Superparamagnetic blocking in Fe-doped diamond films

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We have investigated Fe doping into diamond films grown by microwave plasma chemical vapor deposition techniques to search for the possibility of high-temperature ferromagnetism in diamond [1]. The field-dependent magnetization (*M-H*) curves have shown clear hysteretic behavior at room temperature [2]. Transmission electron microscopy and energy dispersive X-ray spectroscopy analyses have revealed the formation of Fe nanoparticles in diamond [2]. In the present study, we analyzed the magnetic properties in the framework of the coherent magnetization rotation models by Stoner-Wohlfarth (S-W) [3] and Néel-Brown [4, 5], assuming spheroidal Fe nanoparticles with a single-domain structure.

The temperature dependence of *M-H* curves was measured with a SQUID (superconductive quantum interference device) magnetometer in the range of 2–1000 K. Figure 1 shows the temperature dependence of coercivity (H_C). The data points were fitted by the following equation [6]:

$$H_C = H_0\left[1-\left(\frac{T}{T_B}\right)^{\beta}\right], \qquad (1)$$

where H_0 is H_C at 0 K, β is an exponent, and T_B is the superparamagnetic blocking temperature. From the fitting by Eq. (1), H_0 of 667 Oe, β of 1.0, and T_B of 1028 K were extracted. Using the values of H_0 and saturation magnetization of pure Fe (1700 emu/cm^3), we obtained the effective magnetic anisotropy constant of 1.2×10^6 erg/cm^3. This value is almost equivalent to that of Fe nanoparticles with a diameter of 18 nm [7]. The value of β deviates from the value of 0.5 expected in ideal single-domain S-W particles. The large β has also been reported in magnetic nanoparticles with a diameter near the critical diameter at which single-domain to multi-domain transition occurs [6]. For Fe nanoparticles, the critical diameter is known to be ~20 nm [6, 7]. The value of T_B is below the Curie temperature of Fe (1043 K) and is sufficiently higher than the temperature at which magnetic hysteresis is observed. From these results, the obtained magnetic hysteresis seems to originate from superparamagnetic blocking of Fe nanoparticles with a diameter below ~20 nm.

References

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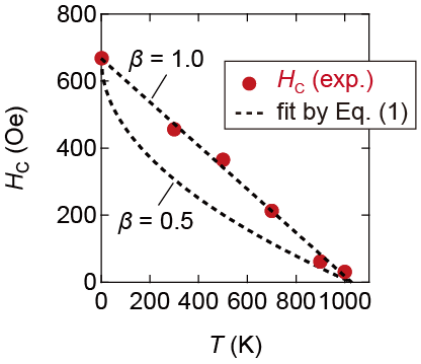

Fig. 1. H_C as a function of T.