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Electrical characterization and photovoltaic properties of 7,7′,8,8′ tertracyanoquinodimethane thin films

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ABSTRACT

Thin films of 7,7′,8,8′ tertracyanoquinodimethane (TCNQ) were deposited using thermal evaporation technique. TCNQ was found to be polycrystalline in powder form and preferred to orient at one plane in thin films. The temperature dependence of the electrical resistivity of Au/TCNQ/Au device was studied. TCNQ thin films were deposited on p-GaAs single crystal substrate; the current–voltage and capacitance–voltage for TCNQ/p-GaAs junction sandwiched between two gold electrodes were investigated. The current of the device obeys the thermionic emission model in the voltage range of $0 < V < 0.5$. The diode parameters such as rectification ratio, series resistance, quality factor and mean potential barrier height were evaluated. The space charge limited conduction dominated by single trapping level is applicable in the voltage range $0.5 < V < 1.5$. The capacitance–voltage measurements showed that the formed junction is abrupt in its nature and the built-in potential is determined. Under illumination, the cell exhibited a photovoltaic characteristic from which the photovoltaic parameters such as open circuit voltage, short circuit current, fill factor and conversion efficiency were calculated.

1. Introduction

Organic semiconductors have attracted attention in the field of electronics and optoelectronics because of their potentially low cost and ease of designing at molecular level [1,2]. They exhibit high absorption coefficients even with small thickness and can be adapted to obtain the specific optical and electrical properties. Hence, organic compounds have been used to fabricate organic photoreceptor as charge photo-generating materials for electrophotography and organic photovoltaic devices [3,4].

Among the organic materials, 7,7′,8,8′ tetracyanoquinodimethane (TCNQ) with the molecular structure as shown in Fig. 1 has attracted particular attention due to its extraordinary electrical, optical properties and the possibility of developing micro- and nano-structures to be used as an active material in electronic devices [5–7]. The applications of TCNQ included organic field-effect transistors [8], switching devices [9] and sensors [10]. According to the scientific literature spectrophotometric measurements carried out in the visible–ultraviolet range [11], the solid state absorption of neutral TCNQ is characterized by a main peak ascribed to a localized electron excitation, located at 400 nm, and by an additional lower energy band, peaked at 440 nm, responsible for which is a surface polaron [12]. The electrical studies presented the TCNQ compound as an acceptor material with an electron mobility of 0.04 $cm^2/V\,s$ [13].

Investigations of hybrid (organic/inorganic) heterojunctions attract some interest due to both the unusual nature of these contacts as well as to the potential new devices that can be applied. These devices combine the unique properties of both organic and inorganic materials to become low in cost and high in performance. Recently, different organic/inorganic heterojunctions were fabricated [14–23] and investigated. These devices have showed photoconversion efficiencies in the range of 0.74–3.5%.

This work aims to study the effect of annealing on the electrical resistivity of TCNQ thin films. The current–voltage measurements of Au/TCNQ/p-GaAs/Au heterojunction are performed at different temperatures to determine the operating conduction mechanisms through which the characteristics of the device are analyzed. The photovoltaic parameters of the formed junction are also determined. The capacitance–voltage measurements are presented to show the nature of the formed junction and to determine the value of the built-in potential.

2. Experimental procedures

The powder of TCNQ (99.7%) used in this study was purchased from Kodak, UK. The high-vacuum evaporation unit (Edwards 306 A) was used to deposit the TCNQ and the gold electrode thin films.

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