17a-C3-2

Ultrahigh-speed Light Emitters Based on Carbon nanotubes

Hideyuki Maki[1], Tatsuya Mori[1], Yohei Yamauchi[1], Satoshi Honda[1]

[1] Department of Applied Physics and Physico-Informatics, Keio University
E-mail: maki@appi.keio.ac.jp

1. Introduction

Electrically driven high-speed light emitters based on compound semiconductors are widely used in the areas of optical communication, time-resolved spectroscopy, etc. However, because of their large footprints, the low crystallinity of the compound semiconductors grown directly on Si wafers, these emitters face significant challenges with respect to their integration with silicon-based electronics, photonics and micromechanical platforms. Single-walled carbon nanotubes (CNTs) are an attractive material for optical and optoelectronic applications, such as optically and electrically excited light sources. Electrically driven CNT emitters, which can be based on electron-hole recombination or blackbody radiation, have several advantages: (i) a small footprint emitter can easily be obtained due to its simple fabrication process, (ii) CNTs can be prepared directly on a Si wafer, unlike compound semiconductor-based light emitters. These advantages could open new routes to photonics or optoelectronics integrated with silicon-based electronics. However, for such applications, the question remains as to whether an electrically driven CNT emitter can be modulated at high frequency as well as compound-semiconductor LEDs and LDs, which have modulation speeds on the order of MHz to GHz. In this study, we report the first electrically driven, ultra-high-speed CNT light emitter based on blackbody emission. Although these emission properties have been studied under steady-state conditions, the transient properties of these emitters have not been reported to date.

2. Results and Discussion

A schematic structure of the fabricated device is illustrated in Fig. 1(a). On a SiO_2/Si substrate, CNT films were grown using an ethanol chemical vapor deposition (CVD) method, and Pd electrodes were deposited as the source and drain electrodes. For time-resolved emission measurements, the electrodes were designed as 50-Ω coplanar transmission lines. The emission from the CNT blackbody emitter was highly localized at the position of the nanotube film [Fig. 1(b)]. The light emission spectra exhibit very broad emission patterns, whose spectra can be fitted with Planck's law, indicating the blackbody radiation generated by Joule heating.

To investigate the dynamic response of this emitter, we carried out time-resolved emission measurements based on a single-photon counting method under applied rectangular bias voltages of 0.8 to 10 ns in width. The emission intensities quickly respond to the applied bias voltage. The 10-90% rise and fall times are < 0.4 ns and are dominated by the response time of the applied bias voltage.

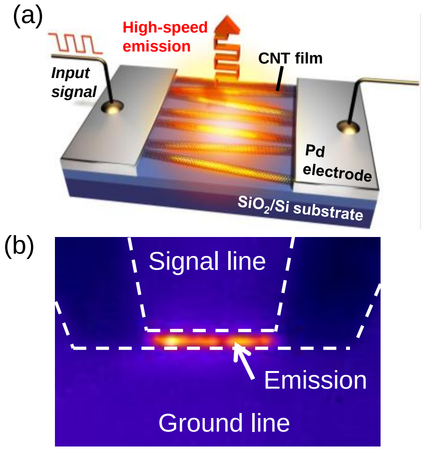

Fig. 1. (a) A schematic illustration of a CNT emitter. (b) A NIR camera image of CNT emission at V_{ds} = 4 V.

We elucidate the relaxation mechanism dominated by the process of heat dissipation to the substrate through the SiO_2 insulator under CNT Joule heating using Green's function. The simulated results are in good agreement with the observed results. This high-speed response is explained by the extremely fast temperature response of the CNT film, which is dominated by the small heat capacity of the CNT film and its high heat dissipation to the substrate.

Moreover, we demonstrated 140-ps-width pulsed light generation, experimental 1-Gbps and theoretical 10-Gbps modulation and experimental 1-Mbps optical communication using this blackbody emitter.

3. Conclusions

We demonstrate the electrically driven ultra-fast CNT blackbody emitter. This emitter, with the advantages of ultrafast response speeds, a small footprint and integration on silicon, can enable novel architectures for optical interconnects, photonic and optoelectronic integrated circuits.

Acknowledgements

This work was partially supported by the Adaptable and Seamless Technology Transfer Program though tar-get-driven R&D from JST, Japan, Grants-in-Aid for the Encouragement of Young Scientists (A) from MEXT, Ja-pan, and the Strategic Information and Communications R&D Promotion Program from MIC, Japan.

References

[1] T. Mori, Y. Yamauchi, S. Honda, H. Maki, Nano Lett. in press.