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Chalcogenide Glass Waveguide-integrated Black Phosphorus Mid-Infrared Photodetectors

Black phosphorus (BP) is a promising 2D material that has unique in-plane anisotropy and a 0.3 eV direct bandgap in the mid-IR [1,2]. However, waveguide integrated black phosphorus photodetectors have been limited to the near-IR on top of Si waveguides that are unable to account for BP's crystalline orientation [3]. In this work, we employ mid-IR transparent chalcogenide glass (ChG) both as a broadband mid-IR transparent waveguiding material to enable waveguide-integration of BP detectors, and as a passivation layer to prevent BP degradation during device processing as well as in ambient atmosphere [4]. Our ChG-on-BP approach not only leads to the first demonstration of mid-IR waveguide-integrated BP detectors, but also allows us to fabricate devices along different crystalline axes of black phosphorus to investigate, for the first time, the impact of in-plane anisotropy on photoresponse of waveguide-integrated devices. The best device exhibits responsivity up to 40 mA/W and noise equivalent power as low as 30 pW/Hz$^{1/2}$ at 2185 nm wavelength. We also found that photodetector responsivities changed by an order of magnitude with different black phosphorus orientations. This work validates black phosphorus as an effective photodetector material in the mid-IR, and demonstrates the power of the glass-on-2D-material platform for prototyping of 2D material photonic devices.

References

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Figures

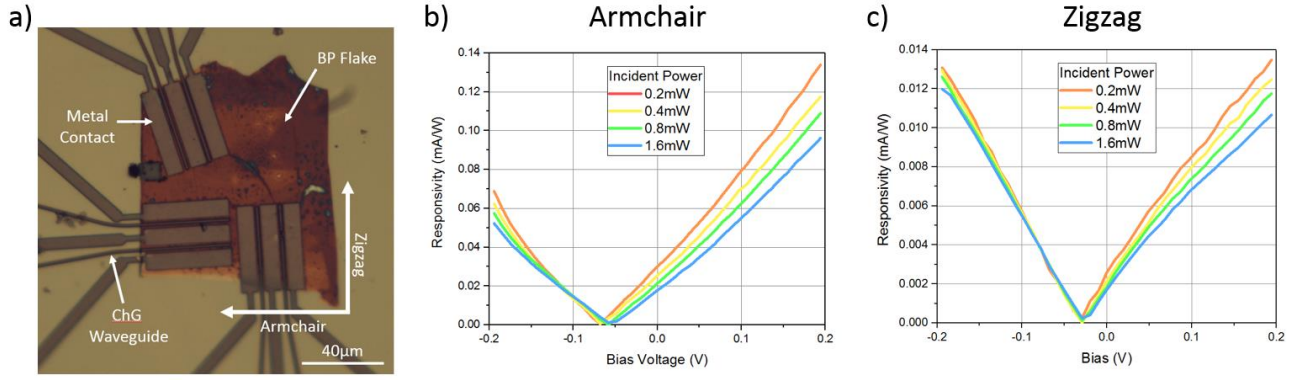

Figure 1: (a) Optical microscope image of six fabricated waveguide-integrated photodetectors on the same BP flake. (b) Responsivity as a function of applied voltage at varying incident 2185nm laser powers for waveguide parallel to armchair directions and (c) zigzag direction.