磁歪材料を用いた単結晶ダイヤモンドMEMS磁気センサ

Single Crystal Diamond MEMS Integrated with Magnetostrictive Material for Magnetic Sensing

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Single-crystal diamond (SCD) is a promising material for micro-electromechanical system (MEMS) devices due to the outstanding mechanical and electronic properties of SCD.[1,2] The obvious merits of SCD MEMS sensor are the high reliability at extreme environments and high sensitivity in terms of the high quality factor of SCD MEMS resonators. We had been making efforts in developing the high quality (Q) factor diamond resonators and succeeded in the batch fabrication of single crystal diamond (SCD) MEMS/NEMS resonators on diamond by using the ion-beam induced phase transition method (IPT).[1,2] In addition, we analysed the energy loss mechanism of the IPT SCD resonators.[3] Based on the analysis, we improved the Q factors by growing a thick SCD layer and etching the defective layer to reduce the energy loss at the bottom of the resonator.[4] Ultimately, we achieved the SCD resonators on diamond with ultrahigh Q factors over one million.[5] Later, we achieved the electrical readout of SCD MEMS resonators.[6]

As a next step, we aim to achieve the practical applications of SCD MEMS. In this work, a magnetic sensor by using SCD MEMS resonator coupling with the ferromagnetic magnetostrictive material (Galfenol, FeGa) was fabricated. The detection principle of the external magnetic field is based on the change of the elastic modulus of the ferromagnetic material during the magnetization process. The growth and magnetic properties of the FeGa films on SCD substrates were investigated in detail. It was observed that the FeGa thin film on the SCD substrates exhibited excellent magnetic properties. The FeGa thin film was deposited on the SCD cantilevers for magnetic sensing. Figure 1 shows the shift of the resonance frequency of the FeGa/SCD MEMS cantilever as a variation of the external magnetic field. At this stage, we achieved the SCD MEMS resonator with a high magnetic field sensitivity of 4.83 Hz/mT and a low detectable force of 2.14×10^{-12} N. The FeGa/SCD MEMS cantilever can also be operated up to 573 K for magnetic sensing.

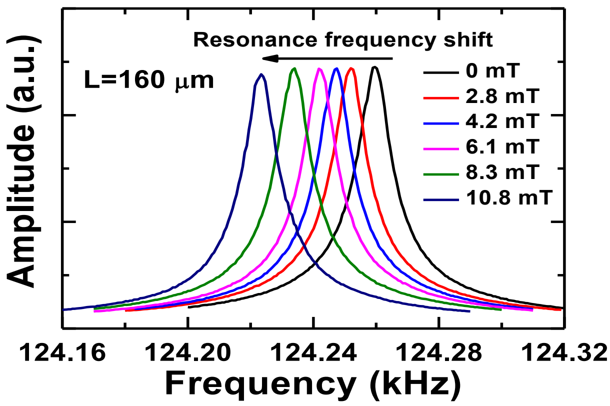

Fig. 1 Resonance frequency response of the FeGa/SCD cantilever upon varying applied magnetic fields. The resonance frequency shifts to the lower frequency side with increasing the applying magnetic field.

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