Wafer-Scale Light-weight and Flexible Graphene-Based Broadband Modulator with Ultrafast Switching Time

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Abstract (Arial 10)

Here we report a wafer-scale light-weight and flexible broadband modulator based on Graphene/P(VDF-TrFE)/Graphene multilayer films. The P(VDF-TrFE) film not only significantly reduces the sheet resistance of graphene throughout heavy doping of ~ 0.8×10^{13} cm^{-2} by nonvolatile ferroelectric dipoles, but also acts as an efficient electro-optic (EO) layer. Such multilayer films integration with high transparency (> 90%), low sheet resistance (~ 302 Ω/□), and excellent mechanic flexibility show the potential of a flexible modulator over a broad range of wavelength. Moreover, the derived modulator exhibits strong field-induced EO modulation even under bending and one large pockels coefficient (~ 54.3 pm/V) is obtained. Such large-area modulator also demonstrates both an ultrafast switching time (< 2 μs) and outstanding environmental stability. These findings are very important for in-depth understanding of graphene and ferroelectric hybrids, enabling future explorations on next-generation high-performance, flexible transparent electronics and photonics.

References

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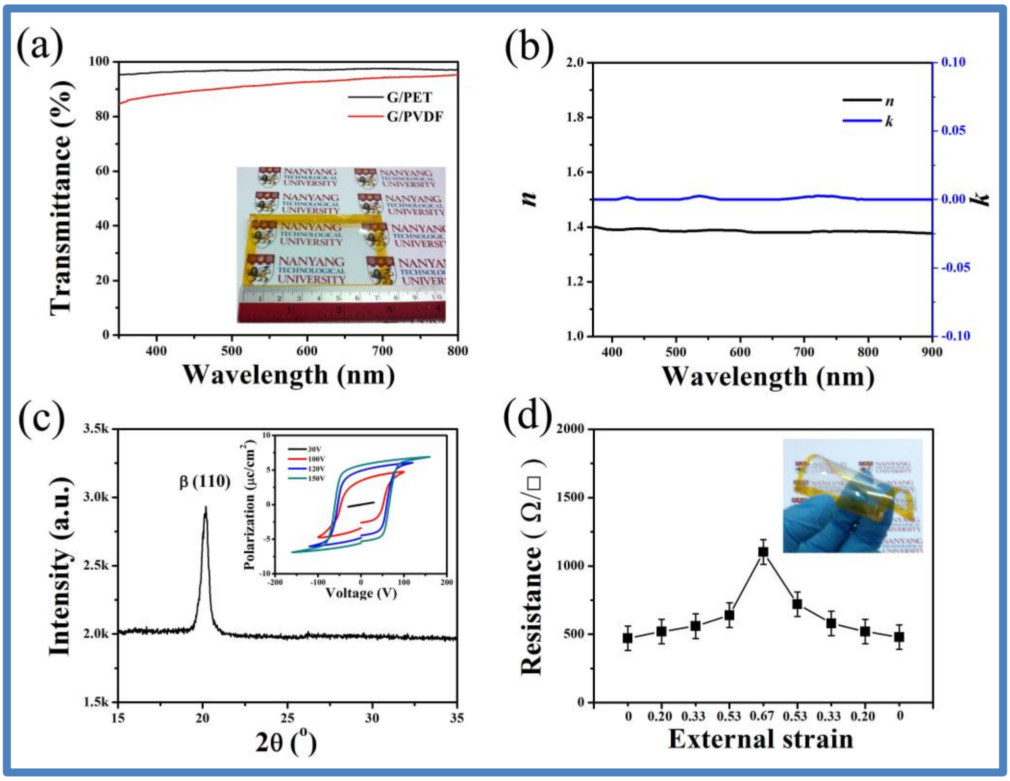

Figure 1. (a) Transmittance spectra of G/P(VDF-TrFE)/G multilayer (> 90%) and pure graphene on PET (97%). The inset is optical image of G/P(VDF-TrFE)/G multilayer on transparent PET substrate. The background is the logo of Nanyang Technological University. (b) Refractive index (*n*) and the extinction coefficient (*k*) of P(VDF-TrFE) film as a function of wavelength. (c) Typical XRD pattern of P(VDF-TrFE) thin film indicating the formation of β phase. The inset is the polarization hysteresis loops of the G/P(VDF-TrFE)/G multilayer under different external voltages of 30, 100, 120, and 150 V. (d) Sheet resistance versus external strain using four probe bending measurement. The inset shows the optical image of G/P(VDF-TrFE)/G multilayer film device under bending.

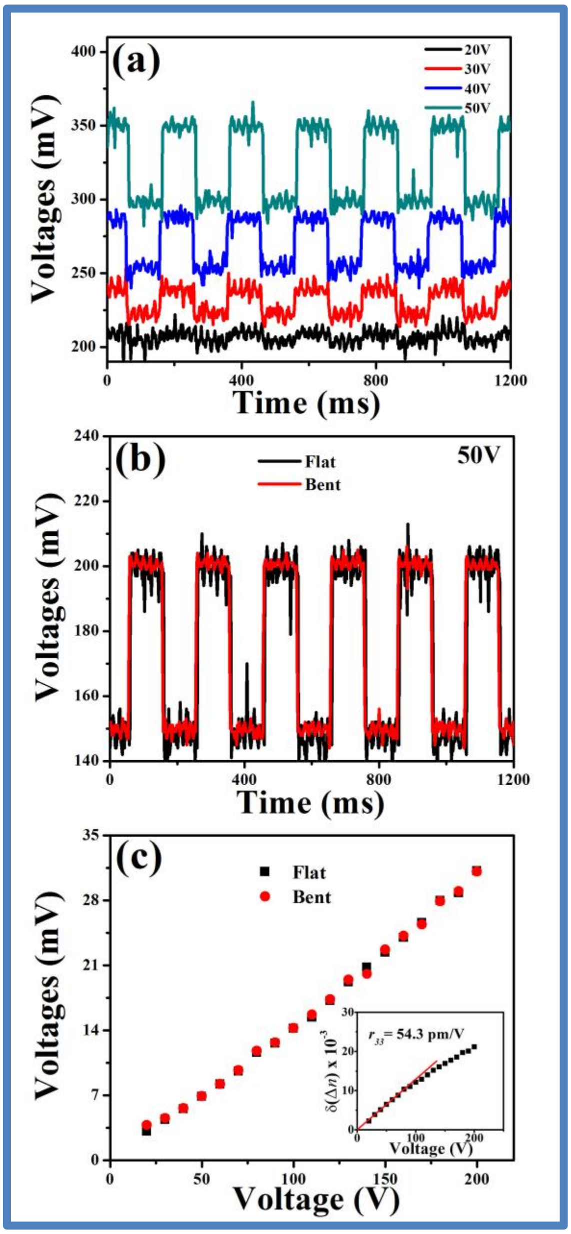

Figure 2. (a) Laser intensity modulation of G/P(VDF-TrFE)/G multilayer film under different external applied voltage. (b) Laser intensity modulation of G/P(VDF-TrFE)/G multilayer with flat and bending status at 50 V. (c) Modulation of G/P(VDF-TrFE)/G multilayer film with flat and bent status as a function of external applied voltage. The inset is change in birefringence $\delta(\Delta n)$ as a function of applied voltage.