別紙４（課程博士）

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Abstract

論文内容の要旨　（博士）

Title of Thesis 博士学位論文名	Control of Spin Wave Flow and Its Application to Magnonic Devices using Yttrium Iron Garnet (イットリウム鉄ガーネットを用いたスピン波制御およびそのマグノニック素子への応用)

(Approx. 800 words)

(要旨　1,200 字程度)

Integrated circuits have been advanced by miniaturization of complementary metal oxide semiconductor (CMOS) devices. The thickness of gate oxide films is reaching below 10 nm, and the ultimate limit is unavoidable in near feature. Thus the investigation of beyond CMOS devices is motivated as a primary task of science. Spin waves (SWs) transmit information even in the insulators, since they transport spin momentum rather than electron. Wavelength ranging from tens of nanometers to millimeters gives easy access to magnonic band with arbitral structures, thus positive utilization of wave nature is expected to yield of another possibility in operations. In this work, yttrium iron garnet, one of notable insulating magnet, was employed as waveguide material. Based on this material, several waveguide structures were investigated to control wave flows, and their potential applications were explored.

First, performance of SWs as magnetic field sensors was studied with artificial magnetic lattices (AMLs). Copper stripes covering the waveguide surface with periodicity in order of wavelength act as AML. When defect layer with extra periodicity was added, a localized mode was observed. Contrary to the optical counterpart, demagnetizing effect of magnetic waveguide caused incoherence of localization. By considering this factor, calculation showed reasonable agreement with experimental results. Large slope of transmission intensity in the vicinity of the localized mode was used for sensors together with the sharp magnetic field dependence of magnonic band. According to the nature of AML, the slope can be enhanced by the numbers of periodic structure. Nevertheless, minimum resolution of the sensor was about 10^{-4} Oe. Limitation was due to temperature drift, and thus differential circuit was applied to magnonic devices. By using this circuit, phase rotation induced by magnetic field and temperature drift can be separated, yielding in suppression of temperature sensitivity from −20 deg./C° to -9.5×10^{-3} deg./C°.

Next, interferometers were studied for the 3-input majority function. Boolean sum and product can be also represented with a majority gate by using one input as a control. Since data was encoded in the phase of propagating waves, forward volume SWs with isotropic dispersion within device plane was employed. In advance, basic properties were investigated with 2 wave interferometry in the linear waveguide. The contributions of backscattered waves from waveguide ends gave rise in instability of operation to the deviation of magnetic field. To terminate the backscattering, surfaces of waveguide ends were covered by thin gold layer with the thickness of tens of nanometers. When the thickness of such conductive layer was extremely reduced, two SW modes with different wavenumber were generated. Attenuation was strongly enhanced at thicknesses when these modes were hybridized. In this manner, the interferometer with terminators exhibited stable performance even when the waveguide was exposed by magnetic field deviation over 30 Oe. This is the first experimental report of the interferometer using forward volume SWs. This principle was expanded in the 3 wave interferometry, which was studied with Ψ-shaped interferometer. In the Ψ-shaped interferometer, obliquely incident SWs to the junction area caused mode transition. Thus waveguide width was limited in order to be single mode. By using this interferometer, control of Boolean sum and product by majority function was demonstrated. Stability of the operation to the magnetic field and wave flow at the junction area were further investigated.

In this study, waveguide structures to control SW flow were investigated in AMLs and interferometers. Controllability of magnonic band holds promise of ultimately short wavelength and high speed clocking in the future, expecting a prospect as beyond CMOS device.