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DOPED POLYMER SEMI-CONDUCTORS: A REVIEW

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ABSTRACT

The proposed use of polymers as active semiconductors in a variety of applications ranging from electronics, through electro-optics to photonics represents a major extension to the current widespread commercial interest in polymers as electrically passive materials. In this paper the authors highlight some of the features of the class of material, namely the conjugated polymers that are of principal interest in this context, and they discuss the characterisation of these materials and their interesting physical responses.

KEYWORDS: The proposed characterisation of these materials and their interesting physical responses.

INTRODUCTION

Materials that are both optically transparent and electrically conductive have attracted significant interest due to their numerous applications, such as in solar cells, flat-panel displays, touch-sensitive screens, light-emitting diodes, and photovoltaic cells. Indium tin oxide (ITO) has become the standard material for such applications. Commercially-available ITO films, with thicknesses in the range of 150–200 nm, have greater than 90% transmittance at visible wavelengths and a sheet resistance of The high cost of indium, however, has made ITO increasingly expensive and, in addition, it is not suitable for flexible devices due to its brittle nature. A metal nanowire network[1] was recently thoroughly investigated as a substitute for ITO in certain promising applications. Films made from conducting polymers such as polyaniline (PANI) composites[2], poly(3,4-ethylenedioxythiophene)/poly(styrenesulfonate) (PEDOT/PSS)[3] and poly(3-alkylthiophene) (P3AT)[4] have also been studied. Such polymers have the advantages of being lightweight, highly flexible and chemically stable. Unfortunately, conducting polymers typically exhibit absorption in the visible wavelength range and thus, they are considered unsuitable for applications that require high-conductivity throughout relatively thick films. We have recently reported a transparent, conductive, polymeric nanofiber mat made from poly(3-hexylthiophene) (P3HT), which exhibits superior transparency and conductivity originating from the presence of highly effective conducting pathways, a large void fraction generated by a bulky nanofiber network and a high dopant concentration due to a large surface area.[5] Compared to materials currently used in actual touch panels, however, the conductivity of this nanofiber mat, at a transmittance of over 88%, is an order of magnitude less than that required. Furthermore, the stability of the doping state was not sufficient and the mat was quite brittle mechanically. Therefore, some of the problems associated with this material must be mitigated prior to its application. On the other hand, conductive nanofiller/polymer composite materials have attracted great academic and industrial attention, as they offer high conductivity in a conventional flexible polymeric film[6-7] and various new materials have been developed to satisfy market needs, exhibiting for example, specific thermal[8], mechanical[9] and electrochemical properties[10] in addition to conductivity. There are several different types of conductive nanofillers, including carbon nanotubes[11], carbon fibers[12], metal particles[13] and conductive polymers.[14] Our aim in the present work was to solve the problems associated with the P3HT nanofiber mat as a transparent, conductive film by using the nanocomposite technique. Qiu et al. have reported that P3HT can be recrystallized into nanofiber form, in combination with conventional non-crystalline polymers such as poly(methyl methacrylate) (PMMA) and polystyrene (PS) to form nanofiber composite films.[15] These nanofiber composite films exhibit semiconducting properties and can be used to fabricate a flexible field-effect transistor (FET) simply by adding electrodes. We have also observed that an effective nanofiber network was percolated over these films by use of a Kelvin-probe microscope (KFM).[16] If these composite films can be doped, they represent potential flexible films with considerable mechanical strength and both high transparency (due to the transparent matrix) and high conductivity (due to the well-developed P3HT nanofiber network). Furthermore, since the nanofibers are embedded in the matrix, these composite films are expected to show high environmental stability.

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