INFLUENCE OF OXYGEN PLASMA TREATMENT ON HYDROGEN CHLORIDE REMOVAL OF ACTIVATED CARBON FIBERS

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Introduction

Air, which we breathe, has been polluted with various components, such as, toxic gases, dust, and some volatile organic solvents. It has been well known that the acidic gases, such as HCl, SO_x and NO_x, are major components of air pollution. Most of all, HCl gas is the highest risk of being exposed to human body, and it can threaten our lives with very little amount in air [1].

Activated carbon fibers (ACFs) are widely used in air and water purification, solvent recovery, etc. It is recognized that the pore structure and surface functional groups are the most important properties of ACFs for their applications in adsorption processes. In viewpoints of surface functionalities, the control of surface functional groups is really important because the adsorption of gas phase material is strongly depended on the functionality of the surfaces of adsorbents [2-4].

The objective of this study is to evaluate the efficiency of HCl removal of the atmospheric pressure oxygen plasma-treated ACFs with treatment times, and to investigate the relationships between the surface functionalities and the amount of adsorption of HCl gas.

Experimental

The starting materials were commercial ACFs, AW2001 (weight 45 g/m^2 and specific surface area 2121 m^2/g), manufactured by Taiwan Carbon Co. that had previously been demineralized by distilled water. Plasma processing (ATMOSTM-Multi, Plasmart in Korea) for the ACFs was carried out using atmospheric pressure and radiofrequency for Ar/O_2 (O_2 1%) mixed gas. The radiofrequency generated by Ar/O_2 mixture plasma was operated at 300 W and 13.56 MHz. The flow rate of Ar/O_2 mixed gas was 5 ℓ/min, and the plasma treatment speed and the distance between electrodes were 5 mm/sec and 7 mm, respectively. The input number of times for oxygen plasma treatment varied between 0 and 4 times, namely, as-received, P-O-1, 2, 3, and 4. For the surface

characterization of the ACFs, FT-IR and XPS were used. HCl removal efficiency of the ACFs was measured by a detecting tube (GASTEC: No. 14L and 14M).

Results and Discussion

Figure 1 shows FT-IR spectra obtained by the KBr pellet technique of the plasma-treated ACFs as a function of treatment time. It is well known that the position of the band for free hydroxyl groups is normally observed around 3500 cm^{-1}. In this point of view, the position of the –OH band in Figure 1 is showed in the range of 3100~3600 cm^{-1}. It indicates that the physically adsorbed free –OH functional group, caused by the oxygen plasma treatment were abundant. Meanwhile, the intensity of the bands is significantly increased with increasing treatment time. It shows that a plasma processing increases the oxygen content on the ACFs.

For the detail studies on the ACF surfaces, specific content of each functional group are calculated from XPS results and showed in Figure 2. It is found that all surface functional groups containing oxygen are significantly increased. Most of all, phenolic and carboxylic group are strongly increased after the oxygen plasma treatment. This result is corresponding with the FT-IR results, resulting in the increase of –OH groups on the carbon surfaces produced by the oxygen plasma.

An understanding of the porosity and specific surface area of an adsorbent can be achieved by the construction of an adsorption isotherm of N_2. Table 1. shows the textural properties of the plasma treated ACFs, including specific surface area, total pore volume and micropore volume. It is found that a gradual decrease of adsorption properties is showed with increasing plasma treatment times.

Figure 8 is the HCl removal results of the plasma-treated ACFs. As seen in Figure 8, the removal efficiency of plasma treated samples is strongly increased with treatment time, up to P-O-3, and it goes down at P-O-4. This result means that the removal efficiency is basically depended on oxygen content or surface polarity, but the specific surface area also affects it, as observed in P-O-4. Normally, the removal efficiency of gas phase materials on the solid adsorbent is mainly depended on the specific surface area and surface functional groups of the adsorbent, though there is no catalytic reaction in the removal mechanism. The oxygen plasma treatment on ACFs do only affect to the structural and textural properties and surface functionality of the ACFs as mentioned above, so there cannot be catalytically active sites by the plasma treatment. In this point of view, HCl removal efficiency of the ACFs has only to be depended on specific surface area and surface functionality. By the plasma treatment, the surface functionality is increased as seen in Figure 1 and 2, but specific surface area isn't. It means that the efficiency of HCl removal is basically dependant on the surface functionality, especially the oxygen functionally groups, such as phenolic and carboxylic groups on the ACFs as shown Figure 2, and the specific surface area also plays a major role in the efficiency of HCl removal.

Conclusion

For studies of the relationship between surface characteristics of ACFs and the removal of hydrogen chloride, atmospheric oxygen plasma treatment were used. It is found that the plasma treatment cause a lot of oxygen containing functional groups on carbon

surfaces, especially phenolic and carboxylic groups though the adsorption properties of the ACFs itself were gradually decreased. Meanwhile, the removal efficiency of hydrogen chloride was strongly increased in all treated samples. However, it is observed that the removal efficiency of P-O-4 was decreased. These results indicates that the control of surface functional groups and specific surface area is the key to get optimal hydrogen removal condition.

References

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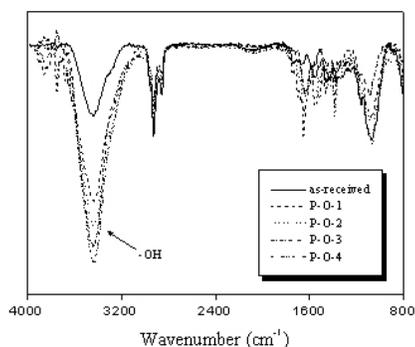
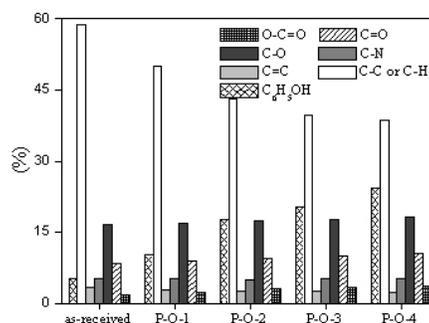Fig. 1. FT-IR spectra of the ACFs as a function of treated time.

Fig. 2. Ratio of the area of carbon sub-peaks in C_{1s} XPS spectra.

Table 1. Textural properties of oxygen plasma-treated ACFs as a function of treated time.

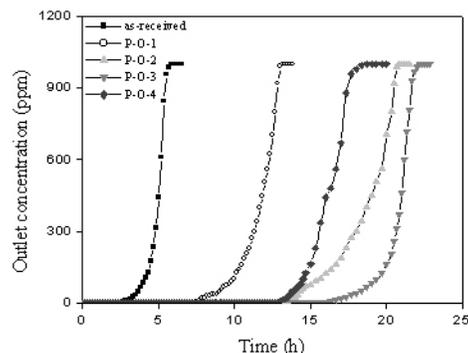|	Specific surface area (m_2/g)	Micropore volume (cm^3/g)	Total pore volume (cm^3/g)
As-received	2121	0.82	1.22
P-O-1	1937	0.74	1.08
P-O-2	1763	0.68	0.98
P-O-3	1615	0.63	0.89
P-O-4	1460	0.57	0.78

Fig. 3. HCl removal by the plasma-treated ACFs as a function of treatmed time.