Progress in Superconductivity Vol.14 No.2 pp.96-98 31 December 2012

Optical Characterization of Superconducting Strip Photon Detector Using MgB_2

H. Shibata[*,a,b]

[a] *NTT Basic Research Laboratories, NTT Corporation, Kanagawa, Japan*

[b] *NTT Nanophotonics Center, NTT Corporation, Kanagawa, Japan*

(Received 17 December 2012; revised 20 December 2012; accepted 24 December 2012)

Abstract

Bias current dependence of a superconducting strip photon detector is studied in the wavelength range of 405 to 1310 nm. The detector is made of an MgB_2 meander pattern with the line width of 135 nm and thickness of 10 nm. At 1310 nm, the detection efficiency exponentially decreases as the bias current decreases. While at 405 nm, the detection efficiency almost saturates in the high bias current region. These features suggest that the intrinsic detection efficiency of the MgB_2 detector is high at 405 nm.

Keywords : MgB_2, SSPD, single-photon detector

I. Introduction

The superconducting strip photon detector (SSPD), which is equivalent to a superconducting nanowire single-photon detector (SSPD, SNSPD), has been widely recognized as a high performance single-photon detector and used in many fields, such as quantum optics and quantum information [1, 2]. An SSPD is usually made of an NbN meander pattern with a line width of 100 nm and thickness of 5 nm and operated below 3 K. To increase the operating temperature, materials with higher T_c have to be used instead of NbN. One possibility is MgB_2. MgB_2 has a T_c of 39 K, which is much higher than the 16 K of NbN. We have previously shown that the single-photon-detection capability of MgB_2 nanowires [3, 4]. However, the detection efficiency of the MgB_2 SSPD was low compared to that of an NbN SSPD. In order to clarify the reason of this, detailed measurements are required. Here, we study the bias current dependence of the MgB_2-based SSPD in the wavelength range of 405 to 1310 nm.

II. Experimental

The meanders were fabricated by dry process of MgB_2 films grown by the molecular beam epitaxy (MBE) method. 10-nm-thick MgB_2 films were grown and passivated with 3-nm-thick AlN in situ. The films were rapidly annealed to improve their superconducting properties [5]. Then the meander pattern was fabricated by e-beam lithography and Ar ion milling. Details of the fabrication process are reported elsewhere [4]. The size of the fabricated meander is 10 μm × 10 μm square, with 135-nm line width and 10-nm thick. T_c and J_c of the meander were 23 K and 4.1×10^6 A/cm^2, respectively. The optical

*Corresponding author. Fax : +81 46 240 4726
e-mail : shibata.h@lab.ntt.co.jp

characterization was performed in a Gifford-McMahon cryocooler. A 1310-nm cw laser diode, 633-nm cw He-Ne laser, and 405-nm cw laser diode were used as the light sources, with the light guided to the meander with optical fiber.

III. Results and discussion

Figure 1 shows the mean photon number (μ) dependence of the count rate of detection signals at λ = 405 nm in various bias current conditions. A linear dependence of count rate is observed in all bias conditions, indicating the single-photon detection capabilities of the MgB_2 meander [1, 3, 4]. In the low-bias region (I_{bias} < $0.93I_c$), the count rate decreases as the bias current decreases. However, the count rate is almost the same in the high-bias region ($I_{bias} > 0.95I_c$), indicating that the detection efficiency is saturated in that region.

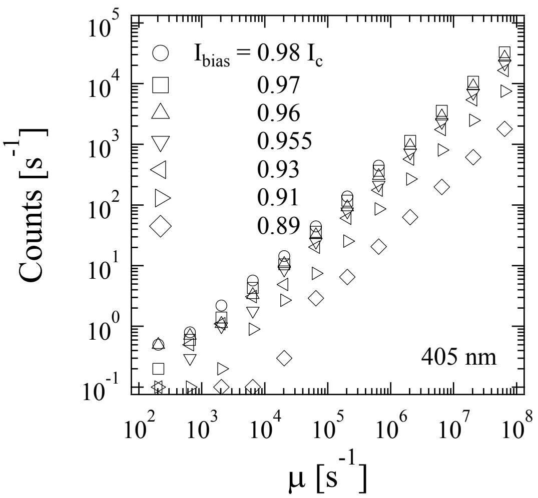

Fig. 1. Mean photon number (μ) dependence of count rate of detection signals at λ = 405 nm for the MgB_2 meander with the 135-nm-wide and 10-nm-thick nanowire.

Figure 2 summarizes the bias current dependence of detection efficiency at various wavelengths. At λ = 405 nm, the detection efficiency strongly decreases in the low-bias region and almost saturates in the high-bias region, which is consistent with Fig. 1. As the wavelength increases, the detection efficiencies are strongly reduced. The detection efficiency decreases exponentially with bias current at λ = 1310 nm. The detection efficiency can be written as the product of coupling efficiency, absorption efficiency, and registering efficiency [2]. The registering efficiency represents the efficiency with which electrical signals appear due to single-photon absorption of the nanowire, and depends on bias current. The exponential decrease of registering efficiency indicates that the nanowire is too large at λ = 1310 nm. On the other hand, the saturation behavior at λ = 405 nm suggests that the registering efficiency is high at λ = 405 nm in the high-bias region. The observed low detection efficiency at λ = 405 nm seems to be due to the low coupling efficiency or low absorption efficiency of the present device.

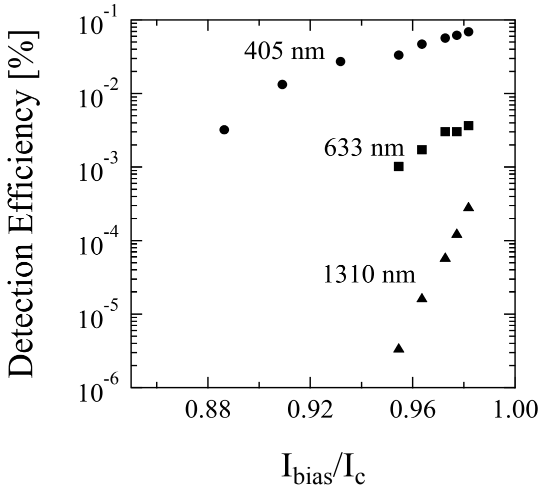

Fig. 2. Bias current dependence of detection efficiency at λ = 405, 633, and 1310 nm.

IV. Conclusions

In conclusion, we reported the bias current dependence of MgB_2-based SSPD from λ = 405 to 1310 nm. The detection efficiency saturates in the high bias region at λ = 405 nm, while exponentially decreases at λ = 1310 nm. The registering efficiency seems high in the high-bias region at λ = 405 nm.

Acknowledgments

This work was supported in part by Grant-in Aid for Scientific Research No. 22360148 from JSPS.

References

[1] G. N. Gol'tsman, O. Okunev, G. Chulkova, A. Lipatov, A. Semenov, K. Smirnov, B. Voronov, A. Dzardanov, C. Williams, R. Sobolewski, "Picosecond superconducting single-photon optical detector", Appl. Phys. Lett. 79, 705-707 (2001).

[2] C. M. Natarajan, M. G. Tanner, R. H. Hadfield, "Superconducting nanowire single-photon detectors: physics and applications", Supercond. Sci. Technol. 25, 063001 (2012).

[3] H. Shibata, H. Takesue, T. Honjo, T. Akazaki, Y. Tokura, "Single-photon detection using magnesium diboride superconducting nanowires", Appl. Phys. Lett. 97, 212504 (2010).

[4] H. Shibata, T. Akazaki, Y. Tokura, "Fabrication of MgB_2 nanowire single-photon detector with meander structure", submitted for publication.

[5] H. Shibata, T. Akazaki, Y. Tokura, "Ultrathin MgB_2 films fabricated by molecular beam epitaxy and rapid annealing", submitted for publication.