SI-GaAs<Cr> PHOTOCONDUCTIVE DIPOLE ANTENNAS FOR TERAHERTZ GENERATION: THE INFLUENCE OF ANTENNA LENGTH AND SHAPE

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Abstract — Photoconductive dipole antennas based on semi-insulating GaAs compensated with Cr (SI-GaAs<Cr>) have been designed and fabricated. Three types of antenna design were tested, namely butterfly, bow-tie and stripline. It was found that at femtosecond laser excitation the terahertz radiation in frequency range 0.05-1.5 THz can be generated in the SI-GaAs<Cr> dipole antennas with nonequilibrium carrier lifetimes as high as 100 ns. The stripline antenna with length of 150 μm was found to be the most efficient terahertz emitter.

ФОТОПРОВОДЯЩИЕ ДИПОЛЬНЫЕ АНТЕННЫ НА ОСНОВЕ SI-GaAs<Cr> ДЛЯ ГЕНЕРАЦИИ ТЕРАГЕРЦОВОГО ИЗЛУЧЕНИЯ: ВЛИЯНИЕ ДЛИНЫ И ФОРМЫ АНТЕННЫ

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Аннотация — Разработаны и изготовлены фотопроводящие дипольные антенны на основе полуизолирующего GaAs, компенсированного хромом (SI-GaAs<Cr>). Протестировано три типа антенн: антенна-бабочка, трапециевидная и полосковая. Установлено, что при возбуждении фемтосекундным лазером в антеннах на основе SI-GaAs<Cr> со временем жизни неравновесных носителей заряда порядка 100 нс может быть генерировано терагерцовое излучение в диапазоне 0.05-1.5 ТГц. Обнаружено, что наиболее эффективным излучателем является полосковая антенна длиной 150 мкм.

I. Introduction

Despite being well known terahertz detectors and emitters for terahertz time-domain spectroscopy (THz-TDS) photoconductive dipole antennas (DAs) still are developed. Role of geometrical configuration, excitation parameters and properties of photoconductive material is studied [1, 2]. The parameters and efficiency of the devices are optimized as well as new types of dipole antennas are designed. For example dipole antennas on InGaAs/InAlAs heterostructures for excitation by 1.55 μm lasers have been created [3]. For these lasers, common for optical communications, high resistivity bulk photoconductor materials are relatively difficult to find.

In most of the cases the dipole antennas are fabricated on LT-GaAs. This material can possess subpicosecond carrier lifetime but requires epitaxial growth technology. In our previous work we studied SI-GaAs<Cr> dipole antennas with antenna length as large as 700 μm to optimize the resonance condition for low terahertz frequencies as the carrier life time is long. We obtained the terahertz emission spectra with clear maxima about 0.1-0.2 THz [4]. In order to check the influence of the resonance condition and antenna shape in the present work we have fabricated another set of antennas with different lengths and of three well-known shapes, namely butterfly, bow-tie and stripline.

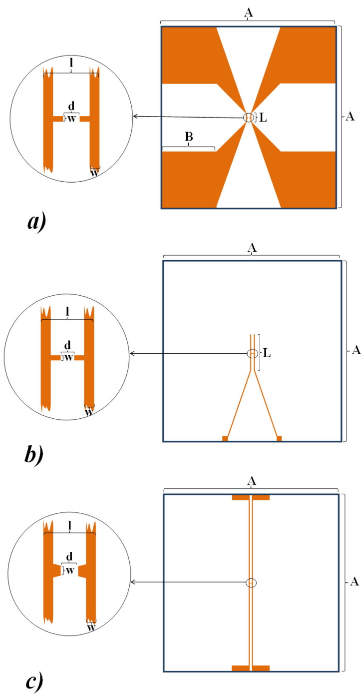

Fig. 1. Dipole antenna geometrical configurations (w=10 μm, d =5 μm, A=5 mm). a) Butterfly (l=25-450 μm, L=100 μm) b) Stripline (l=25-150 μm, L=1 mm) c) Bow-tie (l=25-450 μm).

Рис. 1. Геометрические параметры дипольных антенн (w=10 мкм, d =5 мкм, A=5 мм). a) Антенна-бабочка (l=25-450 мкм, L=100 мкм) b) Полосковая антенна (l=25-150 мкм, L=1 мм) c) Трапециевидная антенна (l=25-450 мкм)

II. Main Part

The geometrical parameters of the fabricated and tested antennas are given in Fig. 1. The antenna structures (1 μm thick Al layer) were formed on SI-GaAs<Cr> wafers by photolithographic process.

The measurements were done using conventional THz-TDS setup. The 100 fs laser pulses were attenuated and focused onto antenna gap. The incident optical

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power was 40-60 mW. The applied voltage was about 18 V. The waveforms were registered by electro-optic sampling in a 1 mm thick GaSe crystal.

In the previous study [4] long stripline antennas were tested. As for the Hertzian dipole, the resonance frequency for dipole antenna is usually written as $\nu = \frac{c}{2nl}$, where n is refractive index of semiconductor wafer, *c* is the speed of light and l is antenna length. Thus we reduced l values to 25-45 µm to test the possibility to get more efficient generation about 1 THz.

We compared first the terahertz emission spectra of different antenna types with the largest lengths (Fig. 2). It is seen that for the stripline antenna the spectrum is broader and exceeds the noise level up to 1.5 THz. The stripline configuration is slightly more efficient than the bow-tie. The butterfly geometry is less efficient for SI-GaAs<Cr> dipole antennas (Fig. 2).

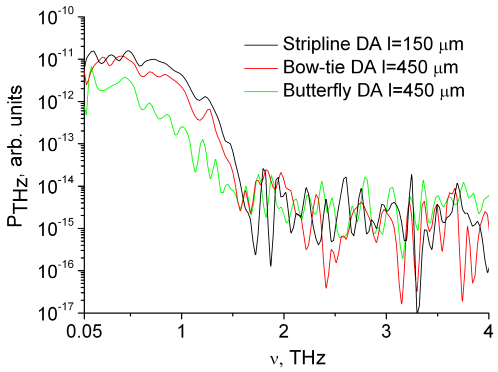

Fig. 2. Terahertz emission spectra of the stripline, bow-tie and butterfly dipole antennas with the largest lengths.

Рис. 2. Спектры генерации терагерцового излучения для полосковой, трапециевидной и антенны-бабочки с наибольшими длинами

When the length of the stripline antenna is reduced to 35 µm the generated terahertz power reduces (Fig. 3). No peak of generation efficiency is observed about 1 THz. The same was observed for the other antenna types. On the other hand when we compared the striline antennas with 150 and 700 µm lengths it was seen that the 150 µm antenna is more efficient (Fig. 4). The emission spectrum of the 700 µm long antenna is shifted to the lower frequencies.

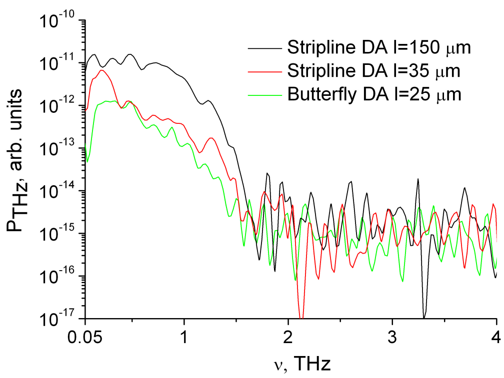

Fig. 3. Comparison of terahertz emission spectra of 25-35 and 150 µm dipole antennas.

Рис. 3. Сравнение спектров генерации терагерцового излучения для дипольных антенн длиной 25-35 и 150 мкм

III. Discussion

To our knowledge, there is no model analysis of influence of different dipole antenna configurations on emitted terahertz power presented in literature. According to our measurements the stripline configuration, being also the most simple, provides the best terahertz generation efficiency. The spectral efficiency of the antenna is determined by parameters of the excitation and material and cannot be radically shifted by resonance condition. The resonance condition is important near the spectral range of efficient antenna operation determined by parameters of the material.

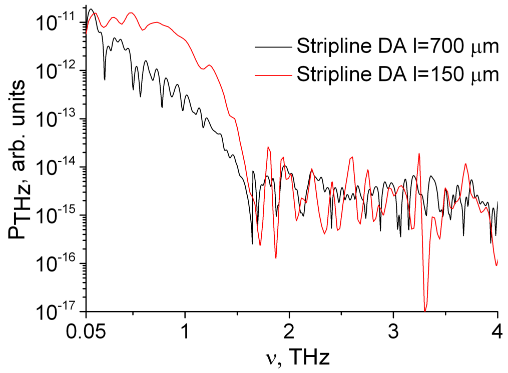

Fig. 4. Terahertz emission spectra of the stripline dipole antennas with lengths of 150 and 700 µm.

Рис. 4. Спектры генерации терагерцового излучения полосковых дипольных антенн длиной 150 и 700 мкм

IV. Conclusion

It was experimentally found that for the semiconductor material with long carrier lifetimes (100 ns) used to make our dipole antennas the most efficient antenna configuration is stripline with length of 150 µm. Using this SI-GaAs<Cr> antenna configuration it is possible to get terahertz emission spectrum spanning from 0.05 to 1.5 THz.

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V. References

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