Fabrication and Transport Measurements of Gate-defined Quantum Dot Structures Formed in a Bull's-eye Optical Cavity

M. Tsuchiya[1], S. Ji[2], R. Fukai[1], H. Kiyama[3], T. Fujita[1,4,5], X.-F. Liu[6], A. Ludwig[7], A. D. Wieck[7], S. Iwamoto[2], and A. Oiwa[1,4,5]

[1]*SANKEN, Osaka University, 8-1 Ibaraki, Osaka, Japan*

[2]*Research Center for Advanced Science and Technology, The University of Tokyo, 4-6-1 Komaba, Meguro, Tokyo, Japan,*

[3]*Graduate School and Faculty of Information Science and Electrical Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka, Japan,*

[4]*Center for Quantum Information and Quantum Biologys, Osaka University, 1-2 Machikaneyama, Toyonaka, Osaka, Japan,*

[5]*Spintronics Research Network Division, Institute for Open Transdisciplinary Research (OTRI), Osaka University, 1-3 Machikaneyama, Toyonaka, Osaka, Japan,*

[6]*Beijing Academy of Quantum Information Sciences, Beijing 100193, China,*

[7]*Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, Gebäude NB, D-44780 Bochum, Germany.*

oiwa@sanken.osaka-u.ac.jp

Semiconductor spin qubits are recognized as a promising platform for scalable fault-tolerant quantum computers because of their relatively long coherence time and semiconductor industrial compatible scalability. Moreover, because of the abilities of semiconductors for optical devices, they can also provide routes to connect qubit modules or quantum computers via optical fibers and construct global quantum networks [1]. The quantum state transfer from single photon polarization to single electron spin in a gate-defined quantum dots (QDs) has been demonstrated to explore photon-spin quantum interface for long distance quantum networking [2]. To improve the low conversion efficiency in the order of 10^{-5}-10^{-4}, gate-defined quantum dot with a charge sensor embedded in a bull's-eye optical cavity has been proposed and over 400 times enhancement in the absorption has been predicted from simulations [3]. From optical characterizations, fabricated bull's eye optical cavities show the polarization-independent absorption enhancement at cavity modes [4]. In this work, we discuss the electrical transport characterizations of the gate-defined QD structures fabricated in the bull's eye cavity.

A 15-nm GaAs quantum well sandwiched by top and bottom highly doped $Al_{0.34}Ga_{0.66}As$ barriers on an $Al_{0.75}Ga_{0.25}As$ sacrificial layer. We fabricated the gate-defined QD and then the dry etching and subsequent HF wet-etching were performed to form a suspended optical cavity. The bull's-optical cavity is supported by the eight beams (Fig. 1). We measure the transport through the beams as a conduction channel with changing the gate voltages to see the depletions of electrons and pinch-off the channel. We could measure the gate-dependent current in the bull's eye cavity through the narrow beams without depletion of the channel. However, reflecting the high carrier density of the order of 1×10^{12} cm^{-2}, both the depletion and pinch-off voltages were largely shifted to negative. The pinch-off behaviors were sometime masked by the gate leakage lowered to around -3 V. Sometimes incidental QD-like behaviors were observed close to pinch-off regions.

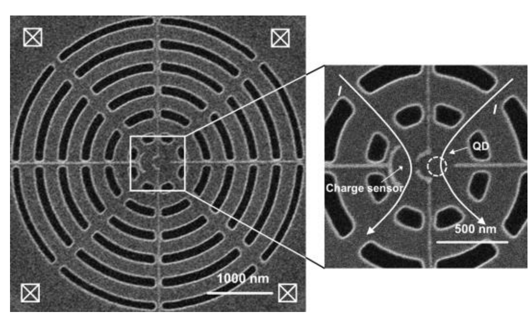

Fig.1. SEM pictures of the gate-defined quantum dot structures in the bull's-eye optical cavity

This work is supported by JST Moonshot R&D Grant No. JPMJMS2066-31 and JPMJMS226B; Grant-in-Aid Scientific Research (S), 23H05458, QSP-013 NRC, Canada.

References

[1] A. Oiwa et al., J. Phys. Soc. Jpn. **86**, 011008 (2017); L. Gaudreau et al., Semicond. Sci. Technol. **32**, 093001 (2017).

[2] K. Kuroyama et al., Phys. Rev. B **10**, 2991 (2019).

[3] S. Ji et al., Jpn. J. Appl. Phys. **60**, 102003 (2021).

[4] S. Ji et al., Jpn. J. Appl. Phys. **62**, SC1018 (2023).