

Giant Faraday Rotation in Organic Thin Films Semiconductors

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The last few decades have witnessed tremendous growth in studies of magneto-optical materials, which have numerous applications in spintronics such as optical magnetometers, magnetic field sensors, waveguides, nonlinear optical devices with large second and third-order susceptibilities, optical isolators etc. One of the commonly used magneto-optical phenomenon is the Faraday rotation, typically observed in inorganic compounds which have permanent spin moments, i.e. unpaired electrons [1]. The most astonishing recent studies have been reported in the field of organic semiconductors, where organic polymers of high carrier mobility are used as the active materials [2] whilst their sensitivity to magnetic field has not been explained yet.

Faraday effect is the rotation of the polarization plane of light due to magnetic field-induced circular birefringence of a material. Quantitatively, the effect can be described as a linear dependence between the optical angle of rotation θ , the magnetic field strength B and the sample thickness d , $\theta=VBd$, where V is the Verdet constant which depends on the type of a material and the wavelength of light. For thin organic materials at room temperature the value of Verdet constant is giant and approaches to 10^4 – 10^5 °/T·m – which is about 1–2 orders of magnitude larger than for inorganic compounds.

From the microscopic point of view, the giant Faraday effect is related to the splitting of energy levels or bands in a magnetic field. Optical transitions occur at different energies for left- and right-circularly-polarized light, which can be related to the difference of the refractive indices ($n_+(\omega)-n_-(\omega)$) (circular birefringence). The difference between refractive indices becomes maximum in the vicinity of the material's absorption band.

In this research the organic polymers of different thicknesses were prepared by blade-coating technique and homogenous, thin films were obtained. π -conjugated, regioregular polymers e.g. P3BT, P3HT [3], P3DDT have been chosen based on their high carrier transport mobility. The maximum of absorbance for these materials is in range of 350–600 nm, thus the giant Faraday rotation is expected for these wavelengths. By controlling the thickness of P3HT layers in the range of 50–150 nm, we increased Verdet constant for wavelengths 450–650 nm by one order of magnitude with respect to what has been already reported [3]. Similar effect was observed for P3BT and P3DDT samples. We investigated the role of alkyl chain length on the value of Verdet constant. The shorter substituents lead to larger magneto-optics sensitivity, which suggest the dominant role of aromatic polythiophene ring in Faraday Effect. It was observed that the ordering of molecules by self-assembling them by heating can also increase the magnitude of Faraday rotation.

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