Preparation of Zeolites from Coal Fly Ash and Adsorption Characteristics for Heavy Metals

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1. Introduction

A large amount of fly ash, exceeding 40% of raw coal material, is generated annually from the combustion of coal in power plants. Most of the fly ash, however, has been disposed by dumping, giving rise to serious environmental pollution. Only a small amount of fly ash is used as an additive to cement[1], mortar and soil stabilization. Recently the development of a more efficient utilization method and the production of high valued compounds from waste ash have been the objects of recent research work world-wide.

The constituents of fly ash are mainly aluminosilicate glass, mullite, and quartz with a small amount of residual coal and ore minerals. Since the glass is a readily available source of Si and Al for zeolite synthesis, fly ash has been used as raw materials for synthesizing zeolite.

This study was conducted for the efficient utilization of a fly ash which is abundantly generated in power plants. Zelolite were synthesizd from raw fly ash. The phase identification, determination of chemical composition onto the synthesized zeolites were carried out. And adsorption abilities of the synthesized zeolites for heavy metals were also investigated.

2. Experimental

Fly ash used in this study was obtained from the Boryeong Power Plant in Chungnam, Korea. The sample was pretreated with HGMS(high gradient magnetic separator) in order to remove Fe_2O_3 and TiO_2 which were reported as the undesirable components of the zeolite synthesis[2]. All the experiments were performed using the same batch of fly ash.

Zeolite were synthesized using the teflon lined stainless steel vessels in a digital-type forced-convection electric oven at 70-200°C during 1-2days without stirring.

Batch reactor experiments had been performed to investigate the effects of initial solution concentration and adsorbent amount. Adsorbent with known amount and metal solution with known concentration were placed in a 1-liter flask container. The solution was stirred with a magnetic stirrer. During the experiment, 2mL of sample in the solution was taken at a given time interval and centrifugated at 6000rpm for 10min, and then the supernant was used to measure the metal ion concentrations.

In the adsorption isotherm experiments, a relationship between the equilibrium concentration and the amount of metal ion adsorbed per unit mass of adsorbent was obtained by employing a series of tests.

X-ray diffraction and SEM techniques were employed to characterize the synthesized zeolites. Powder XRD patterns were obtained by using a diffractometer(Rigaku Model max/IIIA), and SEM observations were made by a Topcon ABT-32 instrument. The concentrations of heavy metal in solution was determined by an Atomic Absorption Spectrophotometer (UNICAM 939/959).

3. Results and Discussion

Fly ash has principally the form of various hollow spheres in size mostly composed of aluminosilicate glasses, similar to the chemical composition of volcanic ashes. The glass exceeds 60-80% of fly ash and is a readily available source material for zeolite synthesis. Quartz(Q, SiO_2) and mullite(M, $Al_6Si_2O_{13}$) are two major crystalline phases. And a small amount of hematite(H, Fe_2O_3) is also identified.

Both temperature and NaOH concentration which are critical factors for the types of zeolites synthesized from fly ash were changed to optimized zeolite synthesis. Varying the temperature and alkali concentration range, five different zeolites were obtained. Faujasite, Na-P1, hydroxy sodalite, analcime and cancrinite phases were identified under various experimental conditions. Only the glassy component of fly ash, not quartz or mullite, is concluded to participate in zeolite synthesis.

Since zeolite has many environmental applications including removal of ammonia and heavy metals due to high ion-exchange and selective adsorption properties, the adsorption ability for some heavy metals of the zeolitized fly ash has been investigated. Fig. 1 compares the lead removal performance of the zeolites synthesized from fly ash. The data demostrated that all zeolites had relatively high removal efficiencies for lead. Fig. 2 illustrates the adsorption abilities of the zeolitized fly ash for some heavy metal ions. The order of decreasing selectivity for metal ions was as follows: Pb^{+2}>Cd^{+2}>Cu^{+2} >Zn^{+2}>Fe^{+2}.

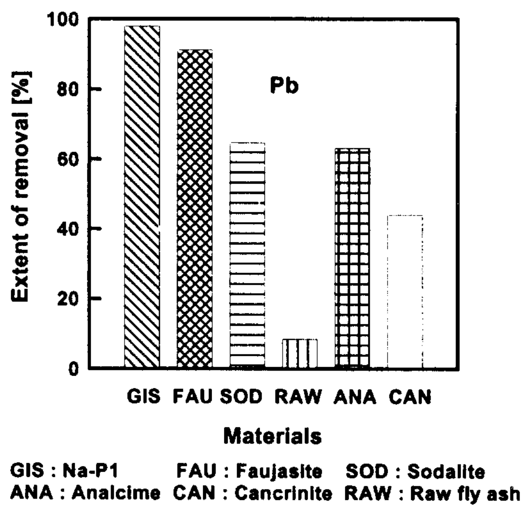

Fig. 1. Comparison of Pb removal efficiency for each synthesized fly ash.

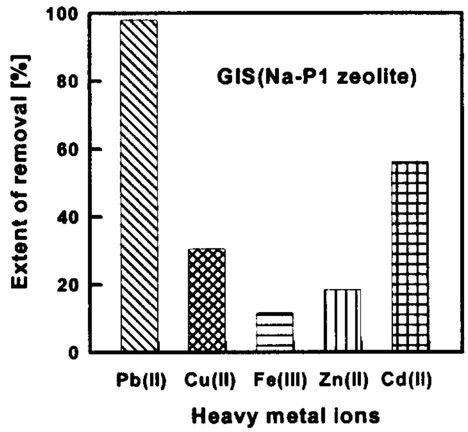

Fig. 2. Comparison of removal efficiency of each heavy metal for Na-P1 zeolite.

Fig. 3 shows the adsorption isotherms for lead of the sythesized zeolites. The data demonstrated that synthesized zeolite had relatively high adsorption capacity for lead, exhibiting exhibiting an observed maximum adsorption capacity of 264mgPb/g of Na-P1 zeolite.

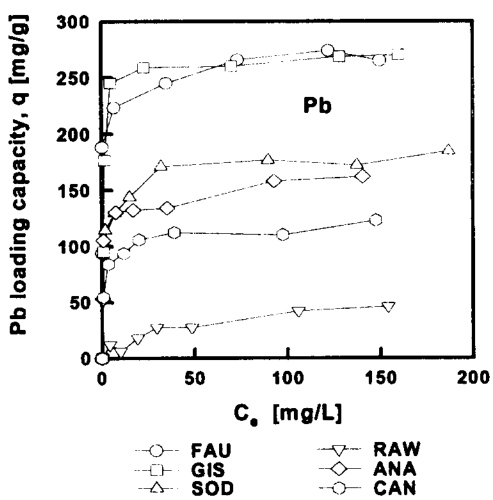

Fig. 3. The adsorption isotherms for each zeolite synthesized from fly ash.

4. Conclusion

Fly ash obtained from Power Plant was used the synthesizing zeolite. Varying the temperature and alkali concentration range, five different zeolites were obtained. Faujasite, Na-P1, hydroxy sodalite, analcime and cancrinite phases were identified under various experimental conditions. The synthesized product, i.e. Na-P1 zeolite, exhibited high adsorption ability of 264mg/g and strong affinity for lead metal ion. Only the glassy component of fly ash, not quartz or mullite, is concluded to participate in zeolite synthesis. In conclusion, zeolites can easily synthesized from waste fly ash and shows the promising possibility for the removal of heavy metal ions.

References

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