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Magnetization study in solid state formation of lithium-titanium ferrites synthesized by electron beam heating

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ABSTRACT

The solid state formation of substituted lithium-titanium ferrites with chemical formula $Li_{0.5(1+x)}Fe_{2.5-1.5x}Ti_xO_4$ (x = 0.2; 0.4) prepared by two different methods were studied by X-ray diffraction and saturation magnetization analyzes. For the first method, lithium-titanium ferrites were prepared by conventional solid state synthesis in laboratory furnace at temperatures of 600, 700 and 750 °C and times of 0, 10, 20, 30, 60, and 120 min. For the second method, the samples were obtained by heating of reaction mixtures in high-energy (2.4 MeV) electron beam using similar time-temperature mode. XRD analysis results for all samples showed a high degree formation of lithium-titanium ferrites, obtained by high-energy electron beam heating at lower temperatures and times of synthesis compared with standard thermal heating. Such samples are characterized by the high values of saturation magnetization due to lithium-titanium ferrites formation. The observed radiation effect consists in significant decrease of the temperature and time of ferrite synthesis compared to conventional thermal heating in high-temperature furnaces.

1. Introduction

It is known that lithium ferrites are widely used in microwave technique [1,2]. To improve the magnetic and electric properties, lithium ferrites are modified by substituting magnetic and/or diamagnetic cations for Fe^{3+} ions. In particular, lithium-titanium ferrites with a formula $Li_{0.5(1+x)}Fe_{2.5-1.5x}Ti_xO_4$ have a high electrical resistance, since the introduction of Ti^{4+} ions in the lithium spinel reduces the formation of Fe^{2+} ions [3,4]. Usually, such ferrites are prepared by the conventional ceramic double sintering method in which solid state reactions between oxides and/or carbonates require prolonged heating at high temperatures that leading to the evaporation of Li_2O from reagents mixture and the increasing of Fe^{2+} ions [5]. As a result, the saturation magnetization and electrical resistance of ferrites are lowered that limiting their use in microwave applications, where high saturation magnetization and high resistivity are required [1]. Thus, achieving of chemical and phase composition homogeneity in the synthesized products are essential conditions that define high mark of functional ferrite materials and products based on them.

The developers try to increase the efficiency of ferrite synthesis by application of special methods, including mechanochemical [6–10], microwave [11], and sonochemical [12,13] treatments of the reaction mixtures. The ferrite materials, obtained by above methods, are extensively studied due to their desirable electric and magnetic properties that render ferrite attractive in microwave applications.

In previously work [14,15], it was demonstrated that the heating of ferrite materials by a high-power beam of accelerated electrons is an efficient method for intensification of solid state reactions and for increasing of phase composition homogeneity. This method is called radiation-thermal (RT) because it combines simultaneous influence of thermal and radiation factors. RT method was successfully tested in the synthesis of some ferrite systems, such as hexaferrites [16], Ni–Zn ferrites [17], lithium substituted ferrites [18,19]. In Ref. [20], the radiation effect of the intensification of ferrite phase formation in Li_2CO_3–TiO_2–Fe_2O_3 system was established by XRD and thermogravimetry analyzes. However, the magnetic properties of lithium-titanium ferrites obtained by RT heating were not extensively investigated.

Thus, in this paper, we report the investigated results of

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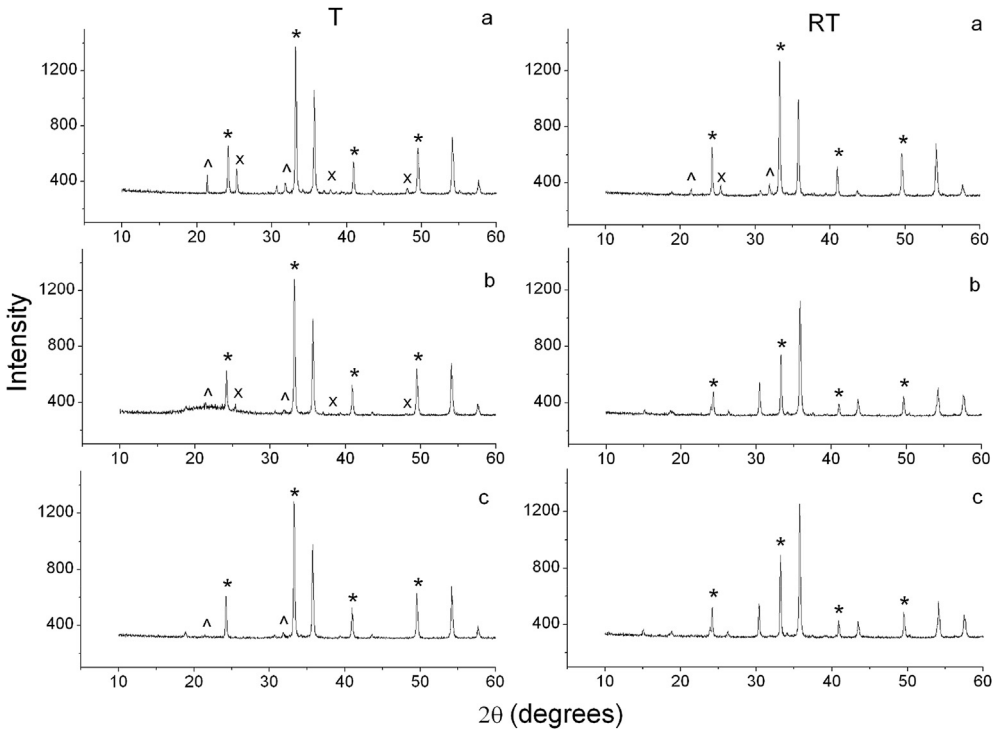

Fig. 1. XRD patterns for $Li_{0.5(1+x)}Fe_{2.5-1.5x}Ti_xO_4$ (x = 0.2) synthesized by T and RT heating at 600 °C and 0 (a), 30 (b), and 120 (c) min. Fe_2O_3 (*), Li_2CO_3 (^) and TiO_2 (x) markers are indicated.

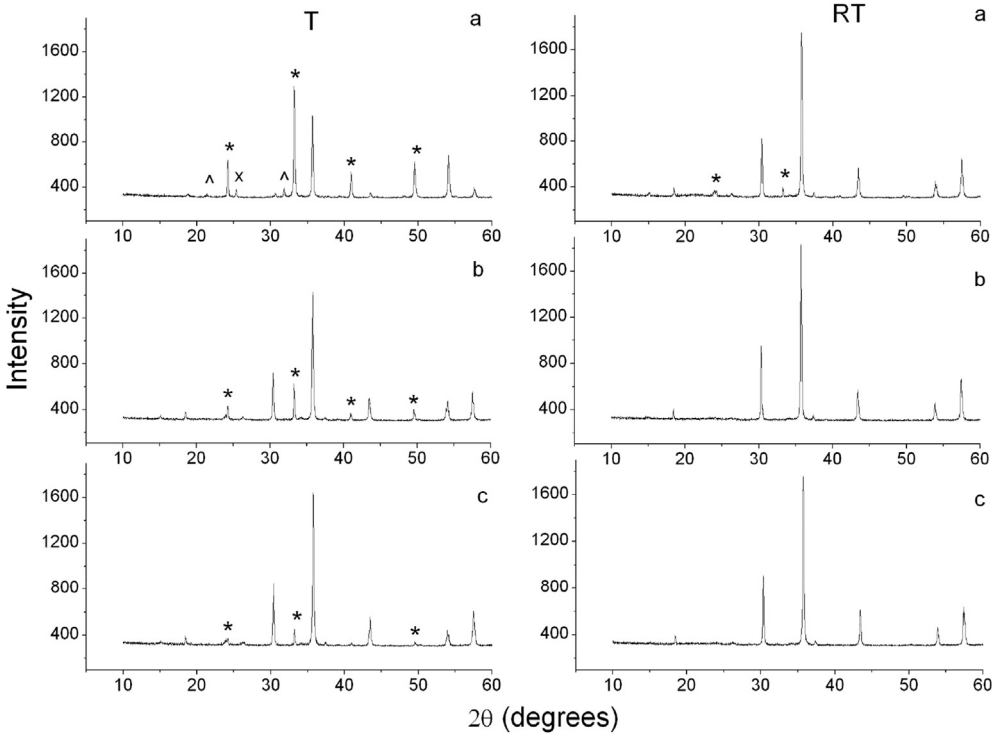

Fig. 2. XRD patterns for $Li_{0.5(1+x)}Fe_{2.5-1.5x}Ti_xO_4$ (x = 0.2) synthesized by T and RT heating at 750 °C and 0 (a), 30 (b) and 120 (c) min. Fe_2O_3 (*), Li_2CO_3 (^) and TiO_2 (x) markers are indicated.

saturation magnetization for lithium-titanium ferrite formation in condition of a heating of reaction mixtures in high-energy electron beam. The received results were compared with the magnetization of lithium-titanium ferrites synthesized by the conventional solid state synthesis in laboratory furnace using the similar time-temperature mode of thermal heating.

2. Materials and methods

Lithium-titanium ferrites with chemical formula