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ZnO Powders for Rapid Removal of Cu(II) Ions in Solution†

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ZnO powders prepared by direct oxidation of Zn powders were used to remove Cu(II) ions in wastewater. Results showed that the as-prepared ZnO powders had an irregular sheet shape and each sheet was packed with many nanorods. Sorption experimental results indicated that ZnO powders could remove effectively Cu(II) ions in water. The equilibrium sorption isotherm of Cu(II) on ZnO has been analyzed by the Freundlich, Langmuir and Redlich-Peterson isotherm equations.

Key Words: ZnO powders, Adsorption, Oxidation, Isotherm models.

INTRODUCTION

ZnO crystals are known with various morphologies such as microspheres, nanobelts, nanosheets *etc.*, have been applied in sensors[1], catalysts[2] and dye-sensitized solar cells[3]. However, the reports about the application of ZnO powders in wastewater treatment are seldom in present.

In this article, we report that Cu(II) ions in solution can be rapidly and effectively removed by ZnO powders at room temperature. Various sorption isotherms were used to evaluate the experimental data.

EXPERIMENTAL

ZnO powders were prepared by direct oxidation of Zn powders precursor at 700 ºC for 3 h. X-ray diffraction patterns were measured on a Philips X'pert diffractometer using CuKα radiation (0.15419 nm). Morphology of the product was observed on a Sirion 200 FEG field emission scanning electron microscope.

Adsorption experiments were carried out by agitating 1 g of ZnO with 100 mL Cu(II) ion solution in a shaker at 25 ºC/120 rpm. The initial pH value of the solutions was 6.0 ± 0.5. The reaction time (0.5 h) was shown to be adequate by preliminary experiments for equilibrium to be attained. The samples were withdrawn from the flasks at predetermined time intervals and analyzed for Cu(II) content by hydride generation atomic absorption spectrophotometry (ICP-AES). The adsorption capacity of the ZnO for Cu(II) was calculated through the following equation:

$$q_e = \frac{(C_0 - C_e)V}{m}$$

where q_e is the amount of Cu(II) adsorbed at equilibrium (mg/g), C_0 and C_e is the initial and final concentration of Cu(II) (mg/L), V is the volume of Cu(II) solution (mL) and m is the mass of the used ZnO (g). All assays were carried out in triplicate and the average was used in the analysis.

RESULTS AND DISCUSSION

Phase and morphology of the absorbents: The corresponding XRD of as-prepared ZnO nanomaterials is illustrated in Fig. 1. The diffraction peaks match well with the standard values of ZnO (JCPDS NO.89-1397), indicating that the as-prepared products are ZnO phase.

From the SEM image of Fig. 1b, it can be found that the as-prepared ZnO nanomaterials prepared from oxidation

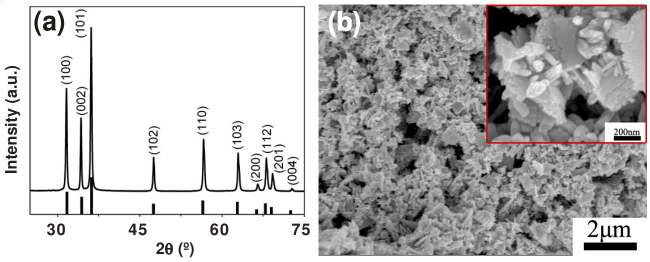

Fig. 1. (a) XRD patterns of the as-synthesized product and standard ZnO powders (the line spectrum), (b) Morphology of the as-prepared ZnO powders

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of Zn powders precursor have irregular sheet morphology, the sheets are packed with many finer rods and have a rough surface. The size of each sheet is about 0.1-0.3 µm (inset of Fig. 1b).

Equilibrium studies: Adsorption isotherms are basic requirements for the design of sorption systems. These data provide information about the capacity of the adsorbent or the amount required for removing a unit mass of pollutant under the system conditions. The equilibrium adsorption isotherm analyses were performed by plotting copper ions adsorbed (q_e) against the equilibrium concentration of copper ions (C_e) in solution (Fig. 2).

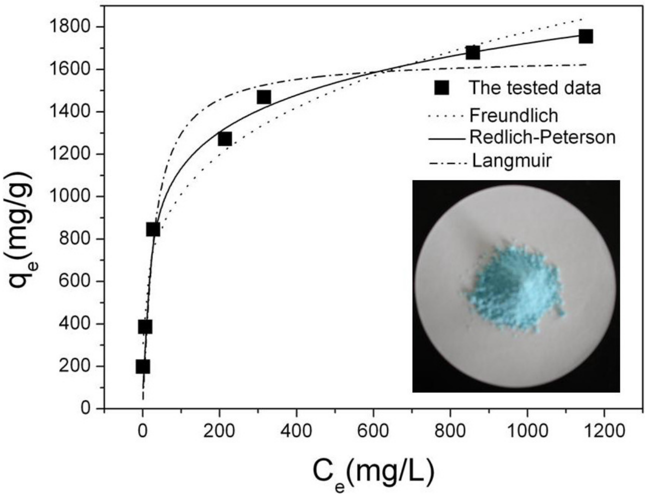

Fig. 2. Adsorption isotherm of Cu(II) on ZnO powders (inset: color of ZnO powders after adsorption for 0.5 h in 100 mL solution with Cu(II) concentration of 500 mg/L

It is well known that the Langmuir sorption isotherm is the best known of all isotherms describing homogeneous sorption, where the sorption of each adsorptive molecule onto the surface has equal sorption activation energy. And the Freundlich isotherm is most frequently used to describe the heterogeneous adsorption of inorganic and organic components in solution. The Redlich-Peterson isotherm contains three parameters and incorporates the features of the Langmuir and the Freundlich isotherms.

In order to further understand the best correlation of equilibrium data. The theoretical Langmuir[4], Redlich-Peterson[5] and Freundlich[6] isotherms were respectively plotted using a dash dot, a solid and a dot line shown in Fig. 2 comparing with the experimental scattered data points. Comparing with each other, the Redlich-Peterson equation which incorporated the features of the Langmuir and Freundlich isotherm models represents the best fit of experimental data than other equations.

From the inset of Fig. 2, we can vividly see that the color of ZnO powders after adsorption for 30 mins in 100 mL solution has become blue. This phenomenon well indicates that the white ZnO powders can effectively and rapidly adsorb Cu(II) in aqueous solution.

Conclusion

ZnO powders could be used as an effective adsorbent for removal of Cu(II) in wastewater. The equilibrium sorption isotherm of Cu(II) on ZnO was identified as the Redlich-Peterson isotherm equation. ZnO materials are expected to be applied in water environment treatment.

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