Artificial Magneto-Photonic Crystals Based on III-V Semiconductors and Their Application to Magneto-Optical Devices

M. Tanaka*, H. Shimizu, and J.M. Sun
Department of Electronic Engineering, The University of Tokyo
CREST, Japan Science & Technology Corporation, *masaaki@ee.t.u-tokyo.ac.jp

It is widely recognized that artificially designed semiconductor heterostructures and nanostructures are essential for electronic/photonic devices. In this research, we try to add a new spin degree of freedom in the semiconductor-based artificial structures and devices, which we believe can contribute to the future photonics, including the new photonics using strong magneto-optical effect and non-linearity of the materials. So far, we have developed a variety of magnetic/semiconductor hybrid materials and structures grown by molecular beam epitaxy (MBE) [1]. Representatives of such hybrid materials are, ferromagnetic metallic MnGa and MnAs thin films on GaAs and Si substrates, ferromagnetic alloy semiconductor (GaMn)As, and ferromagnetic MnAs nanoclusters embedded in GaAs (hereafter, **GaAs:MnAs**). These were shown to have good compatibility with existing III-V heterostructures, as well as large magneto-optical effect, therefore can be good candidate materials for magneto-optical devices integrated with III-V optoelectronics [1].

In this symposium, we show that magneto-optical effect can be engineered and enhanced in a **GaAs:MnAs** hybrid material (thickness $\lambda/2n$) sandwiched by GaAs/AlAs distributed Bragg reflectors (DBR, thickness of each layer is $\lambda/4n$), grown by MBE on a GaAs substrate [2][3]. Since this DBR/**GaAs:MnAs**/DBR structure works as a magnetic microcavity, the lightwave of wavelength λ is localized in the centered magnetic layer, leading to the enhancement of magneto-optical Faraday effect. We have observed significant enhancement of Faraday effect by a factor of 6 - 7 at room temperature, under only 2 kG at the aimed wavelength of 980 nm. This is a new class of semiconductor-based magneto-photonic crystal (SMPC), whose potential strengths are the following: (1) Consisting of all epitaxial III-V based materials, SMPC can be readily integrated with III-V based opto-electronic devices. (2) By choosing various III-V semiconductors and structural parameters, one has a lot of freedom in the design, and the operation wavelength can be tuned in a wide range (in principle from ultraviolet to infrared). (3) Room temperature operation at relatively low magnetic field is possible. We will discuss theoretical design and optimization of the magneto-optical performance in the SMPC structures and how to reduce the optical loss in the GaAs:MnAs magnetic layer [4]. Also, we will present the thermal stability of GaMnAs and GaAs:MnAs materials [5].

References

[1] See for example, M. Tanaka, Physica **E2**, 372 (1998); M. Tanaka, J. Crystal Growth **201/202**, 660 (1999); M. Tanaka, J. Vac. Sci. & Technol. **A18**, 1247 (2000); M. Tanaka, Future Electron Devices **11**, 67 (2000); M. Tanaka, J. Cryst. Growth **227/228**, 839 (2001).

[2] H. Shimizu, M. Miyamura, and M. Tanaka, J. Vac. Sci. & Technol. **B18**, 2063 (2000).

[3] H. Shimizu, M. Miyamura, and M. Tanaka, Appl. Phys. Lett. **78**, 1523 (2001).

[4] H. Shimizu, and M. Tanaka, J. Appl. Phys. **89**, 7281 (2001); H. Shimizu, and M. Tanaka, Physica E, to be published.

[5] J. M. Sun, A. M. Nazmul, H. Shimizu, S. Ohya, and M. Tanaka, *presented at the 20th Electronic Materials Symposium, Nara, paper E3, June 20-22, 2001*; submitted.