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Progress in Magnetic Materials for Hall Effect-Based Devices

Souvik Ganguli, Abhimanyu Kumar and Bhavna Gupta

Thapar Institute of Engineering & Technology, India

Abstract

The phenomenon of production of voltage across a current carrying conductor strip, when placed in a transverse magnetic field, is called Hall Effect. The dependence of Hall devices on current and magnetic field is evident, but its practical implementation very much depends on the choice of material. In 1950s, several studies were published on materials like yttrium, lanthanum, cerium, neodymium, praseodymium, lutetium, ytterbium, thulium, samarium, thorium, uranium, zirconium, titanium, niobium, etc. which emphasized how pronounced is the Hall effect. These studies were conducted under different conditions and temperature ranges. It was firmly concluded that Hall effect was greatly dependent on temperature and purity of the material, which in turn controlled the real behavior of a device/sensor constructed on this principle. Within two decades, the popularity of Hall devices grew in the fields of physics, material science and engineering. The engineering application of the Hall principle motivated the research for more appropriate materials. It was understood that higher the electron mobility, more sensitive the sensor. In 1986, GaAs based Hall sensors with sensitivity in milli Tesla were designed. Highly sensitive InAs sensor with linearity up to 0.18 T were proposed in 1998. Using an ultra-thin film InSb micro Hall sensor, minimum field detection capability was improved in 2004. The research conducted over a span of past three decades presented InSb, GaAs, InP, InAs, and graphene as the most suitable options. Recently, micro-Hall sensors based on multilayered MoSe2 have shown high sensitivities, making the material promising for fabrication of Hall sensors. The search for material was further instigated to reduce the dependence on additional support circuits to reduce noise, offset and temperature dependency. Researchers proposed AlGaN/GaNAlGaN/GaN heterojunction structures for use in Hall sensors which provides low temperature sensitivity till 300° C. An epitaxal layer resistive could be employed to provide temperature independent sensitivity to reduce drift. Materials with loosely bonded electrons are set into motion with slight increase in temperature, which is known as the Johnson noise. Enhancement in magneto-resistive response and reduction in noise was observed with NiFeCr seed and capping layers for thin film and cross junctions based on NiFe/Au/IrMn structures. A magneto-resistive sensor can be fabricated using a standard sputtering deposition method directly on Si substrates resulting in huge offset suppression. Research in 2012 and 2019 provided evidence of the association of shape of a sensor with the noise and offset.