【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : High-performance nanolaser biosensor with an ion-sensitivity

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Research Area : Optical Engineering/ Photon Science
Keyword : Photonic Crystal

【Purpose and Background of the Research】

GaInAsP semiconductor photonic crystal nano-lasers are simply fabricated and easily operated at near infrared by room-temperature photopumping. By functionalizing the device surface with an antibody, and so on, they act as biosensors which detect biomolecules in an analyte solution.

In a previous project (Grant-in-Aid for Scientific Research (S), 2012–2016), we detected various bio-samples such as standard proteins, biomarker proteins for cancers and Alzheimer disease, environmental toxin, and living cells. In particular, we succeeded in sensitive detection of proteins from ≤ fM order ultralow concentrations and their selective detection in contaminated samples with a selectivity of $>10^9$. The high performance cannot be explained by a principle as a refractive index sensor; it was rather suggested to relate with ions in the solution and surface charge on the device.

Based on this discovery, we set the following two purposes in this study: 1) investigation and utilization of iontronic effects in the nanolaser (Fig. 1), which have never been studied for photonic sensors, and 2) development of medical diagnostic system with improved and stabilized performance.

【Research Methods】

Regarding the iontronic effects, we theoretically analyze the electrostatic interaction, nano-fluidic effect, and electro-optic effects in the semiconductor. We compare them with experimental observations obtained by using multi-probe microscope and high-sensitivity infrared camera. We also observe the behaviors of molecular-level adsorption and optimize the functionalization for each target protein.

Regarding the medical diagnostic system, we employ a unified functionalization system using atomic layer deposition. We test the optimized device particularly for detecting proteins related with schizophrenia, which are taken from blood of patients. Integrating nanolasers and simple microfluidic device, we develop a quantitative measurement system with a disposable sensor chip.

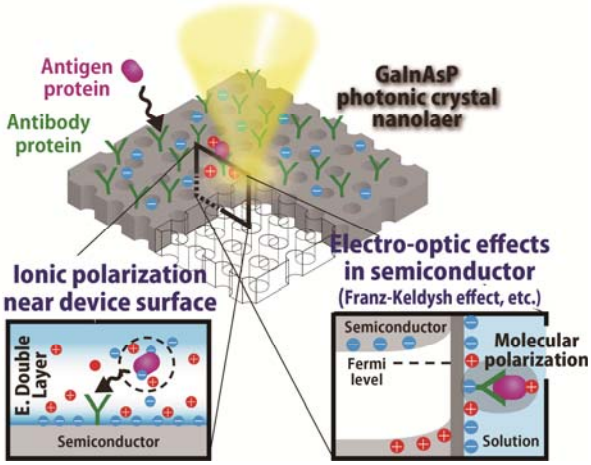

Figure 1 Schematic of photonic crystal nanolaser biosensor and iontronic effects

【Expected Research Achievements and Scientific Significance】

Conventional photonic sensors including surface plasmon and microcavities have been thought to sense the environmental index, although it has not fully been confirmed. In this study, we discuss a novel principle, which we expect to provide more advanced performance and functions.

【Publications Relevant to the Project】

K. Watanabe, Y. Kishi, S. Hachuda, T. Watanabe, M. Sakemoto, Y. Nishijima and T. Baba, Appl. Phys. Lett. **106**, 021106 (2015).
T. Baba, MRS Commun. **5**, 555 (2015).
M. Sakemoto, Y. Kishi, K. Watanabe, H. Abe, S. Ota, Y. Takemura and T. Baba, Opt. Exp. **24**, 11232 (2016).
S. Hachuda, T. Watanabe, D. Takahashi and T. Baba, Opt. Exp. **21**, 12815 (2016).

【Term of Project】 FY2016-2020
【Budget Allocation】 130,400 Thousand Yen
【Homepage Address】
http://www.baba-lab.ynu.ac.jp/babalabe.htm