Magnetic Sensors for Automobile

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In order to address the enhancement of emission regulations, "Electronicization of cars" including electronic control of engines has progressed rapidly and many semiconductor sensor devices have been adopted in automobile. Magnetic sensors, for detecting the rotation angle of Cam and Crank, the position of accelerator pedal, the speed of vehicle / wheel, and the current of battery etc., are mounted about 10 or more pieces in a car, and the quantity of them are increasing. In the future, electric vehicles such as PHEV/EV will increase due to global fuel efficiency regulations and EV strategy of European automobile manufacturers, and the amount of current sensors for inverters and/or EV batteries are expected to grow drastically.

The needs for these current sensors are

1) Miniaturize ; To correspond the space reduction due to increasing the number of battery cells
2) High precision ; To use up batteries for extending the EV cruising distance
3) High current detection : To drive the motor with high current.

In general, Hall sensor is used as magnetic detecting devices for automotive current. It has a magnetic yoke to improve sensitivity and noise tolerance[1]. Others, shunt resistance device and a flux gate device are used as more accurate detection applications. However, these devices have a disadvantage that the size is large.

Current Sensor using MTJ Element[2]

Therefore, we aimed to productionize the small (yokeless) and high precision current sensors, we developed the new type current sensors which detect the magnetic field without yoke using with the high sensitive magnetic tunnel junction (MTJ) element. To realize the high accuracy, we need to reduce the nonlinearity to 0.1% FS or less. In addition, currents to be monitored may be as large as 1,000A, it is estimated that the magnetic sensors should have a dynamic range as wide as the order of 1,000Oe.

For these reasons, we adopted a structure which have in-plane magnetized free layer and perpendicularly magnetized reference layer, compared to the conventional MTJ sensors which have in-plane magnetized free and reference layer of CoFeB / MgO / CoFeB MTJ. In reference layer, we applied the synthetic antiferromagnetic (SAF) structure due to the high exchange bias, the wide dynamic range of +/-2,500Oe. In free layer, in order to optimize the anisotropic magnetic field, we investigated the thickness dependence of it. When the thickness is 1.8 nm or more, it becomes in-plane magnetization, and when the film thickness becomes thick, the slope of minor $G – H$ curve decreases, it is equivalent to the decreasing the sensor sensitivity. This is consistent with the minor G - H curve calculated by the Slonczewski model[3]. As the result, we achieved the nonlinearity <0.1% FS within ± 1,000 Oe.

Reference

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