Effect of processing parameters on the properties of electrolytically prepared Mg(OH)$_2$ powders

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Abstract

In this paper, Mg(OH)$_2$ was prepared by the diaphragm electrolysis method using bischofite (MgCl$_2$·6H$_2$O). The influence of electrolysis process conditions such as current density, electrolysis temperature and electrolyte concentration on powder particle size is discussed. The electrolytic product Mg(OH)$_2$ powder was characterized by laser particle size analysis, XRD, SEM, BET, XRF, and DSC-TGA. The results show that the particle size of Mg(OH)$_2$ powder first increases and then decreases with increasing current density and reaches a maximum D50 value of 20.1 μm at a current density of 0.04 A cm$^{-2}$. The Mg(OH)$_2$ powder particle size first decreases, then increases and then decreases with increasing electrolysis temperature, at an electrolysis temperature of 60°C and 70°C, the particle size reaches a maximum D50 value of 23.8 μm and a minimum D50 value of 7.7 μm, respectively. The Mg(OH)$_2$ powder particle size first increases and then decreases with increasing electrolyte concentration and reaches a maximum D50 value of 22.3 μm at an electrolyte concentration of 0.7 mol l$^{-1}$. The Mg(OH)$_2$ powder prepared at a current density of 0.3 A cm$^{-2}$, electrolyte concentration of 0.3 mol l$^{-1}$ and an electrolysis temperature of 30°C shows an average particle size of 13.8 μm, a purity higher than 98.66%, and a sheet-like structure. The surface area is 58 m$^2$ g$^{-1}$. The Mg(OH)$_2$ powder can be decomposed at 300°C–400°C and calcined at 400°C for 2 h, through SEM and Scherrer formula calculation, the calcined product is nano-MgO powder with good crystallinity.

1. Introduction

Magnesium hydroxide is widely used in ceramic materials [1], environmental protection [2, 3], medicine and other fields because of its strong buffering performance, high activity and adsorption capacity, safety and nontoxicity [4–7]. It is one of the favoured products in the process of sustainable development strategy, environmental protection and beneficial ecological development [8–10]. Among them, high-purity ultrafine magnesium hydroxide is the most important raw material for producing high-purity nano magnesium oxide, so how to prepare high-purity ultrafine magnesium hydroxide has become a current research focus [11–13].

At present, the preparation methods for magnesium hydroxide mainly include physical methods and chemical methods. The physical method involves directly pulverizing brucite ore. The process is simple, but the product purity is low, and the particle size is not easy to control. Chemical methods include the sodium hydroxide method, ammonia method, and lime milk method. The sodium hydroxide method involves simple operation, a high product purity and easy control of particle size but requires specialist equipment with high production cost [14, 15]; the ammonia method reaction is easy to control and the product purity is high, but due to the volatile nature of the ammonia water, the product utilization rate during production is low, and the operation environment is poor and it is easy to generate environmental pollution [16, 17]; the lime milk method is simple to operate and has low equipment requirements, but the product purity is low and cannot be applied to the high-end market [18, 19].

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The electrolysis method refers to the process in which charged ions in an electrolyte solution move to the two poles under the action of an electric field and discharge on the plates to generate products. The reaction of this method is easy to control, and the prepared products have a small particle size and high purity \[20, 21\]. At present, there are few studies on the properties of Mg(OH)$_2$ powder prepared by electrolysis, and there is no report on the effect of processing parameters on product particle size. Therefore, it is of great practical application value and theoretical significance to determine the effect of processing parameters on the performance of Mg(OH)$_2$ powder preparation by electrolysis.

In this paper, magnesium hydroxide powder was prepared by the electrolysis method using waste bischite (MgCl$_2$·6H$_2$O) after potassium extraction from salt lakes. The chlorine generated in the process can be collected and applied to the industrial production of PVC, realizing the dual comprehensive utilization of waste resources and harmful byproducts and developing a process flow for the preparation of harmless magnesium hydroxide. There are many process parameters affecting electrolytic pulverization, including the current density, electrolysis temperature, electrolyte concentration, electrode spacing, and continuous electrolysis time. This paper focuses on the effects of current density, electrolysis temperature and electrolyte concentration on the particle size of the powder and carries out performance characterization and application exploration of the electrolytic product magnesium hydroxide, which lays the foundation for subsequent product application.

2. Experiment

The anode plate is a titanium plate whose surface is covered with RuO$_2$ and TiO$_2$, and the cathode material is a titanium plate \[22\], which is separated by a layer of PTFE film placed between the cathode and anode tanks.

Reagents used in the experiment include analytically pure magnesium chloride hexahydrate (Sinopharm Chemical Reagent Co., Ltd); anhydrous ethanol (Tianjin Zhiyuan Chemical Reagent Co., Ltd); deionized water (homemade).

Instruments used in the experimental process include homemade electrolytic tank (figure 1), DC regulated power supply (ITECH IT6720), circulating water vacuum pump (SHZ-D (III)), Blast drying oven (DHG-9075A), constant temperature water bath (SYP-IIIB).

The prepared magnesium chloride solution with a certain concentration was added to a homemade electrolytic tank, which was placed in a constant temperature water bath for 1 h so that the temperature of the solution reached the water bath temperature. The plates and diaphragms were installed, the electrodes were connected, and the DC regulated power supply was turned on for electrolysis. During the electrolysis process, according to the concentration of the solution, the prepared magnesium chloride solution was added at regular intervals to supplement the electrolyzed magnesium ions. After electrolysis, the precipitate was removed for filtration, washed twice with deionized water and anhydrous ethanol, placed in a drying oven, and dried at 80 °C for 12 h to obtain the magnesium hydroxide product.

The principle of electrolysis is shown in figure 1. The main reaction is expressed as follows:

Anode: $2\text{Cl}^- \rightarrow 2\text{e}^- \rightarrow \text{Cl}_2$

Cathode: $\text{Mg}^{2+} + 2\text{OH}^- \rightarrow \text{Mg(OH)}_2$

$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^- + \text{H}_2$

The particle size of the powder was characterized by a 2600E laser particle size analyser (Dandong Baite); the microstructure of the powder was observed by a S4800 field emission scanning electron microscope (Hitachi, Figure 1. Electrolysis device and schematic diagram.
3. Results and discussion

3.1. Effect of current density on particle size of Mg(OH)$_2$ powder

Under the condition that the process parameters, such as electrolyte concentration 0.3 mol l$^{-1}$, electrolysis temperature 30$^\circ$C, electrode spacing 4 cm, and electrolysis time 4 h, remain unchanged, the effect of different current densities on the particle size of Mg(OH)$_2$ powder was investigated. The current densities were taken as 0.01 A cm$^{-2}$, 0.02 A cm$^{-2}$, 0.03 A cm$^{-2}$, 0.04 A cm$^{-2}$ and 0.05 A cm$^{-2}$. The results are shown in figure 2.

It can be observed from figure 2(a) that with a gradual increase in the current density, the particle size of the Mg(OH)$_2$ powder increases first and then decreases and reaches a maximum D50 value of 20.1 $\mu$m when the current density is 0.04 A cm$^{-2}$.

According to figure 2(b), double peaks are clearly observed at a current density of 0.02 A cm$^{-2}$ and 0.05 A cm$^{-2}$, indicating that the particle size dispersion and uniformity for the products obtained in these two experiments are relatively poor, and the particle size distribution curves for the products obtained under the other current densities are relatively smooth with no obvious double peak, indicating that the product particle size has good dispersion and uniformity.

Current density is an important parameter in electrolysis production and directly affects production efficiency and product quality. The higher the current density, the greater the number of OH$^-$ ions generated in the cathode per unit time, the greater the number of Mg(OH)$_2$ nuclei generated, the greater the deposition rate compared to the growth rate, and the finer the grains. The smaller the crystal grains, the greater the surface energy, and the more obvious the agglomeration of the crystal grains, which is reflected in the increase in the particle size of the Mg(OH)$_2$ powder in the macroscopic view that reaches a maximum value at 0.04 A cm$^{-2}$. At a current density of 0.05 A cm$^{-2}$, the particle size of the powder suddenly sharply decreases, which may be due to two reasons: one is that the relatively large current density increases the nucleation rate of the crystal, the newly formed crystal nucleus occupies the space for crystal growth, and the crystal does not have time to grow, which makes the particle size of the powder smaller; second, the existence of stress in the powder makes it difficult for particles to agglomerate or the powder after agglomeration is redispersed. In addition, from the appearance, the surface uniformity of the powder prepared at a current density of 0.05 A cm$^{-2}$ is poor, indicating that the powder prepared under this condition may be agglomerated and show poor dispersibility. Agglomeration occurs, but a powder with a smaller D50 is obtained, which further proves that the existence of internal stress redisperses the agglomerated powder.

The XRD pattern for the powder prepared by electrolysis (figure 2(c)) shows that the width of the diffraction peak of the Mg(OH)$_2$ crystal gradually increases and the peak intensity decreases when the current density is increased from 0.01 A cm$^{-2}$ to 0.03 A cm$^{-2}$, indicating that the crystal grain size is gradually reduced; when the current density is greater than 0.03 A cm$^{-2}$, the width and peak intensity of the diffraction peak are basically unchanged, and the crystal grain size is basically unchanged. As the current density increases, the nucleation rate of the crystal is higher than the growth rate of the crystal, so the crystal size decreases and reaches equilibrium after a certain degree, and the size remains unchanged. It can be observed from the peak intensity in figure 2(c)
that the Mg(OH)₂ crystals preferentially grow on the (001), (101) and (110) crystal planes. According to the crystal and molecular structure diagram of Mg(OH)₂ shown in figure 3(b), the primitive planes grow on the (001) crystal plane, while the number of primitive layers grows on the (101) and (110) crystal planes [23]. The primitive planes and the number of primitive layers increase at the same time, and the crystal grain size increases.

Figure 3 shows the Mg(OH)₂ crystal structure (a) and molecular structure (b). The figure shows that Mg²⁺ (blue) occupies the interstitial position of the octahedron formed by OH⁻ (red), and the octahedrons are arranged in a common edge manner to form the Mg(OH)₂ molecular structure. OH⁻ (red) forms a face-centred cubic structure, while Mg²⁺ (blue) is located on the diagonal of the face-centred cubic structure, which is similar to the crystal structure of diamond.

3.2. Effect of electrolysis temperature on the particle size of Mg(OH)₂ powder

Under the condition that the process parameters, such as electrolyte concentration 0.3 mol l⁻¹, current density 0.03 A cm⁻², electrode spacing 4 cm, and electrolysis time 4 h, remain unchanged, the effect of different electrolysis temperatures on the particle size of Mg(OH)₂ powder was investigated. The electrolysis temperatures were taken as 20 °C, 30 °C, 40 °C, 50 °C, 60 °C and 70 °C. The results are shown in figure 4.

It can be observed from figure 4(a) that with a gradual increase in the electrolysis temperature, the particle size of the Mg(OH)₂ powder shows a trend of first decreasing, then increasing and then decreasing, reaching a maximum D₅₀ value of 23.8 μm and a minimum D₅₀ value of 7.7 μm at an electrolysis temperature of 60 °C and 70 °C, respectively.

According to figure 4(b), when the electrolysis temperature is 70 °C, the particle size distribution curve for the Mg(OH)₂ powder is skewed to the left, indicating that the powder particle size is small at this temperature, and there are obvious double peaks, indicating that the particle size dispersion and uniformity are relatively poor. The particle size distribution curves for the products obtained at other temperatures are relatively smooth, and there is no obvious double peak, indicating that the products have good dispersibility and uniformity.

Powder agglomeration is the result of the combined action of surface energy and internal stress. When the electrolysis temperature is lower than 30 °C, the temperature increases, which promotes crystal growth, the crystal particle size increases continuously, the surface energy decreases, and the internal stress of the powder is large, which reduces the agglomeration problem between magnesium hydroxide particles and improves its dispersibility, so the particle size for the Mg(OH)₂ powder shows a decreasing trend first. When the temperature is higher than 30 °C, the particle size of the powder gradually increases because the stress in the powder gradually decreases with increasing temperature, and the dispersion trend for the agglomerated powder decreases, so the particle size of the Mg(OH)₂ powder increases at this time. The surface uniformity of the powder prepared at 70 °C is poor, indicating that the powder prepared under this condition can appear agglomerated and the dispersibility may be poor. However, as observed from figure 4(d), the powder is in the form of flakes, which is not conducive to the perfect growth of crystals, and the internal stress between the powders is large, which leads to re-dispersal of the agglomerated powders, and the macroscopic data reflects the fact that the powder particle size decreases sharply at this temperature.

The XRD pattern for the powder prepared by electrolysis (figure 4(c)) shows that with increasing electrolysis temperature, the diffraction peaks due to the (001), (101) and (110) crystal planes gradually increase, indicating that Mg(OH)₂ crystals preferentially grow on the (001), (101) and (110) crystal planes; that is, the increase in the number of primitive layers and primitive planes at the same time will inevitably increase the size of a single crystal. In addition, a high electrolysis temperature promotes the growth of crystals, which is why the crystal size
increases with increasing electrolysis temperature [24, 25]. When the electrolysis temperature is 70 °C, the diffraction peak of the (001) crystal plane is significantly enhanced, indicating that the primitive plane obtained under this condition grows better than the number of primitive layers, the shape tends to be thinner and flake-like, and the increased internal stress leads to the redispersal of the agglomerated powder.

3.3. Effect of electrolyte concentration on particle size of Mg(OH)$_2$ powder

Under the condition that the process parameters, such as current density 0.03 A cm$^{-2}$, electrolysis temperature 30 °C, electrode spacing 4 cm, and electrolysis time 4 h, remain unchanged, the effect of different electrolyte concentrations on the Mg(OH)$_2$ powder particle size was investigated. The electrolyte concentrations were taken as 0.05 mol l$^{-1}$, 0.1 mol l$^{-1}$, 0.3 mol l$^{-1}$, 0.5 mol l$^{-1}$, 0.7 mol l$^{-1}$, 0.9 mol l$^{-1}$ and 1.5 mol l$^{-1}$. The results are shown in figure 5.

Figure 5(a) shows that with a gradual increase in the electrolyte concentration, the particle size of the Mg(OH)$_2$ powder shows a trend of first increasing and then decreasing, reaching a maximum D50 value of 22.3 μm at an electrolyte concentration of 0.7 mol l$^{-1}$.

As shown in figure 5(b), when the electrolyte concentration is 0.05 mol l$^{-1}$ and 0.1 mol l$^{-1}$, the Mg(OH)$_2$ powder particle size is small and relatively concentrated and has good dispersibility. When the electrolyte concentration is greater than 0.1 mol l$^{-1}$, the particle size distribution of the Mg(OH)$_2$ powder is relatively uniform.

From the XRD patterns (figure 5(c)), when the electrolyte concentration is 0.05 mol l$^{-1}$, the diffraction peak due to the (001) crystal plane is significantly stronger in intensity than that for other crystal planes, indicating that the growth of the primitive plane is better than that of the number of primitive layers, which is not conducive to the perfect growth of the crystal, and the internal stress between the powders is large, which leads to redispersal of the agglomerated powder, and the macroscopic data reflects the fact that the powder particle size is smaller under the electrolyte concentration. With a gradual increase in the electrolyte concentration, the
concentration of magnesium ions increases, the speed of Mg(OH)$_2$ grain deposition is large, and the dispersibility is poor, which leads to an increase in powder particle size. When the demolition concentration is greater than 0.07 mol l$^{-1}$, the crystal growth rate is higher than the crystal nucleation rate, the crystal size is larger, the surface energy is reduced, the agglomeration phenomenon is weakened, and the stress dispersion effect works together, resulting in the particle size of Mg(OH)$_2$ powder showing a decreasing trend.

### 3.4. Characterization of Mg(OH)$_2$ powder properties

The electrolytic product Mg(OH)$_2$ powder prepared at a current density of 0.3 A cm$^{-2}$, an electrolyte concentration of 0.3 mol l$^{-1}$ and an electrolysis temperature of 30 °C was characterized by XRF, BET, SEM, XRD and DSC-TGA, and the results are discussed below.

Table 1 shows the results of analysing the content of impurity elements in Mg(OH)$_2$ powder by x-ray fluorescence spectrometry. The Mg(OH)$_2$ powder purity is higher than 98.66%, which belongs to high purity products and can be used in high-end fields with high added value.

![Figure 5.](image1.png)

#### Figure 5. Effect of MgCl$_2$ concentration on Mg(OH)$_2$ powder: (a) powder particle median diameter, (b) powder particle size distribution, (c) powder XRD patterns.

| Element | Fe  | Ba  | CaO | SiO$_2$ | SO$_4^{2-}$ | Cl$^-$ | Mg(OH)$_2$ |
|---------|-----|-----|-----|---------|----------|------|------------|
| Content (wt%) | <0.01 | <0.01 | 0.05 | <0.05 | <0.001 | 1.22 | >98.66 |

Figure 6 shows the SEM patterns for the Mg(OH)$_2$ powder. It can be observed from the figure that the product is a sheet-like structure, the particle size is small and the thickness is small, most of the particles are less than 100 nm in size, and the agglomeration phenomenon is obvious.

The specific surface area of the Mg(OH)$_2$ powder was detected, and its specific surface area can reach 58 m$^2$ g$^{-1}$.

Figure 7 shows the XRD pattern for Mg(OH)$_2$ powder. According to the figure, the purity of the product is relatively high, and Mg(OH)$_2$ crystals preferentially grow on the (001), (101) and (110) crystal planes, with the growth rate on the (101) crystal plane particularly more pronounced.

Figure 8 shows the differential scanning calorimetry-thermogravimetric analysis of Mg(OH)$_2$ powder. It can be observed from the figure that the electrolysis product Mg(OH)$_2$ begins to decompose at approximately 300 °C, and the decomposition is completed at approximately 400 °C. There are mainly two stages of mass loss in the process: In the temperature range of 300 °C–350 °C, the mass loss rate of Mg(OH)$_2$ is relatively high, indicating that the dehydration of Mg(OH)$_2$ is faster at this stage. The water loss process of the sample continues in the temperature range of 350 °C–400 °C, but the mass loss rate of the samples is significantly reduced at this stage, and the kinetic rate of the water loss process is slow, which may be due to the diffusion of product water in the particles in the later stage of weight loss being hindered by the magnesium oxide film, resulting in a decrease in the weight loss rate of magnesium hydroxide [26, 27].

### 3.5. Preparation of nano-MgO by Mg(OH)$_2$

The product Mg(OH)$_2$ powder was calcined at 400 °C for 2 h to obtain MgO powder, which was analysed by XRD and SEM. The results are shown in figures 9 and 10.

Figure 9 shows the XRD pattern obtained for the powder after calcination of Mg(OH)$_2$ powder. According to the figure, the purity of the product is relatively high, and Mg(OH)$_2$ crystals preferentially grow on the (001), (101) and (110) crystal planes, with the growth rate on the (101) crystal plane particularly more pronounced.

Figure 10 shows the SEM pattern for the Mg(OH)$_2$ powder. It can be observed from the figure that the calcined product is MgO, the diffraction peak is sharp, and the peak width is
very narrow, indicating that the product has good crystallization along the (200) crystal plane. There are no other impurity peaks. Using the Scherer formula to calculate the particle size of MgO crystals, the particle size is less than 100 nm, which meets the standard for nano-MgO. Figure 10 shows the SEM pattern for the MgO powder. It can be observed that most of the MgO crystal particle sizes are less than 100 nm, which is consistent with the calculation result obtained from the Scherrer formula, which further shows that the electrolytic product Mg(OH)₂ powder can be used to prepare nano-MgO powder.

4. Conclusion

The particle size of Mg(OH)₂ powder first increases and then decreases with increasing current density and reaches a maximum D50 value of 20.1 μm at a current density of 0.04 A cm⁻². The Mg(OH)₂ powder particle size first decreases, then increases and then decreases with increasing electrolysis temperature, at an electrolysis temperature of 60 °C and 70 °C, the particle size reaches a maximum D50 value of 23.8 μm and a minimum D50 value of 7.7 μm, respectively. The Mg(OH)₂ powder particle size first increases and then decreases with increasing electrolyte concentration and reaches a maximum D50 value of 22.3 μm for an electrolyte concentration of 0.7 mol l⁻¹. The Mg(OH)₂ powder prepared at a current density of 0.3 A cm⁻², electrolyte concentration of 0.3 mol l⁻¹ and an electrolysis temperature of 30 °C shows an average particle size of 13.8 μm, a
purity higher than 98.66%, and a sheet-like structure. The surface area is 58 m² g⁻¹. It can be decomposed at 300 °C–400 °C and calcined at 400 °C for 2 h, through SEM and Scherrer formula calculation, the calcined product is nano-MgO powder with good crystallinity.

**Data availability statement**

All data that support the findings of this study are included within the article (and any supplementary files).

**Author contributions**

Lili Guo is the experimental designer and executor of this study, completing the data analysis and writing the first draft of the paper; Zhen Li, Xinzhong Deng, Na Chen, Li Yang and Yang Su participated in the experimental design and analysis of the experimental results; Xiaomin Wang directed experimental design, data analysis, paper writing and revision. All authors read and agree to the final text.
Figure 10. SEM patterns for MgO powders.

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References

[1] Bedair T M et al 2021 Biocompatible and functional inorganic magnesium ceramic particles for biomedical applications J. Biomaterials Science. 9 1903–23
[2] Wu S et al 2021 Polarization of CO2 for improved CO2 adsorption by MgO and Mg(OH)2 J. Applied Surface Science. 562 150187
[3] Das P S et al 2018 Unique microstructure of 3D self-assembled Mg(OH)2 nanoparticles for methylene blue degradation in presence of direct sun light J. Transactions of the Indian Ceramic Society. 77 226–34
[4] El Bouraie M and Masoud A A 2017 Adsorption of phosphate ions from aqueous solution by modified bentonite with magnesium hydroxide Mg(OH)2 J. Applied Clay Science. 140 57–64
[5] Mochane M J, Mokhothu T H and Mokhena. T C 2022 Synthesis, mechanical, and flammability properties of metal hydroxide reinforced polymer composites: a review J. Polymer Engineering & Science. 62 64–65
[6] Hajibeygi M et al 2021 Fabrication and study of thermal and combustion resistance of DOPO-functionalized polyamide reinforced with organo-modified Mg(OH)2 nanoparticles J. Polymer International. 70 317–30
[7] Luevano-Hipolito E and Martinez L M T 2018 Mg(OH)2 films prepared by ink-jet printing and their photocatalytic activity in CO2 reduction and H2O conversion J. Topics in Catalysis. 61 1574–84
[8] Li X J, Guo R S and Qian X D 2021 Preparation and absorption carbon monoxide properties of a novel flame retardants based fire-fighting J. Foams and Frontiers in Materials. 8 646509
[9] Liu X M et al 2020 Research progress in the environmental application of magnesium hydroxide nanomaterials J. Surfaces and Interfaces. 21 106701
[10] Shen H Y and Liu Y Z 2018 One-step synthesis of hydrophobic magnesium hydroxide nanoparticles and their application in flame-retardant polypropylene composites J. Chinese Journal of Chemical Engineering. 26 2199–205
[11] Liu S S et al 2021 Preparation of aerogel Mg(OH)2 nanosheets by a combined sol–gel-hydrothermal process and its calcined MgO towards enhanced degradation of paraoxon pollutants J. Journal of Sol–Gel Science and Technology. 99 122–31
[12] Calderón D J et al 2020 Effect of synthesis variables on the characteristics of magnesium hydroxide nanoparticles and evaluation of the fluorescence of functionalised Mg(OH)2 nanoparticles J. Advances in Natural Sciences: Nanoscience and Nanotechnology. 11 025008
[13] Karthik K et al 2019 Fabrication of MgO nanostructures and its efficient photocatalytic, antibacterial and anticancer performance J. Journal of Photochemistry and Photobiology B: Biology. 190 6–20
[14] Nelh Ravathi C et al 2011 Synthesis and anion-exchange reactions of a new anionic clay alpha-magnesium hydroxide J. Journal of Colloid and Interface Science. 354 793–7
[15] Sun Q et al 2015 Preparation of transparent suspension of lamellar magnesium hydroxide nanocrystals using a high-gravity reactive precipitation combined with surface modification J. Industrial & Engineering Chemistry Research. 54 666–71
[16] Chai S et al 2021 Controlled synthesis of Mg(OH)2 nanorods using basic magnesium chloride as precursor J. Molecular Crystals and Liquid Crystals. 724 90–101
[17] Jiang D M et al 2019 Preparation of mesoporous spherical magnesium hydroxide particles via the static self-assembled method J. Journal of Molecular Structure. 1175 858–64
[18] Yousefi S and Ghasemi B 2021 Mg(OH)$_2$ nanostructures using impure brine: optimization of synthesis parameters by taguchi robust design and study of optical properties J. Research on Chemical Intermediates 47 2029–47
[19] Wu C Y et al 2018 Preparation of magnesium oxysulfate cement using magnesium-rich byproducts from the production of lithium carbonate from salt lakes J. Construction and Building Materials. 172 597–607
[20] Kang J et al 2021 Galvanostatic electrochemical deposition of Cu-doped Mg(OH)$_2$ thin films and fabrication of p–n homojunction J. Materials Research Bulletin. 137 111207
[21] Nieto C H D et al 2019 Membrane electrolysis for the removal of Mg$^{2+}$ and Ca$^{2+}$ from lithium rich brines J. Water Research. 154 117–24
[22] Pan X J et al 2020 Electrochemical separation of magnesium from solutions of magnesium and lithium chloride J. Hydrometallurgy. 191 105166
[23] Wu J S, Du J and Gao Y M 2014 Crystal growth morphology of magnesium hydroxide J. Turkish Journal of Chemistry. 38 402–12
[24] Battaglia G et al 2022 Analysis of particles size distributions in Mg(OH)$_2$ precipitation from highly concentrated MgCl$_2$ solutions J. Powder Technology. 398 117106
[25] Wang S Y et al 2016 Characterizations and preparation of Mg(OH)$_2$ nanocrystals through ultrasonic–hydrothermal route J. Research on Chemical Intermediates. 42 4135–45
[26] Turner R C, Hoffman I and Chen D 2011 Thermogravimetry of the dehydration of Mg(OH)$_2$ J. Canadian Journal of Chemistry. 41 243–51
[27] Liu C J, Liu T and Wang D J 2018 Non-isothermal kinetics study on the thermal decomposition of brucite by thermogravimetry J. Journal of Thermal Analysis and Calorimetry. 134 2339–47
[28] Hafeez M et al 2020 Green synthesis of cobalt oxide nanoparticles for potential biological applications J. Materials Research Express 7 025019