High-Gain Ultraviolet Photodetectors Based on Oxygen Plasma Treated Epitaxial Graphene

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We demonstrate a simple dry method of mild oxygen plasma surface modification of epitaxial graphene (EG) for high-gain ultraviolet (UV) photodetectors. The spectral photoresponse of the oxygen plasma treated EG (OPTEG) active channel exhibits a high photoconductive gain of ~ 10^4 at an excitation wavelength of 300 nm in the UV region. The high-gain photoconductivity and prolonged photoresponse time of the photodetector are attributed to the presence of charge carrier traps in OPTEG. The large photoconductive gain, high selectivity, and detectivity of ~ 10^{12} Jones in the UV spectral range, underscores its potential over Si and many other semiconductor UV photodetectors. The compatibility with CMOS fabrication process makes it an attractive approach to fabricate graphene based high-gain UV photodetectors for applications in UV photodetection, imaging and intrachip optical interconnects.

Results and Discussion

❑ Oxygen plasma treated epitaxial graphene (OPTEG) devices & photoconductive charcteristics

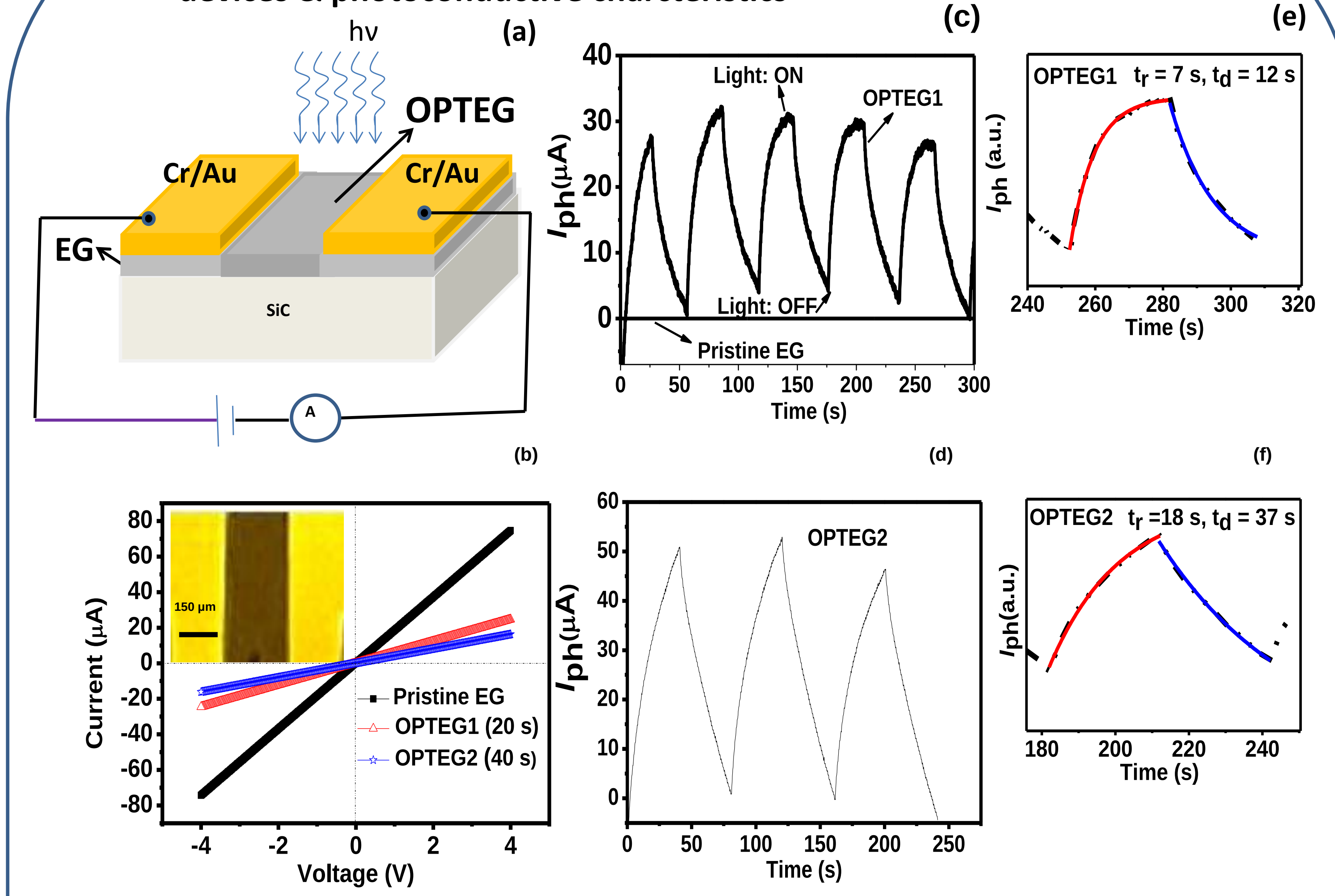

Figure 1. (a) Schematic of the device showing EG (~4-layer) and active OPTEG regions. (b) Change in resistance of the device during oxygen plasma treatments. (c)-(f) Temporal photoconductive characteristics of the OPTEG devices.

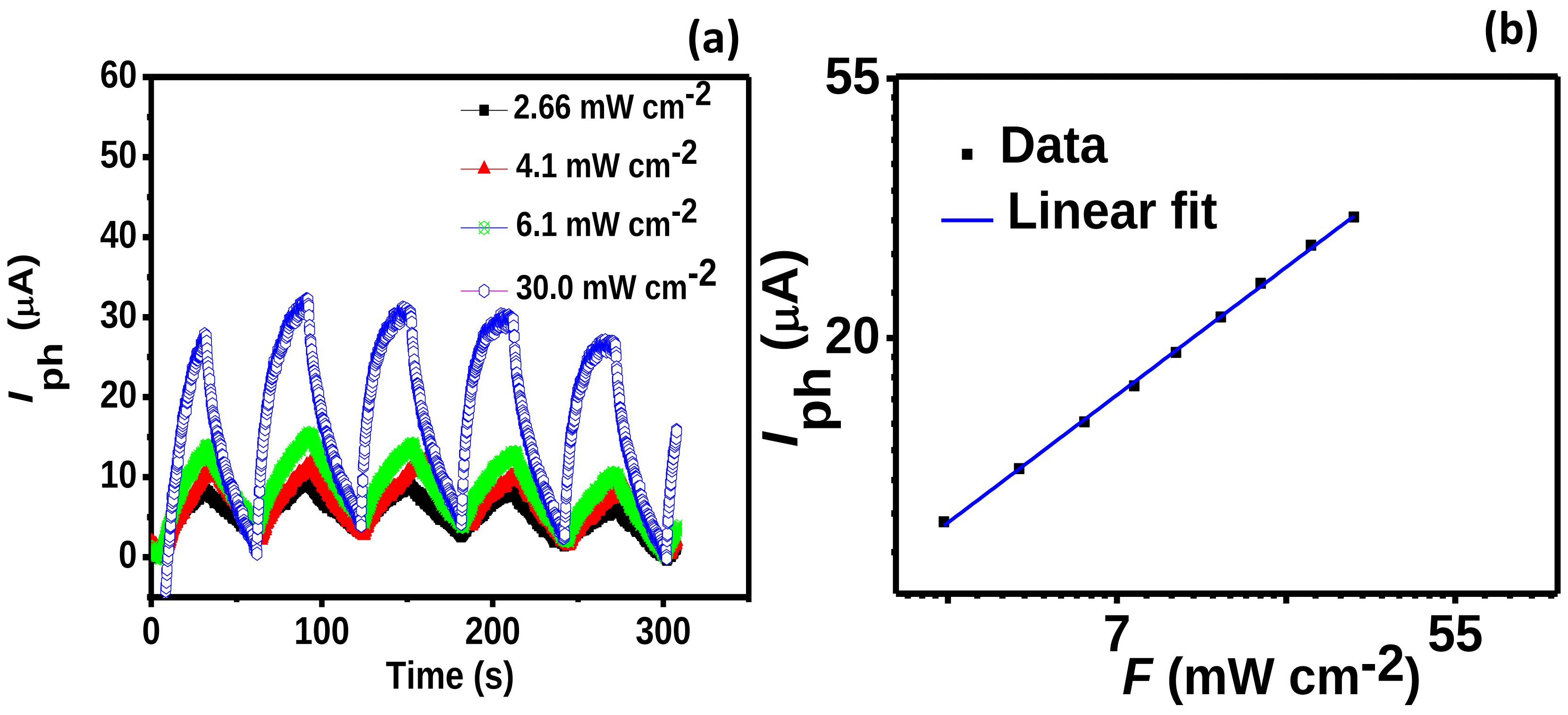

Figure 2. (a) Light intensity dependent photoconductive characteristics. (b) Photocurrent vs. light intensity *F* (Log-Log plot) following power law: $I_{ph} \propto F^n$, where n= 0.49.

❑ Spectral phororesponse of OPTEG devices

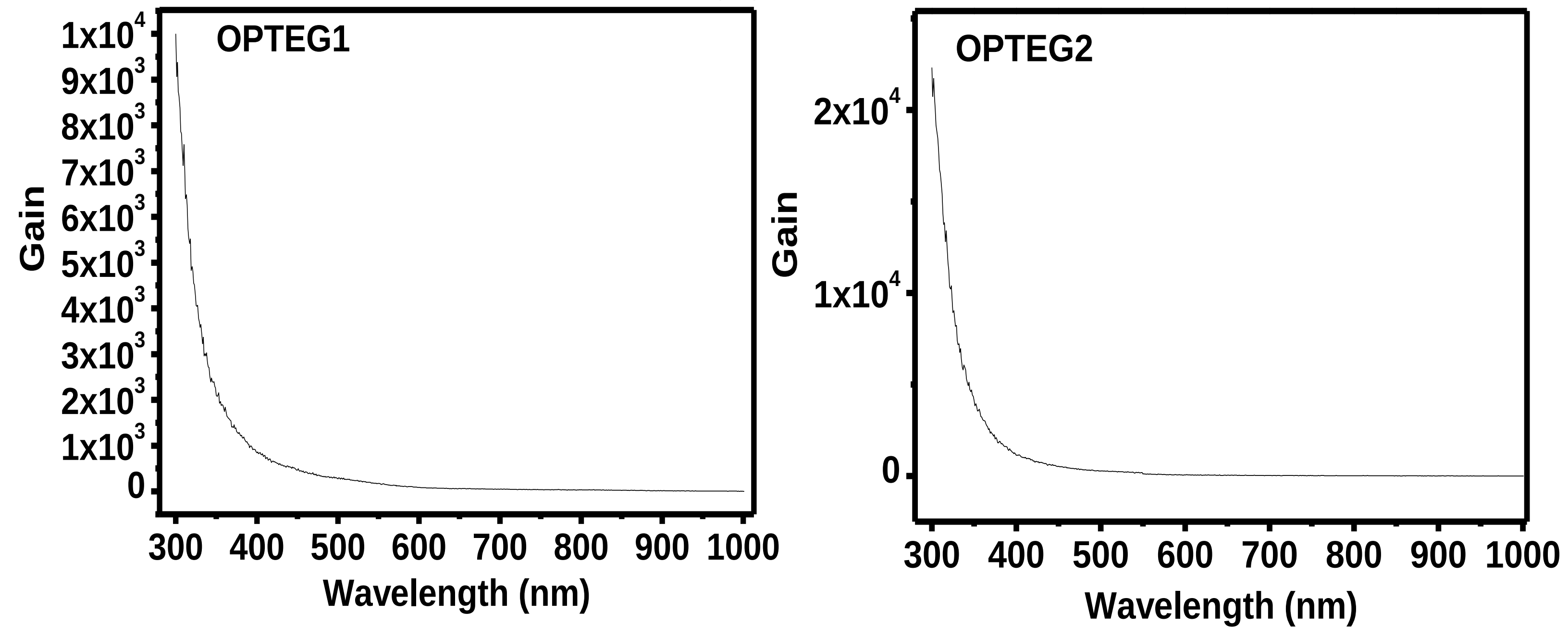

Figure 3. Spectral (300 nm-1000 nm) photoresponse observations at a fixed 2V bias in (a) OPTEG1 device, and (b) OPTEG2 device

- ✓**Maximized high-gain (exceeding 10^4) in UV spectral region**
- ✓**High detectivity exceeding 10^{12} Jones**
- ✓**Comparatively low-power (best performance with 2V bias) consuming UV photodetector**

❑ Characterizations of OPTEG materials

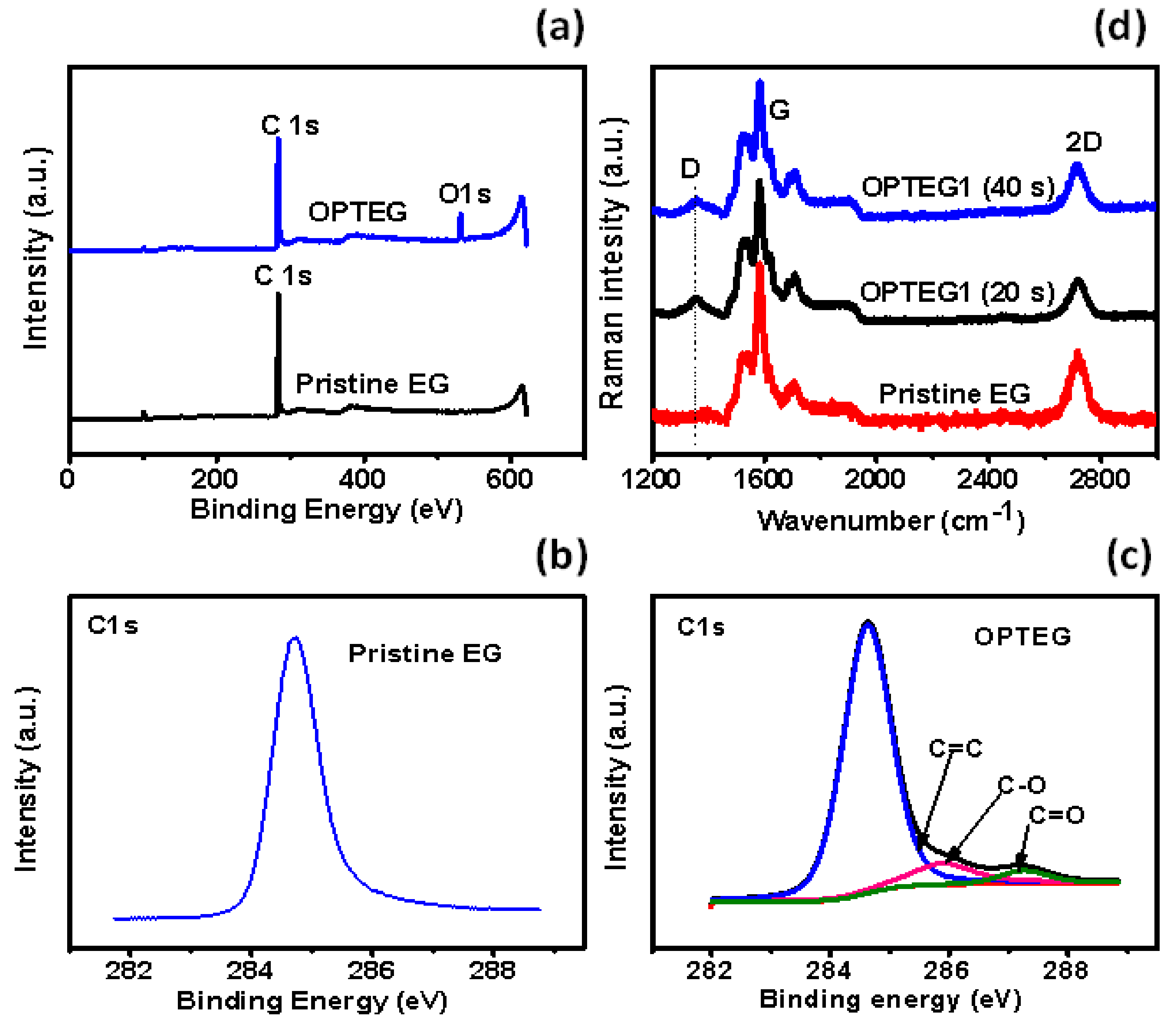

Figure 4. Photoemission spectroscopy (PES) and Raman characterizations of pristine EG and OPTEG. (a) A wide-scan synchrotron PES core level spectra obtained from pristine EG and OPTEG. (b) C 1s of pristine EG. (c) C 1s of OPTEG showing the content of chemisorbed C-O and C=O species. (d) Raman spectra obtained from pristine EG and OPTEG devices for two different treatment times: 20 s (OPTEG1) and 40 s (OPTEG2).

- ✓High photoconductive gain and prolonged response time (in range of few seconds) of the device attribute to the presence of oxygen related traps in OPTEG as presented in XPS (Figure 4(b, c))

❑ Conclusion

we have demonstrated that mild oxygen plasma treatment in epitaxial graphene (EG) based devices can be harnessed to produce high-gain ultraviolet (UV) photodetectors. Oxygen plasma treated EG (OPTEG) surface is investigated using Raman spectroscopy, synchrotron-based high resolution core-level photoemission spectroscopy, and electrical *I-V* measurements. The photoconductive characteristics of OPTEG devices are studied under illumination of white light, and subsequently the spectral photoresponses from infrared (1000 nm) to ultraviolet (UV) (300 nm) light are investigated. The OPTEG device exhibits photoconductive gain as high as ~ 2 × 10^4 at UV (300 nm) spectral light. The large gain, high selectivity, and detectivity in range of 1 × 10^{12} to 3 × 10^{12} Jones of the OPTEG devices in the UV spectral range highlight their potential advantages over Si and many other semiconductor UV photodetectors. The plasma process on SiC wafers is compatibile with CMOS fabrication processes making it possible to scale up the fabrication of graphene based high-gain UV photodetectors.

❑ References

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