N-type doping of black phosphorus by using benzyl viologen.
DEWU YUE, DAEYEONG LEE, JUNGJIN RYU, MIN SUP CHOI, HYE JIN NAM, DUK-YOUNG JUNG, WON JONG YOO, Sungkyunkwan Univ, NDPL COLLABORATION — Black phosphorus (BP) meets several critical material requirements for the development of future nanoelectronic applications, but the realization of n-type semiconductor behavior form it has remained elusive. Here, we report the ambipolar characteristics of few-layer BP, induced using a novel technique: chemical doping with benzyl viologen (BV), which serves as a surface charge transfer donor for BP flakes. The n-doped BP devices exhibit excellent electron mobility up to $\sim 83$ cm$^2$/V$^{-1}$s$^{-1}$ from 2-terminal measurement at 300K, thereby demonstrating n-type behavior. On the basis of ambipolar BP devices, we also comprehensively analyzes temperature and BP thickness dependence of ambipolar devices, in which we found the degenerate doping limit below around 150K and highest electron transport performance in $\sim 10$ nm BP flakes at 300K. As a proof of concept, ultrafast BP photodetectors were fabricated with a very high photoresponsivity of $\sim 10^4$ mA/W over the UV, visible, and IR spectral ranges. Furthermore, we fabricated a homogeneous BP based inverter through BV doping and h-BN capping that offers a feasible approach to fabricating a key building block of future 2D logic semiconductors.

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