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Magnetic and catalytic properties of cubic copper ferrite nanopowders synthesized from secondary resources

M.M. Rashad [a,*], R.M. Mohamed [a,b,c], M.A. Ibrahim [a], L.F.M. Ismail [d], E.A. Abdel-Aal [a]

[a] Advanced materials department, Central Metallurgical R&D Institute, CMRDI, P.O. Box 87 Helwan, Cairo, Egypt
[b] Chemistry Department, Faculty of Science, King Abdulaziz University, P.O. Box : 80203 Jeddah: Saudi Arabia
[c] Center of Excellence in Environmental Studies, King Abdulaziz University, P.O Box: 80216 Jeddah 21589, Saudi Arabia
[d] Chemistry Department, Faculty of Science, Al-Azhar Universty, Cairo, Egypt

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ABSTRACT

Cubic copper ferrite $CuFe_2O_4$ nanopowders have been synthesized via a hydrothermal route using industrial wastes. The synthesis conditions were systematically studied using statistical design (Box–Behnken Program) and the optimum conditions were determined. The results revealed that single phase of cubic copper ferrite powders can be obtained at different temperatures from 100 to 200 °C for times from 12 to 36 h with pH values 8–12. The crystallite size of the produced powders was in the range between 24.6 and 51.5 nm. The produced copper ferrite powders were appeared as a homogeneous pseudo-cubic-like structure. A high saturation magnetization (M_s 83.7 emu/g) was achieved at hydrothermal temperature 200 °C for 24 h and pH 8. Photocatalytic degradation of the methylene blue dye using copper ferrite powders produced at different conditions was investigated. A good catalytic efficiency was 95.9% at hydrothermal temperature 200 °C for hydrothermal time 24 h at pH 12 due to high surface area (118.4 m^2/g).

1. Introduction

Copper ferrite ($CuFe_2O_4$) is one of the important spinel ferrites MFe_2O_4 because it exhibits phase transitions, changes semiconducting properties, shows electrical switching and tetragonality variation when treated under different conditions in addition to interesting magnetic and electrical properties with chemical and thermal stabilities [1]. It is used in the wide range of applications in gas sensing [2], catalytic applications [3–5], Li ion batteries [6] high density magneto-optic recording devices, color imaging, bioprocessing, magnetic refrigeration and ferrofluids [1,7]. Moreover, $CuFe_2O_4$ assumes great significance because of its high electric conductivity, high thermal stability and high catalytic activity for O_2 evolution from alumina–cryolite system used for aluminum production [8].

$CuFe_2O_4$ is known to exist in tetragonal and cubic structures. Under slow cooling Cu-ferrite crystallizes in a tetragonal structure with lattice parameter ratio c/a of about 1.06. Tetragonal phase of Cu-ferrite has inverse spinel structure with almost all Cu^{2+} ions occupying octahedral sublattice, whereas Fe^{3+} ions divide equally between the tetrahedral and octahedral sublattices [9]. The tetragonal structure is stable at room temperature and transforms to cubic phase only at a temperature of 360 °C and above due to Jahn–Teller distortion. The distortion is directly related to the magnetic properties. The cubic structure possesses a larger magnetic moment than that of the tetragonal one, because there are more cupric ions (Cu^{2+}) at tetrahedral sites in cubic structure as compared to that in the case of tetragonal structure [10]. Nanosized copper spinel ferrites show unusual properties in comparison with their bulk analogs and receive enormous attention during last decade because of their potential applications. They can be obtained by variety of methods such as solid state reaction [11], mechanochemical [12], sol–gel [13], co-precipitation [14], and combustion synthesis [15], polyol route [16] and microemulsion-hydrothermal route [17]. Most of the previous route led to the formation of tetragonal copper ferrite. From the best of our knowledge, a rarely reported mentioned the synthesis of cubic copper ferrite powders via the hydrothermal route. The correlation between the magnetic and catalytic properties and the microstructure of the produced cubic copper ferrite via the hydrothermal technique need intensive work.

Due to the potential applications of ferrites, recently, special attention is focused to synthesis ferrites from industrial wastes. Copper ferrite $CuFe_2O_4$ is prepared from copper sludge which collected from a filter press of waste-water treatment process in a surface finishing plant with analytical grade iron oxide powder using ball milling technique [18]. Nano-sized magnetic particles are synthesized from spent pickling liquors by ultrasonic-assisted chemical co-precipitation [19]. Furthermore, $Zn_xFe_{3-x}O_4$, $Ni_xFe_{3-x}O_4$

* Corresponding author. Tel./fax: +20 2 25010639.
E-mail address: rashad133@yahoo.com (M.M. Rashad).

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