ZnO and PbO reduction from slag particles in an ICP fuming process

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ABSTRACT

Micro-sized slag particles containing ZnO and PbO were prepared for inductively coupled plasma (ICP) fuming processes. On the basis of experimental work, a mathematical model was developed to describe the reduction process of slag particles. Fick's second law was used to account for the diffusion of metallic oxides, and the diffusion coefficients of various components were determined by experimental data fitting. The predicted concentration profiles of zinc oxide and lead oxide are in good agreement with the measurements.

INTRODUCTION

Inductively-coupled plasma (ICP) can be used as a model system to understand the interaction between plasma and slag. The plasma is characterized by high energy densities and temperatures, which allows to achieve high heat and reactant transfer rates, so fuming rates are high even at low Zn/Pb content. However, the process involves a series of complicated phenomena. There is in general a very limited understanding of the process kinetics. The research aims to give a quantitative understanding of the zinc and lead fuming behavior under the ICP driven process.

MODEL DEVELOPMENT

A model for the reduction of zinc oxide and lead oxide by hydrogen in a laboratory ICP set-up was developed. It incorporates the complex process phenomena such as gas-particle flow, heat transfer, slag melting, mass transfer and chemical reactions. Considering the high temperature and turbulent gas surrounding the slag particle, the diffusion of metallic oxides to the reaction interface is assumed to be the rate-limiting step. Fick's second law was employed to describe the diffusion of metallic oxides in the slag particles. The apparent diffusion coefficient (assuming a constant at a certain power) would be used. The apparent diffusion coefficients were calculated by fitting with experimental data.

RESULTS

The concentrations of ZnO and PbO outside the particles are significantly lower than those inside the particles, forming a typical diffusion profile of ZnO and PbO. The concentration profiles of zinc and lead predicted by the present model agree very well with the measurements (Figure 1).

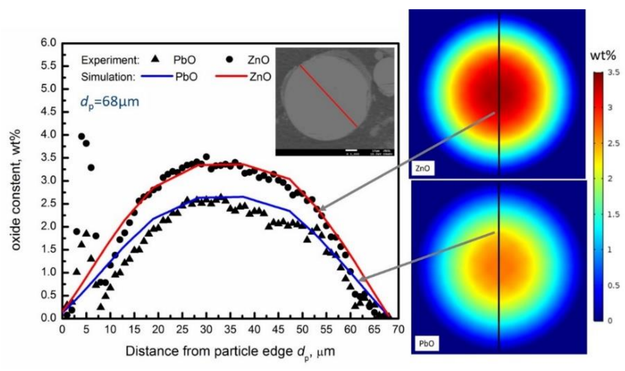

Figure 1: Comparison between the simulation results and the experimental data for the concentration profiles of ZnO and PbO, particle diameter equal to 68 μm

Particle residence time decreases with the increase of particle diameter. The simulation shows the particle of 68 μm will be completely melted during the ICP fuming, because its residence time (0.15 s) is longer than the melting time (0.04 s). However, a large particle of 150 μm is only partially melted due to the short residence time (Figure 2).

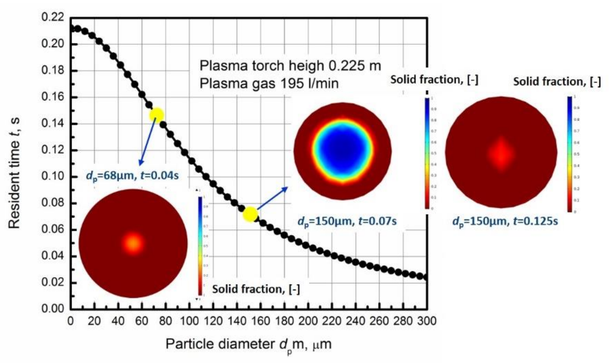

Figure 2: the relationship between residence time and particle diameter, and the melting degree of particles with different diameters when passing through the plasma torch

CONCLUSIONS

- ✓A mathematical model has been developed for ICP fuming.
- ✓Fick's second law was used to describe metallic oxide diffusion.
- ✓The predicted concentration profiles of zinc oxide and lead oxide are in good agreement with the measurements.
- ✓Lead fuming is faster than the zinc fuming.
- ✓Small particles are favorable for melting, and have a higher fuming rate.

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