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Structural, Electromagnetic and Microwave Properties of Magnetite Extracted from Mill Scale Waste via Conventional Ball Milling and Mechanical Alloying Techniques

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Abstract: This study presents the utilization of mill scale waste, which has attracted much attention due to its high content of magnetite (Fe_3O_4). This work focuses on the extraction of Fe_3O_4 from mill scale waste via magnetic separation, and ball milling was used to fabricate a microwave absorber. The extracted magnetic powder was ground-milled using two different techniques: (i) a conventional milling technique (CM) and (ii) mechanical alloying (MM) process. The Fe_3O_4/CM samples were prepared by a conventional milling process using steel pot ball milling, while the Fe_3O_4/MM samples were prepared using a high-energy ball milling (HEBM) method. The effect of milling time on the structural, phase composition, and electromagnetic properties were examined using X-ray diffraction (XRD) and a vector network analyzer (VNA). XRD confirmed the formation of magnetite after both the magnetic separation and milling processes. The results revealed that Fe_3O_4 exhibited excellent microwave absorption properties because of the synergistic characteristics of its dielectric and magnetic loss. The results showed that the Fe_3O_4/CM particle powder had a greater absorption power (reflection loss: <-10 dB) with 99.9% absorption, a minimum reflection loss of -30.83 dB, and an effective bandwidth of 2.30 GHz for 2 mm thick samples. The results revealed the Fe_3O_4/MM powders had higher absorption properties, including a higher RL of -20.59 dB and a broader bandwidth of 2.43 GHz at a matching thickness of only 1 mm. The higher microwave absorption performance was attributed to the better impedance matching property caused by the porous microstructure. Furthermore, the magnetite, Fe_3O_4 showed superior microwave absorption characteristics because of the lower value of permittivity, which resulted in better impedance matching. This study presents a low-cost approach method by reutilizing mill scale waste to fabricate a high purity crystalline Fe_3O_4 with the best potential for designing magnetic nano-sized based microwave absorbers.

Keywords: magnetite (Fe_3O_4); mill scale; conventional milling (CM); mechanical alloying milling (MM); microwave; electromagnetic properties

Citation: Elmahaishi, M.F.; Azis, R.S.; Ismail, I.; Mustaffa, M.S.; Abbas, Z.; Matori, K.A.; Muhammad, F.D.; Saat, N.K.; Nazlan, R.; Ibrahim, I.R.; et al. Structural, Electromagnetic and Microwave Properties of Magnetite Extracted from Mill Scale Waste via Conventional Ball Milling and Mechanical Alloying Techniques. *Materials* **2021**, *14*, 7075. https://doi.org/10.3390/ma14227075

Academic Editor: Jose Antonio Alonso

Received: 30 September 2021
Accepted: 9 November 2021
Published: 22 November 2021

1. Introduction

Microwave absorbing materials (MAMs) are materials that can interact with electromagnetic (EM) waves and dissipate into other forms of thermal energy through their electric