Magneto-Optical Neural Network Devices using Bi-Substituted Magnetic Garnet Films

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We proposed a magneto-optical neural network device that combines the high speed and parallel processing capabilities of optical-based diffractive deep neural network devices (D^2NNs) with the advantages of magneto-optic materials, such as their optical activity and non-volatile magnetic properties. To realize such devices, we prepared epitaxial bismuth-substituted magnetic garnet films on a $Gd_3Ga_5O_{12}$ (111) single-crystal substrates using the metal-organic decomposition method that we developed. The chemical formula of the fabricated bismuth-substituted magnetic garnet is $Y_{0.5}Bi_{2.5}Fe_4GaO_{12}$. To utilize a large magneto-optical effect, the rare earth ions in the dodecahedral site was substituted with a bismuth ions, and with the bismuth composition of 2.5, a large Faraday rotation angle of up to 20 degrees/μm in the visible light region is obtained. Furthermore, to achieve perpendicular magnetization, iron ions were substituted with non-magnetic gallium ions. By writing magnetic domain patterns into the prepared $Y_{0.5}Bi_{2.5}Fe_4GaO_{12}$ thin film by the thermos-magnetic recording technique, spatial light modulation is realized. To realize a neural network device with a garnet film, the magnetic domain patterns are determined by learning simulation. By arranging magnetic domains of several microns in a 112×112 array, we attempted handwritten digit classification, and we have achieved an accuracy of 83.4% for 500 handwritten digits. These results demonstrate that neural network devices utilizing magneto-optical effects have high computational performance.