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Facile synthesis of FeCo alloys with excellent microwave absorption in the whole Ku-band: Effect of Fe/Co atomic ratio

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ABSTRACT

The different atomic ratios of FeCo alloys with various morphologies have been prepared through a simple liquid-thermal reduction method. It is found that the atomic ratio of ferrum and cobalt has great influence on the formation of FeCo alloys. Via adjusting Fe/Co atomic ratio (3:7, 5:5, 7:3), the surface of alloy becomes smooth gradually from distinct cone structure, and the saturation of alloys have been improved with the increase of Fe proportion. The impedance matching is also related tightly with atomic ratio and the best condition can be achieved by Fe_7Co_3 with lower dielectric constant and higher permeability. It is delighted to find that the optimal reflection loss (RL) value of Fe_7Co_3 can reach −53.6 dB at 14.3 GHz with a thin thickness of 1.55 mm and the RL values less than −10 dB can be gained from 11.2 to 18 GHz, which covering the whole Ku-band. The excellent performance derived from strong magnetic loss and well dielectric loss guarantees it as an ideal high-frequency microwave absorbent.

1. Introduction

Recently, serious electromagnetic pollution come from electronic devices, wireless communication tools and radar systems bring great threatens to human health and commercial equipment. In order to solve these problems, the high-efficiency microwave absorbent with “strong absorption, broad bandwidth, light weight and thin coating thickness” is greatly demanded [1–4]. So far, many composites with dielectric loss and magnetic loss were applied in the area of microwave absorption [5,6]. However, the complicated synthesis process restricts the development of these materials. As we all know, the impedance matching is important for the absorber, so the lower complex dielectric constant and higher complex permeability is needed [7]. Therefore, as typical soft magnetic material, metal or metal alloy exhibits many merits such as simple preparation process, strong magnetic loss, high saturation magnetization and high Curie temperature [8]. For instance, the flaky carbonyl particles were fabricated by a heating-balling method, which showed broad bandwidth in the 8–18 GHz below −8 dB [9]. Liu et al. reported the different morphologies of the $Co_{20}Ni_{80}$ nanoparticles which exhibited distinct microwave absorption properties. It was found that the reflection loss value of urchin-like $Co_{20}Ni_{80}$ can reach as high as −33.5 dB at 3 GHz and the absorption bandwidth is about 5.5 GHz for the flower-like morphology [10].

According to the impedance matching equation express as follows: [11,12].

$$Z = Z_1/Z_0 \tag{1}$$

$$Z_1 = (\mu_r/\varepsilon_r)^{1/2} Z_0 \tag{2}$$

where Z_0 represents the impedance of the free space, Z_1 means the impedance value of the absorption material, μ_r is complex permeability values and ε_r is complex permittivity values. The best way to achieve impedance matching is to make the relative complex permittivity ε_r closer to the relative complex permeability μ_r. Due to its high permeability, FeCo alloy is suitable as microwave absorbers if dielectric constant can be reduced [13]. Our group fabricated the hexagonal-cone like $Fe_{50}Co_{50}$ alloy which possess decent microwave absorption performance with RL values of −22 dB and frequency bandwidth of 7.1 GHz [14]. Nevertheless,

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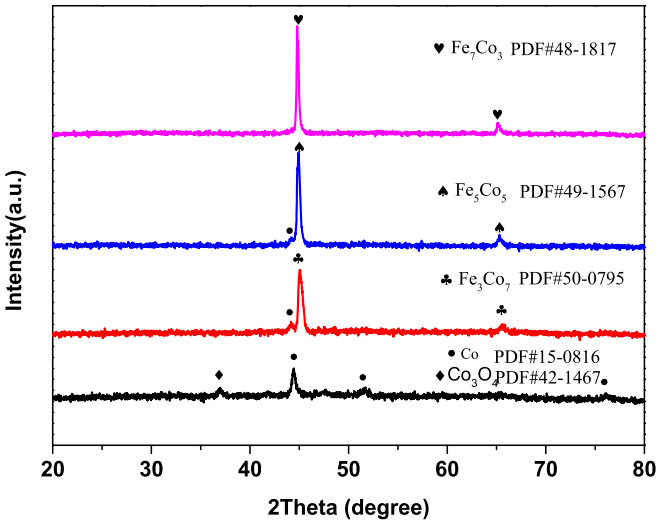

Fig. 1. The XRD pattern of FeCo alloys obtained with different atomic ratios.

the atomic ratio of FeCo alloys was scarcely reported, which has significant influence on the microwave absorption. On the other hand, the high value of *Ms* can lead to high value of μ_0 ($(\mu_0\text{-}1)f_0 = 1/3\pi\gamma Ms$), but high value of ε_r for FeCo alloys give rise to the most microwave be reflected, so the microwave will not be attenuated effectively.

In this study, we introduce the FeCo alloys with different atomic ratio and high saturation magnetization synthesized by a simple liquid-thermal reduction process. It was found that the atomic ratio of Fe/Co has great influence on the dielectric constant and morphology. So the well impedance matching, strong microwave absorption and wide frequency range can be attained by adjusting atomic ratio of Fe/Co. Generally, the increase of Fe proportion in FeCo alloys is a valid way to bring down dielectric constant and improve impedance matching which makes FeCo alloy become an ideal microwave absorber.

2. Experimental section

2.1. Synthesis of FeCo alloys with different atomic ratios

All of the regents used in this experiment are analytical pure without further purification. A simple liquid-thermal reduction method as previous report with a little modified was used to prepare alloys [15]. Typically, a certain ratio amount of $FeCl_2$ and $CoCl_2$, totally 40 mmol, was dispersed uniformly in 150 mL deionized water with adding 0.3 mol citrate trisodium,

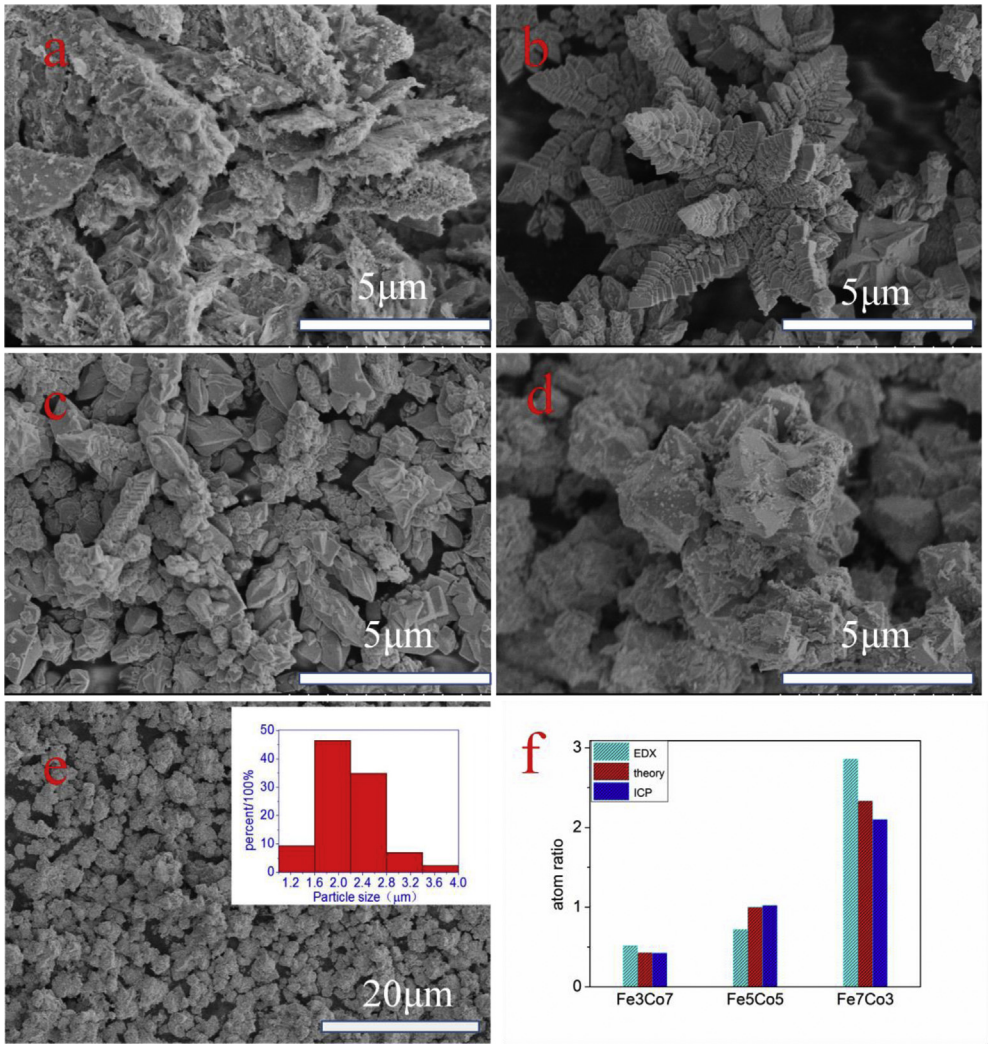

Fig. 2. SEM images of FeCo alloys (a) Fe_0Co_{10} (b) Fe_3Co_7 (c) Fe_5Co_5 (d) Fe_7Co_3; (e) image of Fe_5Co_5 and size distribution; (f) the theory atomic ratio compare to EDS and ICP.