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RESEARCH ARTICLE OPEN ACCESS

Influence of Thickness on Optical Properties of Metal Substituted Phthalocyanine Thin Films

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ABSTRACT

The interest of electronics industry in new organic semiconductors for the manufacture of optoelectronic devices has increased substantially in the last decade. Organic semiconductors thin films have also been used in optoelectronics and photovoltaic devices. They exhibit a high potential for production of low cost, efficient and low temperature optoelectronic devices with the option for large area applications. To develop better light-capturing nanostructures, we plan to connect an excellent light-harvesting organic semiconductor. The aim of this work is to study the influence of film thickness on spectral behavior in the UV-Visible range of thermally evaporated metal substituted phthalocyanine thin films. In this paper, we reported the optical studies of two organic semiconductors such as copper phthalocyanine (CuPc) and cobalt phthalocyanine (CoPc). For that, we investigate the UV spectrum at room temperature obtained from thermally evaporated thin films of these organic materials.

Keywords: Thin films, Optoelectronics, Organic semiconductors, Copper phthalocyanine, Cobalt phthalocyanine.

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I. INTRODUCTION

Organic semiconductor based electronics are nowadays emerging technologies for their potential applications in optoelectronic devices. Organic semiconductors are a very important class of materials having wide range of properties. These materials are suitable for the fabrication of optoelectronic circuits with low temperature, low cost and high sensitivity. Also several light sensors can be made using organic semiconductors. The properties like mechanical flexibility, high stability and low processing temperature make the semiconductor based devices suitable for these applications. The electronic conductivity of these materials lies between that of metals and insulators. Organic semiconductors are advantageous for the fabrication of electronic devices because of the ease of processing at low temperature, architectural flexibility, material variety, and environmental safety.

Metal substituted derivatives of phthalocyanines can function as active components in various optoelectronics devices. Because of the very good optical absorption of these molecules in the UV -visible region, there is considerable interest in the characterization of phthalocyanine thin films. Since most of the phthalocyanines are found to exhibit very good optical absorption and emission in the 600-700 nm regions, they can be considered as suitable candidates for optical amplification in this region [1]. The peaks in the absorption spectra are due to overlapping of electron orbitals created by the conjugated double bonds within the crystal structure of the film. These electrons are able to transfer energy throughout the structure [2].Fig. 1 shows the molecular structure of phthalocyanine molecule.

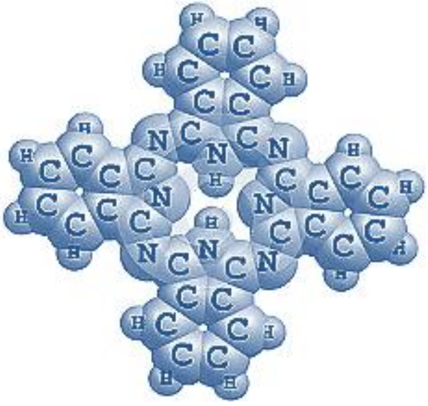


Fig. 1. Molecular structure of Phthalocyanine

In the present study, CuPc and CoPc thin films were deposited by vacuum deposition and their optical properties were studied. Puigdollers et al. reported two absorption bands in the 300-450nm and in the 600-750nm regions in CuPc thin films [3]. Similar behaviors of the absorption spectra are obtained for CoPc thin films [4]. The higher energy band occurring at around 650 nm is generally known as the Q band, and often exhibits vibrational structure in thin film. The intense band at 300-450nm, which gives the absorption edge, is related to direct electronic transition and is called the B band. The Q-band exists in the visible region of spectra while others B exist in the UV region of spectra.Fig. 2 shows the structures of copper phthalocyanineand cobalt phthalocyanine molecules.

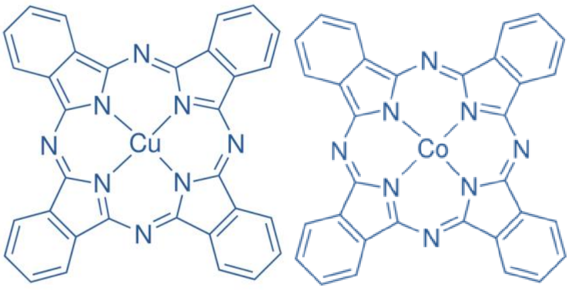


Fig. 2. Molecular structure of (a) Copper Phthalocyanine and(b) Cobalt Phthalocyanine

II. EXPERIMENTAL

The metal phthalocyanine powders with high purity used in this study are obtained from Sigma Aldrichchemicals. Thin films of both CuPc and CoPc with different thicknesses were prepared using a Hind-Hivac thermal evaporation plant (Model No.12A4D) by thermal evaporation technique. The films are deposited on to glass substrate at various thicknesses. Prior to the deposition, the glass substrate was cleaned in an ultrasonic bath for 10 min using acetone followed by isopropyl alcohol and finally rinsing in deionized water. Then the substrate was dried in open air in a cleaned room.

A molybdenum boat was used as a heating source for evaporation. The organic materials are evaporated on to glass substrates from a molybdenum boat of dimension 75mm x 25mm x 1.5mm by resistive heating method. During deposition, the pressure in the vacuum chamber was kept constant at about $2x10^{-5}$ mbar and the deposition rates of all the films were at about 3nm/min. Also the substrate is placed at a distance of 10cm from the molybdenum boat. Thickness of the film is measured from the crystal monitor [5].Fig.3 shows the evaporated thin film of phthalocyanine on a glass substrate. The absorbances of the films were measured at normal incidence in the spectral range 250-800 nm using a UV-VIS spectrophotometer (Model: UV-1600/1700 series, SHIMADZU).

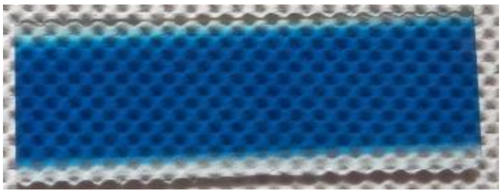
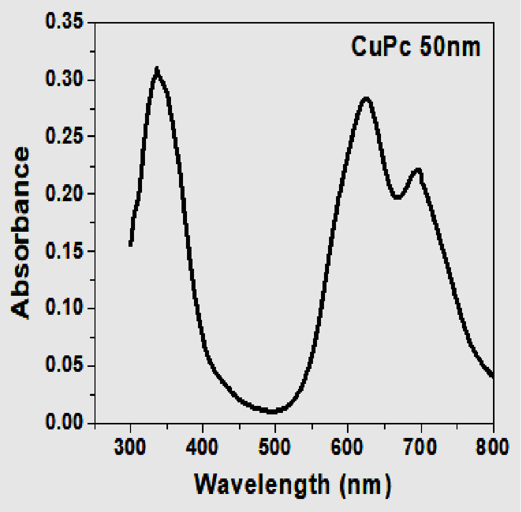


Fig. 3. Phthalocynine thin film on glass substrate

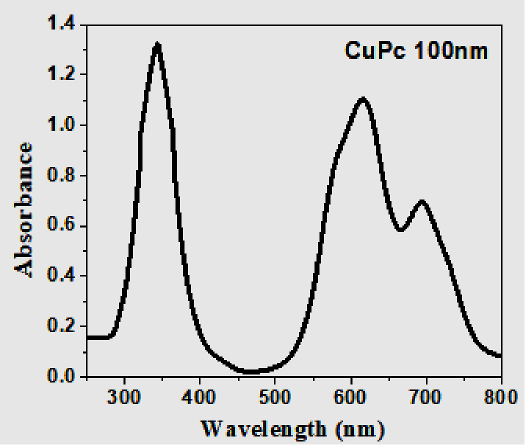
III. RESULTS AND DISCUSSION

The samples of CuPc films were prepared for two thicknesses as 50nm and 100nm. Also CoPc films were prepared for two thicknesses as 50nm and 150nm.These films were prepared on a glass with base pressure of approximate 10^{-5} mbar using thermal evaporation technique.The optical properties and spectral behavior of phthalocyanine films as a function of various thicknesses were studied at room temperature using UV - Visible absorption spectra. Increase in thickness, leads to increase absorbance of films and shifts peak position of all bands towards low energy side of spectra [6].

To study the effect of thickness on optical properties, thin films of CuPc and CoPc are deposited on the substrates with different thickness at room temperature. Hsieh et al. stated that the characteristic of vacuum sublimed organic films varies with deposition parameters like thickness, substrate temperature and annealing [7]. The optical properties of thin films of metal phthalocyanine have been investigated in the spectral range 250-800 nm. The lower energy band, occurring at around 650 nm, is generally known as the Q band. In the solid state, these bands are broadened and overlap so that phthalocyanines absorb light throughout the entire visible region of the electromagnetic spectrum [8]. It has been suggested that the UV-Vis spectrum of MPcs originates from the molecular orbitals within the aromatic 18 Π-electron system and from overlapping orbitals on the central metal [9].Fig. 4 shows the absorbance versus wavelength spectra ofCuPcthin films with differentthicknesses of 50nm and 100nm respectively.



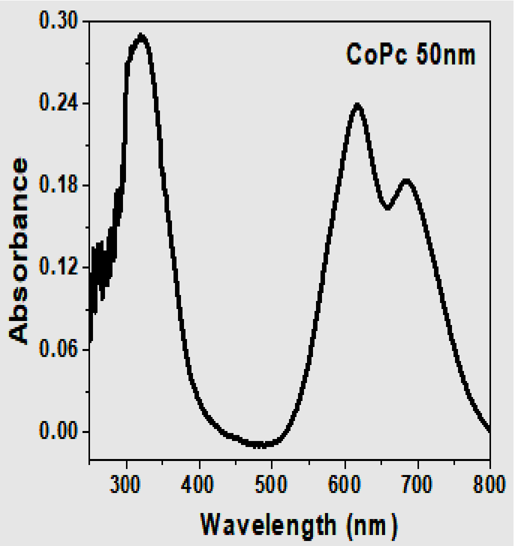
(a)



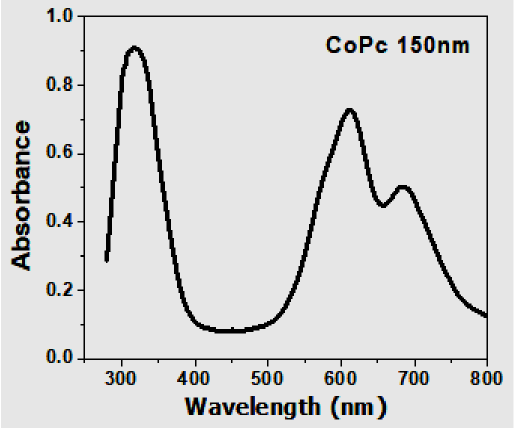
(b)

Fig.3. Absorbance versus wavelength spectrum of CuPc thin film of (a) 50nm thickness (b) 100nm thickness

Present study shows the, Q-band and B-bands in the absorption spectrum of CuPc thin films. From figure, it is clear that, there are distinct characterized peaks in the spectral distribution of absorbance of CuPc thin films for various thicknesses. It is observed that the peak of high intensity absorption maxima of Q band observed at 614nm. The band became prominent with increasing thickness, however there was no shift found with increasing film thickness. The absorption maxima of low energy peak of Q band observed at 697nm also become prominent with increasing film thickness. Also the maxima of B band observed at 342nm.The spectral distribution of absorbance in the wavelength range 250-800 nm for as deposited CoPc films with different thickness of 50nm and 150nm were shown in Fig.4.



(a)



(b)

Fig.4. Absorbance versus wavelength spectrum of CoPc thin film of (a) 50nm thickness (b) 150nm thickness

The absorbency spectra in the UV–VIS region of spectra for CoPc thin films of different thickness 50nm and 150nm shows that absorbance of films increases with increasing film thickness.CoPc molecules shown in figure have two main absorption bands in the UV-visible region of the spectrum, and this is agreement with many researchers [10,11]. In the Q-band region, it is noticed from figure that the doublets are the only features in absorbency spectra CoPc films [12,13].These representing the first and second Π–Π* transition appear at 688nm and 618nm respectively.In the near UV region a single peak is observed at 328nm (B-band).The high energy peak of the Q-band has been assigned to the first π-π* transition on the metal phthalocyaninemacrocycle [14]. The low energy peak of the Q-band has been variously explained as a second π-π* transition.

IV. CONCLUSION

From the present work, we can conclude that the metal substituted phthalocyanine thin films of various thicknesses on glass substrate have been prepared successfully by vacuum evaporation technique. Optical characterizations of the CuP and CoPc thin films were carried out with different film thickness at room temperature. The Q and B bands are observed in the absorption spectrum of the films of two materials at all different thicknesses. The main optical parameter, absorbance was found to be dependent of the film thickness for the studied films. That is, the intensity of the Q and B bands are found increased with increasing thickness. Due to the large absorption, these materials are expected to play an important role in photosensitivity.

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