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Original Research Paper

Opto-magnetic properties of nano-structured MgO:Al powders prepared in a micro drop fluidized reactor

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ABSTRACT

Nano-structured MgO and MgO:Al powders were prepared in a continuous micro drop fluidization scheme with one step process. The optical and magnetic properties of MgO:Al powders were developed effectively by providing the micro drops with plausible contacting with micro bubbles by means of fluidization during the formation of powders. The micro shear force generated at the surface of micro drops during the formation stage could affect the defect-induced opto-magnetic properties of the MgO:Al powders. The doping effects of small amount of Al^{3+} (0.5 at.%) ions into MgO lattice could be enhanced considerably by adjusting the reaction condition such as flow rate of micro bubbles (U_{MB}). The bandgap energy became narrow and the surface area increased by the doping of Al^{3+} ions, with increasing U_{MB}. Both vacancies of oxygen and Mg^{2+} which were generated due to the doping of Al^{3+} ions in the micro drop fluidized reactor could affect the magnetic properties of MgO:Al, and the value of saturation magnetization of MgO:Al powders increased effectively with increasing U_{MB}.

1. Introduction

MgO has been particularly interested in the development of new materials due to its defect-induced magneto-optical and opto-electronic properties, in addition to the wide band gap structure and low cost. It can be extensively utilized in the fields of catalyst, remediation of toxic waste, refractory industry due to its optical, electronic, magnetic, thermal, mechanical and chemical properties [1–10]. For instances, the room temperature magnetism in MgO nanoparticles can have effects on the magnetic order in semiconductors, microelectronic devices and spintronics [11–14]. Foreign material doped MgO has been believed to have the abilities of catalytic performance for the gas phase hydrogenation of furfural [15–17], cathodoluminescence [18] and optical fiber amplifiers [19,20]. In addition, antibacterial activities of MgO nanoparticles in aqueous environments have been discussed by considering the characteristics for the formation of superoxide anions on the surface of powders [21–23].

The versatile properties of MgO has been developed by doping of foreign materials into the MgO lattice structure, since the wide band gap could permit the drastic modification of any possible electronic contribution in the lattice of host materials. Several ions like Li, N, Cr, Fe, Cu, Ni and Al have been used as dopant ions to develop and modify the unique features of MgO powders and films [12,17–19,24–27]. It has been noted that the properties of MgO and modified MgO by doping of foreign materials depending on the different demands of applications have been influenced by the preparation method and synthesis route. Because the grain size, structure of lattice, electron configuration and state, breaking and coupling of atoms and ions, and band gap structure could be determined by means of preparation pathway, which have been regarded as important parameters for tuning the properties of oxide materials [12,17–19,24–27].

The powders and films of doped and un-doped MgO have been prepared and modified by means of (nano)-templating method, vacuum annealing process, Sol-Gel, hydrothermal, (flame) spray pyrolysis, (co-)precipitation, combustion, and vapor phase oxidation methods [28–41]. However, most of them were batch system taking a long time, and required additional processes for the post treatment of prepared materials. In addition, the amount of prepared materials (powders or films) has been extremely small, since the reaction conditions have been highly restricted and uncontrollable. In order to develop and explore new functions of MgO materials, the reaction or formation conditions should be controllable and adjusted suitably. Therefore, more effective scheme has been

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required by making compromise the previous preparation methods for the continuous production, to meet the required functional materials with considerable production efficiency.

In the present study, thus, the micro drop fluidized reactor was employed to prepare nano-structured MgO and MgO:Al powders continuously with reasonable production efficiency. The reaction condition was controlled and adjusted in order to explore the opto-magnetic properties of MgO:Al powders, since the reaction condition is directly related to the prepared materials.

2. Experimental

The powders of MgO and MgO:Al were prepared in a micro drop fluidized reactor, which was composed of four parts such as micro drop generating, micro bubble generating, powder formation reaction and powder collection parts, as shown in Fig. 1. The micro drops containing the designed composition of precursor solutions were generated in the ultrasonic atomizing chamber (Htech Green Tech., 1.7 MHz) and transported to the top of the reactor by a carried gas. The micro bubbles, which were generated by using a micro bubble generator with a micro flow controller (MFC) [42–44], were injected to the bottom of the reaction part in a given flow rate (U_{MB}). The reaction condition was controlled by adjusting the flow rates of micro drop carrier gas (U_C) and micro bubbles (U_{MB}) in order to fluidize the micro drops during the reaction in the reaction part. The reaction temperature was kept at 1073 K using a vertical furnace with a temperature controller, which was optimum to prepare MgO:Al powders by using the micro drop fluidized reactor [42]. The prepared powders of MgO and MgO:Al were collected by using the powder collecting system, which was made of a thimble filter (ADVANTEC), connected to the end of the reaction part, vacuum pump, liquid scrubber and vent system. The precursor solutions contained a 0.4 M magnesium chloride 200 ml in deionized water and aluminum nitrate which was used as a source of Al ion. The atomic ratio of Al/Mg was 0 and 0.5 at.%.

X-ray patterns (XRD, MAX-2200Ultima, Rigaku Corp.) were used to confirm the prepared powders of MgO and MgO:Al. The light absorption ability of them were analyzed by using the diffuse reflectance spectra (DRS, Solidspec-3700, Shimadzu Corp.) with an UV–VIS-NIR spectrophotometer (Shimadzu, UV-3101 PC). The surface morphology and shape were analyzed by means of a field-emission scanning electron microscope (FE-SEM, JSM-7000F). To analyze the oxygen spectra X-ray photoelectron spectroscopy (XPS) was used with different oxygen coordination (XPS, VG ESCA-

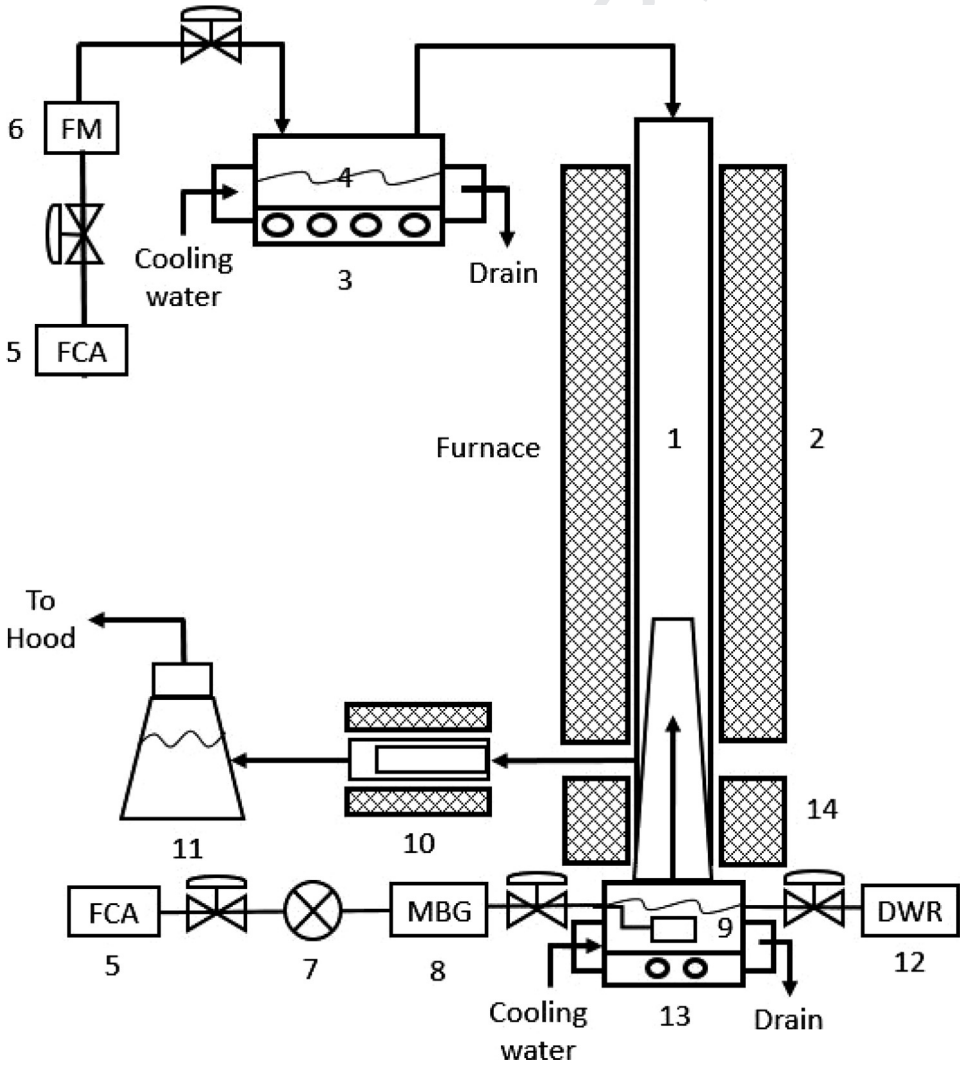

Fig. 1. Schematic diagram of experimental apparatus.1. Reactor, 2. Furnace, 3. Ultrasonic atomizer, 4. Precursor solution, 5. Filtered & compressed air, 6. Flow meter, 7. Regulator & controller, 8. Micro bubble Generator, 9. Micro bubble port, 10. Filter & collector, 11. Separator, 12. Distilled water reservoir, 13. Liquid foam generator, 14. Calming Section.

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