ABSTRACT

In the research on Phthalocyanines, some attention has been given to Lead Phthalocyanine (PbPc) because of its characteristic structural and electrical properties. PbPc is an attractive material for device applications in various fields such as Opto electronics, gas sensors, organic light emitting devices (OLEDs), field effect transistors (FETs), etc.

PbPc thin films on a glass substrate are prepared by vacuum deposition method. The thicknesses of the films prepared were 150 nm, 300 nm and 450 nm on glass substrate and 150 nm on potassium chloride (KCl) substrate. The thickness of the film 450 nm is annealed at 323 K and 373 K temperatures.

The structural and compositional analysis of the PbPc thin films were investigated by X-Ray Diffraction (XRD), Energy Dispersive Analysis using X-Rays (EDAX), Fourier Transform Infrared spectroscopy (FTIR) for different thickness, substrate and annealed temperature. The result obtained from X-ray diffraction measurement indicates the patterns at lower thickness (150 nm) shows peaks at 2θ values 6.85°, 14.16° and 24.55° that were assigned to monoclinic (001), (320) and (111) lines respectively. The patterns at thickness (300 nm) shows an extra peak at 2θ value 17.49° and is assigned to the monoclinic (420) line. A peak at 2θ value 30.26° coinciding with the triclinic (400) line is seen for higher thickness (450 nm). From the XRD patterns of PbPc films of different thicknesses, it is clear that as thickness increases, triclinic grains (T) are seen along with monoclinic (M) forms of PbPc. The film thickness of 450 nm is annealed at 323 K and 373 K
temperatures. Annealed at 323 K shows peaks at 2θ values 14.9°, 22.4° and 30.3° assigned to the triclinic (200), (300) and (400) lines respectively. When temperature is again increased to 373 K one more peak at 2θ value 7.43° arises, which gets assigned to the (100) reflection of triclinic phase. The PbPc films deposited at different thickness, substrate and annealed temperature were evaluated by EDAX technique. The percentage of lead is same in both the cases and its amount is very low (1.35%). The percentage of carbon increases from 65.56% to 84.81%, when annealed at high temperature. The nitrogen amount is very poor. The peak corresponding to carbon, nitrogen, silicon, sodium and oxygen shows a transition from L to the K-shell which can be termed as a K-Alpha peak (Kα). The elemental composition of the PbPc films deposited at different thickness, annealed temperature was evaluated by FT-IR technique. The C-C and C-H benzene ring peaks intensities increases with thickness and temperature. The material characterization of these films by FT-IR spectroscopy clearly provides a convenient diagnostic technique in the development of PbPc based thin film sensors.

The effects of film thickness, substrate and annealed temperature of surface studies of the PbPc thin films are investigated by Scanning Electron Microscope (SEM) and Atomic Force Microscope (AFM). SEM is one of the best tools to investigate the surface smoothness and to find the grain size of the particles. From the image it is evident that the surface of the films is smooth and grain size is less than a micrometer. The SEM image of lower thickness film of 150 nm shows small cloud like structure. The size of particle increases with increasing thickness. Along with this cloudy structure rod like structures are also seen in the case of film with higher thickness 450
nm. If the film is annealed, the smoothness and uniformity of the film increases. AFM indicates a rough surface, which can be alpha or beta phase films. The alpha phase film have smoother planar than the beta phase film. The crystallite size is roughly constant. The grain size is calculated for all films of different thicknesses and is found to be in between 100-125 nm, 170-200 and 200-230 for 150, 300 and 450 nm respectively. The roughness also decreases with increase in the film annealing temperature.

The optical studies of PbPc films at 303 K have determined both the absorption and reflectivity data for wavelength in the UV and visible regions. It shows evidence for the existence of two absorption bands, which is identical as exciton absorption at low energy below 2.4 eV and the fundamental absorption spectrum of monoclinic PbPc films shows a doublet of energies at 1.86 and 1.74 eV. The spectrum for triclinic shows a strong absorption band at 1.61 eV and two shoulders at 1.72 eV and 1.95 eV.

The photoluminescence (PL) research on PbPc thin films gave better understanding of the absorption, transmittance and photoluminescence studies of materials and characterization. Thus material quality can be measured by quantifying the amount of radiative recombination. The photoluminescence energy associated with photoluminescence can be used to determine impurity levels and concentration as well as the bandgap. The amount of photoluminescence and its dependence on the level of photo excitation and temperature are directly related to the dominant recombination process.

The photoconduction properties of thin films of PbPc on glass and KCl substrates were prepared by vacuum deposition. The current-voltage
characteristics were measured under dark and illumination conditions at the temperature of 303 K using a double beam spectrometer. The light intensity varied from 0 to 1 mW/cm$^2$ and applied voltage is from -30 V to 30 V. The conductivity of PbPc on the glass substrate is around 20 times larger than KCl substrate. The difference in the electrical property of PbPc between the glass and KCl substrate is caused by the orientation of the molecular planes in the films.

The dielectric and AC conduction studies of PbPc films at 303 K have been determined. Dielectrics are basically insulating materials having a special property of storing and dissipating electrical energy when subjected to electromagnetic fields. A dielectric and AC conductivity phenomenon yields information about the mechanism of conduction in thin films. The present work is a detailed study on dielectric properties of Al-PbPc-Al structures and ac conduction studies of PbPc films of thickness 150 nm, 300 nm and 450 nm deposited on glass substrates.

Current Voltage conduction properties of PbPc thin films have been studied. At the higher temperatures, the slope of I – V curves indicates that the thermally generated carrier density exceeds that of the injected charges. This region is considered as ohmic. The plots of $\ln (J/T^2)$ versus $1000/ T$ at different voltages tend to be straight lines at higher temperatures. This straight line behaviour occurs at a temperature of above 320 K. However the domination of the thermionic emission behaviour is observed at higher temperatures.