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TECHNICAL PAPER

Breakage Mechanism of Mg During Ball Milling with NaCl, KCl and Urea for Nanopowder Production

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Abstract In this research, ball milling of magnesium fillings with NaCl, KCl and urea was investigated as a simple way to produce Mg nanoparticles. Effects of feed geometry and milling time on crush mechanism and product size were determined. Optical, scanning and transmission electron microscopes were used to study the morphology of the products. Spherical charge particles were milled under argon atmosphere with 10 wt% cuboidal NaCl at 250 rpm for 50 h. With ball to powder ratio of 10:1, the average diameter of the product was 17 nm. Addition of NaCl changed the breakage mechanism from ductile–ductile to ductile–brittle, reduced particle size, stopped agglomeration and prevented the undesirable adhesion of particles to walls and balls of the milling machine. Using more than 70 wt% NaCl resulted in conversion of the mechanism from ductile–brittle to brittle–brittle. This resulted in fracture of the particles, but reduced the yield of the system.

Keywords Breakage mechanism · Ball-milling · NaCl · KCl · Urea · Mg nanoparticles

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1 Introduction

Most known materials face alteration in properties like catalytic effect and absorptivity, as they move from macro to nano scale [1]. Significant role of the specific area in provision of desirable properties justify area enhancement by size reduction. Mg nanoparticles (Mg NPs) are suitable for advanced applications like hydrogen production [2], hydrogen storage [3], fuel driving force [4], biochemistry and biomedicine [5], batteries [6], composite fillers for phase strengthening [7] and ammonium perchlorate decomposition [20].

Efforts have been made to produce highly reactive nanoparticles. Conventional methods include chemical precipitation [4], plasma metal-hydrogen reaction [8], laser deposition [9], electro-sono-chemical procedure [10] and vapor deposition [11]. Because of complicated and expensive apparatus needed for large scale nano-particle production, these processes haven't been commercialized yet. Milling is, however, simple, clean, controllable and feasible at both small and large scale industries [12].

For ball-milling, powders are mixed with a desired number of balls in the same container and milled until a steady state smaller particle size is reached [13]. After some time, a balance is established between welding and fracture of the powders that causes enlargement and shrinkage of the particles respectively. Smaller particles resist fracture; but tend to enlarge temporarily via an impact welding process. Eventually, both small and large particles reach a relatively smaller mean diameter [14].

Ball-milling is much more complex than it seems. Various factors like milling machine, milling container, milling velocity, milling time, ball to powder ratio, empty portion of the container, control agent, milling medium condition, milling temperature and type and size of the