gas was obtained from a high-pressure tank balanced with nitro-
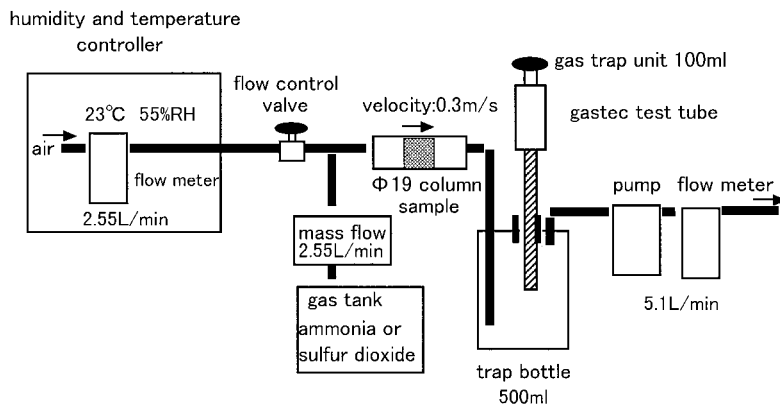

Figure 1   Total evaluation system.

gen (Sumitomo Seika Chemicals Co., LTD., Osaka, Japan) and was diluted to an appropriate concentration (5–30 ppm) with pure air. The pure air was passed through the adsorbents and the humidity and temperature were controlled to 55% RH and 23°C, respectively, by a controlled air generator (Tabai Espec Corp., Osaka, Japan).

Filter samples were cut to 19-mm ϕ-sized pieces and set in an acrylic column (19 mm ϕ). The time course of the removal efficiencies was measured. The total evaluation system is shown in Figure 1.

Measurement of Removal Efficiency. Removal efficiency was determined by measuring the concentrations of ammonia or sulfur dioxide gas before and after column treatment by gas test tubes (Gastec Corp., Ayase, Japan). Removal efficiencies were calculated according to the equation described below at every time during the experiment:

$$R = Ci - Co/Ci \times 100$$

where R is the removal efficiency (%); Ci, the concentration of ammonia or sulfur dioxide gas before column

treatment; and Co, the concentration of ammonia or sulfur dioxide gas after column treatment.

RESULTS AND DISCUSSION

The breakthrough curve of ammonia gas with the cation-exchange resins filter is shown in Figure 2 in comparison with that of the conventional filter. The initial removal efficiency of the cation-exchange resins filter was 99.2%, while that of the conventional filter was 94.0%.

Concerning the velocity of ammonia gas adsorption, it is assumed that cation-exchange resins adsorb ammonia gas earlier than do phosphoric acid-impregnated activated carbon beads, because sulfonic acid is a stronger acid than is phosphoric acid. Moreover, ammonia gas molecules adsorbed with cation-exchange resins could move inside the cation-exchange resins, while those with phosphoric acid-impregnated activated carbon beads could not move. In the cation-exchange resins, adsorbate tends to diffuse to a uniform level in the resins. For these reasons, the initial removal efficiency of the cation-exchange resins filter was much higher
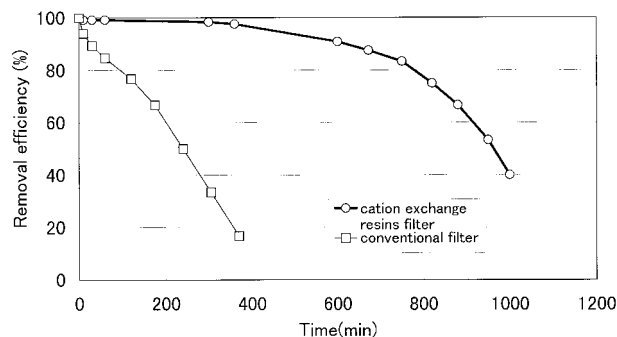

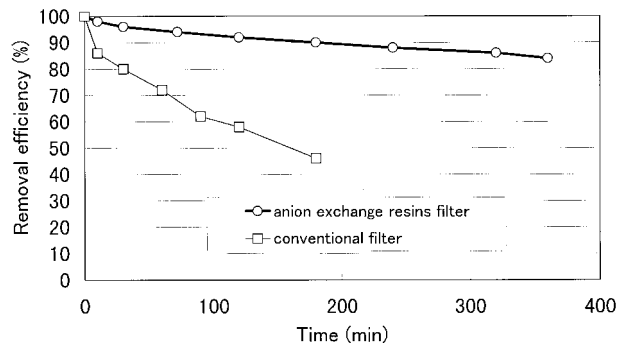**Figure 2**   Breakthrough curves of ammonia gas.

Figure 3   Breakthrough curves of sulfur dioxide gas.

than that of the phosphoric acid-impregnated activated carbon beads filter.

The breakthrough curve of sulfur dioxide gas with the anion-exchange resins filter is shown in Figure 3 in comparison with that of the conventional filter. The initial removal efficiency of the anion-exchange resins filter was 98.0%, while that of the conventional filter was 86.0%. The same phenomenon in the case of cation-exchange resins is assumed to occur as described above, so the initial removal efficiency of the anion-exchange resins filter was much higher than that of the potassium carbonate-impregnated activated carbon beads filter.

Concerning the lifetime, the ion-exchange resins filter sustained higher removal efficiencies than for the acid- or base-impregnated activated carbon beads filter. The theoretical adsorptive capacity of ion-exchange resins is larger than that of acid- or base-impregnated activated carbon beads. This is the reason for the longer lifetime of the ion-exchange resins filter.

On the other hand, it is known that activated carbon releases adsorbed gas under some conditions. We assumed that ion-exchange resins did not release the adsorbed gas. It was found that the ion-exchange resins filter has a much better performance than that of the acid- or base-impregnated activated carbon beads filter for removal of acidic and basic gases.

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