Graphene Photonics and Optoelectronics

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Graphene has huge potential in photonics and optoelectronics, where the combination of its unique optical and electronic properties can be fully exploited, the absence of a bandgap can be beneficial, and the linear dispersion of the Dirac electrons enables ultra-wide-band tunability [1]. The rise of graphene in photonics and optoelectronics is shown by several recent results, ranging from solar cells and light emitting devices, to touch screens, photodetectors and ultrafast lasers [1]. Despite being a single atom thick, graphene can be optically visualized [2]. Its transmittance can be expressed in terms of the fine structure constant [3]. The linear dispersion of the Dirac electrons enables broadband applications [4,5,6,7]. Saturable absorption is observed as a consequence of Pauli blocking [7,8]. Chemical and physical treatments enable luminescence [1,9]. Broadband nonlinear photoluminescence is also possible following non-equilibrium excitation of untreated graphene layers [10,11,12]. Graphene-polymer composites prepared using wet chemistry [7,8,13] can be integrated in a fiber laser cavity, to generate ultrafast pulses and enable broadband tunability [7,8]. Graphene's suitability for high-speed photodetection was demonstrated in optical communication links operating at 10Gbits^{-1} [5]. By combining graphene with plasmonic nanostructures, the efficiency of graphene-based photodetectors can be increased by up to 20 times [14]. Wavelength and polarization selectivity can be achieved by employing nanostructures of different geometries [14].

I will give a thorough overview of the state of the art of graphene photonic and optoelectronic devices, outlining the major stumbling blocks and development opportunities. In the first part of the talk I will focus on solar cells where graphene can fulfill the following functions: as the transparent conductor window [15], antireflective material [16], photoactive material [17], channel for charge transport [18], and catalyst [19].

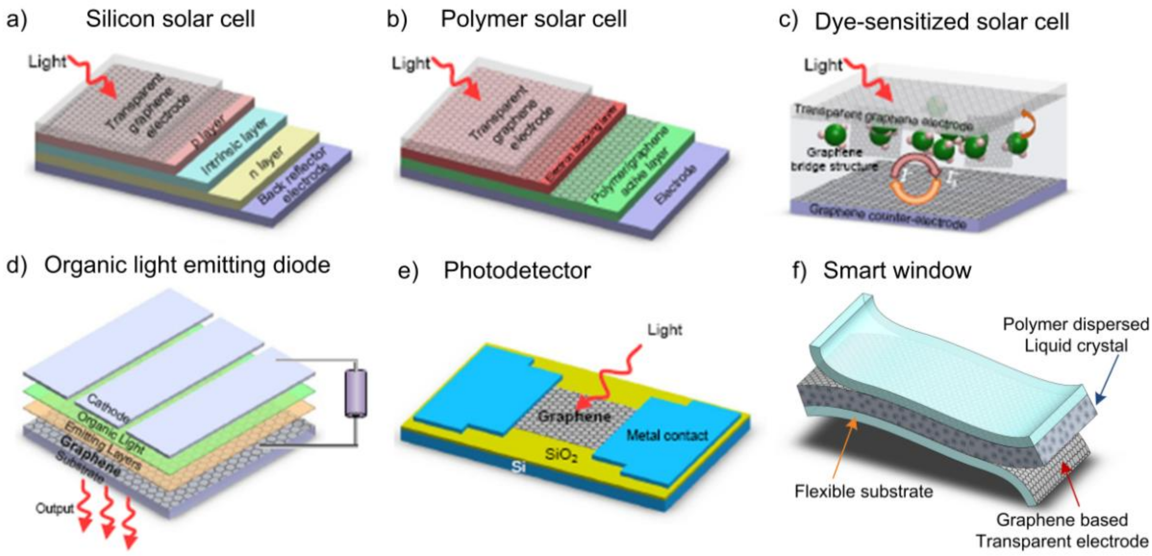

Figure 1: *Schematics of (a) inorganic solar cell, (b) polymer solar cell, (c) dye-sensitized solar cell, (d) organic light emitting diode (e) photodetector and (f) smart window.*

A variety of configurations have been demonstrated to date, ranging from silicon solar cells (fig 1a) [16], to polymer (fig 1b) [17] and dye-sensitized solar cells (fig 1c) [15,18,19]. I will also show how plasmonic nanostructures can be used to increase dramatically the light harvesting properties in solar cells [14]. In the second part of the talk I will turn to a broader consideration of graphene applications in other photonic and optoelectronics devices, such as electroluminescent devices (fig.1 d) [20], photodetectors (fig.1 d) [5,6,14], smart windows (fig.1 f) [1] and ultrafast lasers [7,8].

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