Strongly enhanced emission of terahertz radiation from nanostructured Ge surfaces

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***Abstract* — We report strong emission of terahertz radiation from germanium wafers with nanostructured surfaces. The power of the terahertz radiation from a Ge wafer with an array of nano-bullets is comparable to that from n-GaAs wafers, which have been widely used as a terahertz source. We find that the THz radiation from Ge wafers is even more powerful than that from n-GaAs for frequencies below 0.6 THz. Our results suggest that introducing properly designed nanostructures on indirect band gap semiconductor wafers is a simple and cheap method to improve the terahertz emission efficiency of the wafers significantly.**

I. INTRODUCTION

TERAHERTZ (THz) radiation has attracted considerable interest in recent years because it could be useful in nondestructive diagnosis, home security, and medical imaging. To realize the potential applications, an efficient and practical THz radiation source is necessary [1-2].

When semiconductors are illuminated by a femtosecond (fs) laser pulse, photo-carriers excited by the laser cause transient currents that generate THz radiation. Therefore, direct-gap semiconductors such as GaAs and InAs wafers are more efficient than indirect-gap semiconductors such as Ge and Si wafers in generating THz radiation [1-3].

In this presentation, we show that Ge wafers with arrays of nano-bullets are much better emitters of THz radiation than bare-Ge wafers. The power of the THz radiation from the nanostructured Ge wafers is almost five times larger than that from a bare-Ge wafer and is comparable to that from a n-GaAs wafer. Our result indicates that introducing the properly designed nanostructures on semiconductor surfaces can be a simple and cheap method to improve the THz emission efficiency of semiconductor wafers.

II. RESULTS

Two dimensional (2D) hexagonal arrays of nano-cones and -bullets with periods of 380, 510, and 630 nm were fabricated on a p-type (100) Ge wafer. Figure 1(a) shows the measured time domain waveforms of THz radiation from six nanostructured samples and a bare-Ge wafer. Their spectral data acquired through the Fourier transformation is shown in Fig. 2(b). The samples are labeled to indicate their shapes and periods. For example, B380 indicates an array of nano-bullets with a period of 380 nm and C630 indicates an array of nano-cones with a period of 630 nm. The results demonstrate that arrays of nanostructures on Ge wafers can enhance the amplitude of THz radiation from a bare-Ge wafer without changing the spectral range.

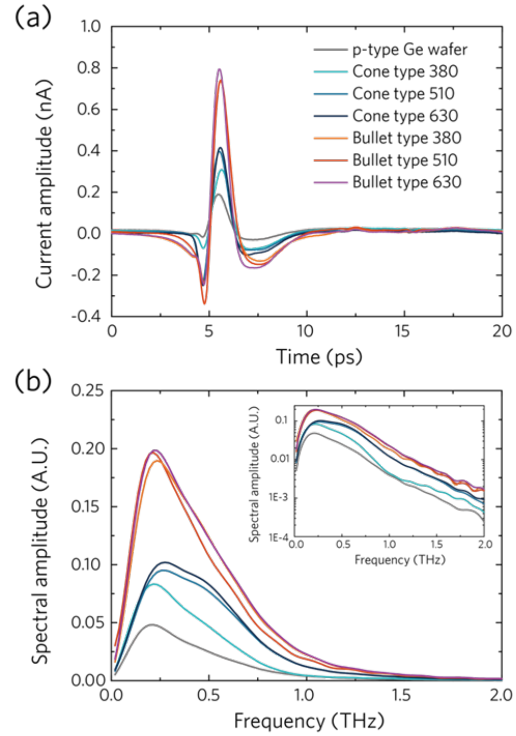

Fig. 1 Measured time domain waveforms of THz radiation from six nanostructured samples and a bare-Ge wafer (a) and their spectral data (b). The samples were labeled to indicate their shapes and periods. For example, B380 indicates an array of nano-bullets with a period of 380 nm and C510 an array of nano-cones with a period of 510 nm.

III. SUMMARY

We have found that Ge wafers with arrays of nano-bullets have an increased effective charge separation distance. This leads to a significant enhancement in the amplitude of THz radiation from bare Ge wafers. The enhanced power of THz radiation is comparable to THz radiation from a n-GaAs wafer. Our approach opens a simple and practical way to make indirect band gap semiconductors useful in emitting THz radiation.

REFERENCES

[1] Y.-S Lee, Principles of Terahertz Science and Technology, (Springer, New York, 2009).
[2] K. Sakai, Terahertz Optoelectronics, (Topics Appl. Phys. 97, Springer-Verlag, Berlin Heidelberg, 2005).
[3] A.Bici unas, V.Pacebutas and A.Krotkus, Physica B 404, 3386 (2009).