Room Temperature THz Detection with Thin Layers of Black Phosphorus

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Abstract Two-dimensional materials attracted interest for optoelectronic devices during the last years. One of the relatively new, very promising materials that can be exfoliated in the same way as graphene is black phosphorus [1]. Unlike graphene, black phosphorus provides a direct bandgap and therewith enables higher on-off ratios, but at the same time maintaining high carrier mobility. The photo response of thin layers of black phosphorus has been investigated in several studies [2], demonstrating the potential of black phosphorus for near- and mid-infrared optoelectronic devices. Moreover, the high mobility of black phosphorus enables intraband absorption of THz photons. Here we present the THz response of an antenna-coupled black phosphorus field-effect transistor operating at room temperature.

Thin flakes of black phosphorus were fabricated by mechanical exfoliation from a bulk crystal. 300 nm SiO_2 on Si served as substrate for the devices, and electrical connection to the flake was made via a log-periodic antenna for an efficient coupling of the THz radiation to the flake that is of subwavelength dimensions (cf. Fig. 1(a)). To prevent degradation of the flake, a 100 nm thick layer of Al_2O_3 was deposited on top of the device by atomic-layer deposition [3]. A methanol gas laser served as continuous-wave source at a frequency of 2.5 THz with an average power of about 10 mW at the sample position for the photocurrent measurements. The responsivity of the device depends on the gate voltage (cf. Fig. 1(b)) and the polarization angle of the THz radiation, while the bias voltage has only minor influence on the performance. The responsivity reached a peak value of 80 nA/W at a gate voltage of 10 V, which corresponds to a slightly p-doped regime. We attribute this strong photocurrent to a photothermoelectric effect that has been observed in the near-infrared range recently [4]. With this high THz responsivity, black phosphorus outperforms similar devices based on graphene by more than one order of magnitude [5].

References

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Figures

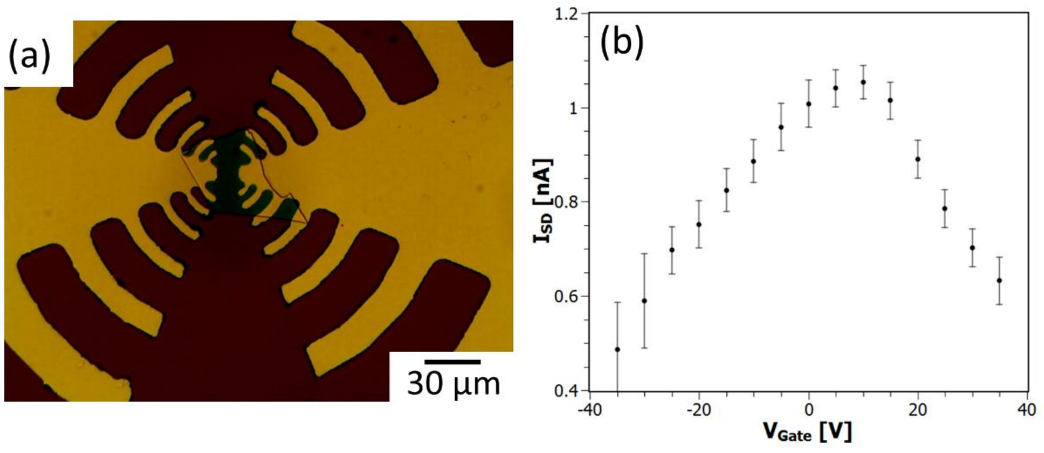

Figure 1: (a) Inner part of a log-periodic antenna that is connected to a black phosphorus flake in its center. (b) Gate dependence of the THz induced source-drain current.