ダイヤモンドMEMSを用いた高温磁気センサ

High-temperature Magnetic Sensor Based on Single-crystal Diamond MEMS

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Magnetic sensors based on MEMS technology yield several prominent advantages of small dimensions, batch fabrication, low-power consumption, high sensitivity and resolution, and facile integration with CMOS technology. Especially, for harsh environments such as high temperatures over 773 K, most of the current magnetic sensors fail to work. Although MEMS magnetic sensor provides a route with performance super to the traditional ones, the magnetic sensors able to working above 773 K has not been achieved due to the poor thermal reliability of silicon material.

Single-crystal diamond (SCD) presents as a promising material to achieve high-performance and high-reliability MEMS devices super to other semiconductor materials (Si, III-nitride, SiC, etc,) in terms of its outstanding mechanical strength, thermal conductivity, ultra-wide bandgap, and chemical inertness. Galfenol (FeGa) has a huge magneto-strictive coefficient and excellent thermal stability with an ultra-high Curie temperature of 948K.[1] The FeGa film deposited on SCD presents excellent soft magnetic properties of a low coercivity, a low saturation magnetization field and a high remanence ratio. SCD MEMS coupling with a FeGa film based on the magneto-strictive effect offers an ideal platform for high-temperature magnetic sensing with high performance and high reliability.

At the first step, we succeeded in the batch fabrication of SCD MEMS/NEMS resonators on diamond by using the smart-cut method.[2] In addition, we analyzed the energy loss mechanism of the IPT SCD resonators and obtained the high-Q factor resonator with 1 million.[3] By using the SCD MEMS resonator, we demonstrated the magnetic sensing at room temperature.[4]

In this work, we propose and show the high-temperature (773K) magnetic sensor based on the hybrid structure of Galfenol/Ti/SCD MEMS resonators.[5,6] Figure 1 shows the variations of the resonance frequency shift of the FeGa/Ti/SCD cantilever at elevated temperatures and magnetic fields. It is observed that the magnetic sensitivity is improved at elevated operation temperatures. The developed magnetic sensor exhibits a stable high-sensitivity of 71.1 Hz/mT and a noise level of ~10 nT/√Hz at 773 K, which exceeds those of the reported magnetic sensors. The concept of SCD MEMS integrating with multilayers offers a promising strategy for developing reliable high-temperature magnetic sensors.

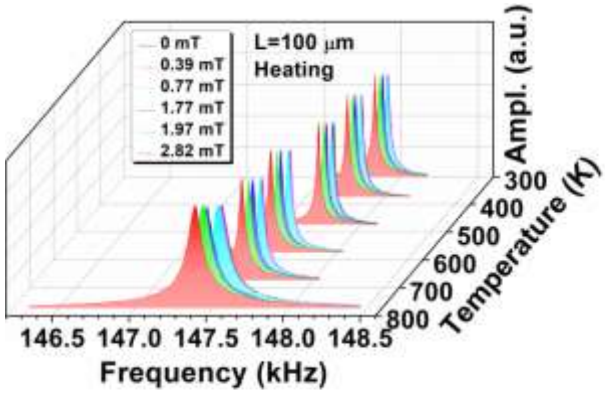

Fig. 1 The resonance frequency shift of a 100 μm-length FeGa/Ti/SCD cantilever as a function of the measurement temperature and the external magnetic field.

References

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