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Formation Process of the Integrated Core(Fe-6.5wt.%Si)@Shell(SiO_2) Structure Obtained via Fluidized Bed Chemical Vapor Deposition

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Abstract: As electromagnetic functional materials, soft magnetic composites (SMCs) have great potential for applications in high-energy electromagnetic conversion devices. The most effective way to optimize the performance of an SMC is to incorporate it into insulated ferromagnetic core-shell particles with high structural uniformity and integrity. Fluidized bed chemical vapor deposition (FBCVD) is a facile and efficient technique for the synthesis of ferromagnetic/SiO_2 core-shell particles. However, the formation mechanism and conditions of integrated ferromagnetic/SiO_2 core-shell structures during the FBCVD process are not fully understood. On this basis, the formation process and the deposition time required for transformation of the Fe-6.5wt.%Si substrate into the Fe-6.5wt.%Si/SiO_2 composite, and finally into the Fe-6.5wt.%Si/SiO_2 core-shell structure, were investigated. Deposition of the insulative SiO_2 coating onto the Fe-6.5wt.%Si particles was described by the three-dimensional island nucleation theory. The SiO_2 islands were initially concentrated in rough areas on the Fe-6.5wt.%Si particle substrates owing to the lower heterogeneous nucleation energy. Deposition for at least 960 s was necessary to obtain the integrated ferromagnetic/SiO_2 core-shell structure. The uniformity, integrity, and thickness of the insulative SiO_2 coating increased with the increasing deposition time. The results in this study may provide a foundation for future kinetics investigations and the application of FBCVD technology.

Keywords: Fe-6.5wt.%Si/SiO_2 core-shell structure; formation process; deposition time; fluidized bed chemical vapor deposition

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The schematic illustration of the intrinsic contact angle (θ) and epigenetic contact angle (θ^*) between the SiO_2 nucleus and the Fe-6.5wt.%Si particle is shown in Figure S1. The smooth part of the Fe-6.5wt.%Si particle surface can be considered as a plane owing to a huge size difference between the SiO_2 nucleus and Fe-6.5wt.%Si particle (Figure S1(a)). In that case, the roughness factor (f) value is 1 and the intrinsic contact angle (θ) is an acute angle and is exactly equal to the epigenetic contact angle (θ^*). It can be seen from Figure S1(b) that the wrinkles and pits on the Fe-6.5wt.%Si particle surface will increase the roughness factor and the θ^* value. It is indicated that the cosine of θ^* for the wrinkles and pits of Fe-6.5wt.%Si particle surface is higher than that of the smooth part of the Fe-6.5wt.%Si particle surface. The heterogeneous nucleation energy decreases at the same time.

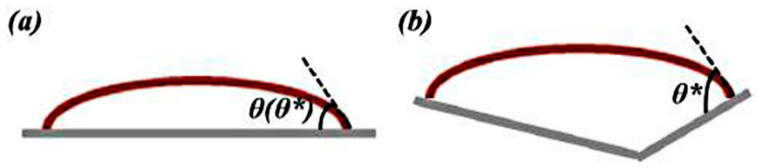

Figure S1. Schematic illustration of the intrinsic contact angle (θ) and epigenetic contact angle (θ^*) between the SiO_2 nucleus and Fe-6.5wt.%Si particle in (**a**) smooth areas and (**b**) wrinkles and pits.

According to the reference [1] these are two peaks of Fe_{3p} at 55.97 eV and 56.83 eV, which correspond to Fe_2O_3 and $Fe(OH)_3$, respectively. The Fe_{3p} spectra exists in all of the particles.

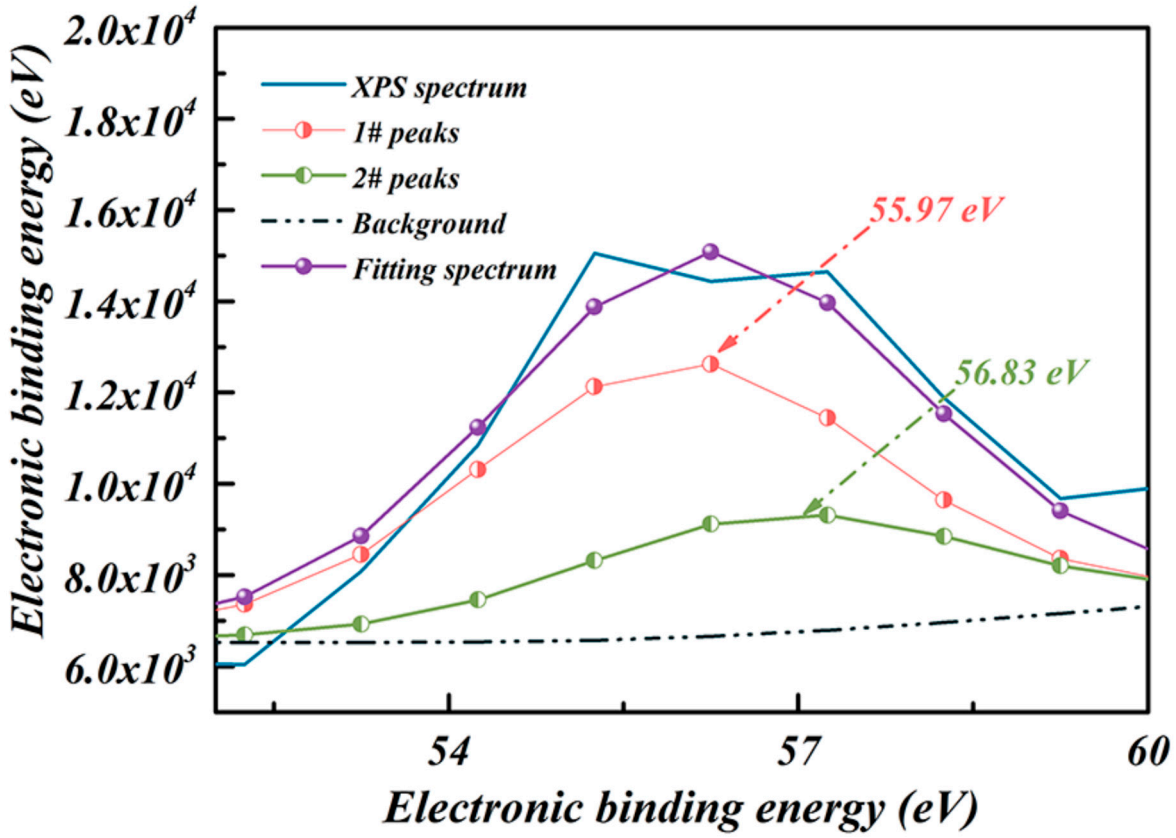

Figure S2. The deconvoluted Fe3p spectra for electrons on the surfaces of Fe-6.5wt.%Si/SiO_2 C-S particles after deposition for 1920 s.

References

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