Graphene to protect environmentally unstable transparent electrodes

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Abstract

The exploration for transparent electrodes (TEs) which are inexpensive and can replace indium tin oxide (ITO), is extremely crucial for many applications, including touch screens, LCDs, OLEDs, and technologically important solar cells. Alternative electrode materials have recently been the subject of intensive research for the last few years. Up to now, several indium-free TEs have been developed, including aluminum-doped zinc oxides (AZOs), ultrathin metal film (UTMF), and 1 or 2-dimensional nano-structures (carbon nanotubes/films, silver nanowires/films, etc.), and their demonstrations in applications for organic photovoltaic (OPV) devices and organic light emitting diodes (OLEDs). Among these materials, AZO and UTMF have drawn much interest due to their material abundance, low cost, and easy fabrication.

However, AZO and UTMF are subjected to oxidation, which could alter significantly their electrical and optical properties. It is thus crucial to design and develop new TE structures which include protection of films subjected to degradation, as it is the case of AZO and Cu based UTMFs. To this end, a range of materials, such as SiO_2, SiN_x, TiO_2 and Al_2O_3, have been used as permeation blocking layer, both at the top and bottom of the sensitive films. In principle, the thinner they are made the more flexible they become. However their brittleness could result in a high probability that micro-defects propagate to form top-to-bottom cracks, which render such films permeable in atmospheric gases.

One alternative way of avoiding oxidation and overcoming this instability is to use a capping layer to protect the active surfaces with minimal influences in electrical and optical properties. Graphene, which is a single sheet of sp^2 bonded carbon atoms having bandgap of zero eV and thickness of about 0.34 nm, is currently under intensive research due to its enormous potential applications. It is one of the most transparent materials and absorbs about 2.3% of the incoming light over the whole spectrum. Recently, Bunch et al showed that a monolayer of graphene can be impermeable to standard gases like helium. It has already been reported that a graphene layer can function as a corrosion-inhibiting coating for underlying bulk metals. The high transparency combined with its mechanical flexibility and structural stiffness makes thus graphene an ideal corrosion resistant and anti-permeation layer.

In this paper, we show that graphene can be used as a protective layer for transparent electrodes made of materials which would otherwise deteriorate when exposed to the environment. In particular, we investigate aluminum-doped zinc oxides and ultrathin copper films capped with one-atom graphene layer in damp heat (95% relative humidity and 95 ºC) and relatively high temperature (up to 180 ºC) conditions. The results clearly indicate that a graphene layer can strongly reduce degradation in

electrical, optical properties and surface morphology, thus preserving the functionality of the transparent electrodes. The proposed technique is particularly suitable for flexible optoelectronic devices thanks to the mechanical strength of graphene when subjected to bending.

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