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Anomalous behavior of the magnetization at the surface of Fe3O4(100)

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Magnetite (Fe_3O_4) is attracting attention as a potential material for spintronic devices due to the predicted half-metallic behavior with a high Curie temperature of 858 K [1]. The recent trend toward high densification of devices increases the importance of the surfaces. In our previous work, non-collinear magnetic structures are revealed at the Fe/MgO(001) interface [2] and on the Fe_3O_4(111) surface [3]. On the other hand, it is theoretically pointed out that the critical behavior at the surface is different from that in the bulk if the surface exchange interaction is different from the bulk one [4].
In this work, we investigated the magnetic phase transition and the magnetization direction of the Fe_3O_4(100) surface by means of the conversion electron Mössbauer spectroscopy (CEMS). The sample is $^{57}Fe_3O_4$(100) with a thickness of 20 nm deposited on the Fe_3O_4(100) to raise the surface sensitivity of CEMS. The temperature dependence of CEMS was measured in helium and the internal magnetic field was obtained from the spectral analysis. The Curie temperature is estimated at 861 K. The critical exponents of the tetrahedral (A) and octahedral (B) sites of Fe are respectively estimated at 0.237±0.010 and 0.277±0.006. These are close to the value of 0.23 of the 2D XY-model in contrast to the bulk values which are described by the 3D Heisenberg model [5]. The magnetization directions of the A and B sites are in-plane up to 680 K, which is different from the easy magnetization axis of [111] of magnetite. Furthermore, it was found that the magnetization directions gradually cant from in-plane to out-of-plane above 720 K. Considering the probing depth of CEMS, these characteristics have a depth of larger than 50 nm.
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