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Optical Anisotropy in Organic – Inorganic Composite Perovskite Quantum Wells: Applicability to Light Emitting Diodes

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Quantum well structures allow for a range of material properties to be achieved which otherwise would not be possible in bulk materials. Dielectric quantum wells, in particular, allow for a large exciton binding energy, depending upon the dielectric constants of the well and barrier materials. Organic – inorganic perovskite structured dielectric quantum wells have been shown to give a range of excitonic binding energies by changing the chemistries of the organic barrier and, to a lesser extent, the inorganic well layers.[1] Thus, variations in luminescent wavelengths due to excitonic transitions can be achieved.

In addition, these materials have the added benefit of self-organizing into multiple quantum well structures, eliminating the need for non-equilibrium growth techniques.[2] The wells arrange parallel to the surface of the substrate, leading to a high degree of optical anisotropy. PEPI thin films have been shown to crystallize with either orthorhombic or monoclinic symmetry (space groups Cc, $Pbc2_1$ or Pbca),[3] depending on the length of the organic chain, introducing further optical anisotropy. Due to this anisotropy, optical refractive index data (n and k) of these materials is needed in order to engineer them as useful light emitting devices. In this study, bis-phenethyl-ammonium lead iodide (PEPI; $(C_6H_5C_2H_4NH_3)_2PbI_4$) layers spin-coated on glass substrates were studied in order to determine their optical and structural properties.

Variable angle spectroscopic ellipsometry (VASE) and polarization dependent absorption measurements were used in order to determine the anisotropy of n and k with respect to the crystal axes. VASE was used in the low-absorption region in order to determine the anisotropy of the real part of the refractive index, as well as the thickness of the film. Variable polarization transmission spectroscopy was used to determine the anisotropy of the absorption coefficient in the plane of the substrate, and variable angle transmission spectroscopy was used to determine the variation of k perpendicular to the substrate.

No change in n or k is observed in these films with respect to their axes parallel to the substrate (Figure 1). This is due to the polycrystalline nature of the film in this direction. However, a significant change in k is observed in the direction perpendicular to the substrate due to the texturing of the film perpendicular to the substrate, as evidenced by X-ray diffraction (Figure 2). The excitonic absorption energy (2.37 eV) coincides well with photoluminescence and electroreflectance data. These results illustrate that excitonic absorption due to dielectric confinement dominates perpendicular to the substrate; however, there is a miniumum parallel to the substrate, in agreement with the selection rules for excitons in quantum well structures.

References

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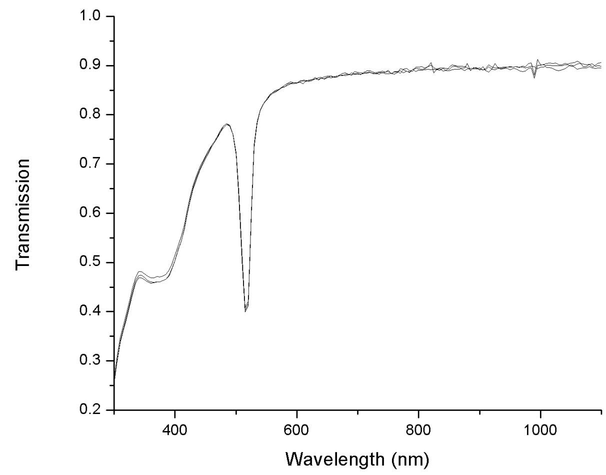

Figure 1. Variable polarization (p, s, and 30 degrees towards s), normal incidence transmission spectra of a PEPI film illustrating isotropy in the plane of the substrate.

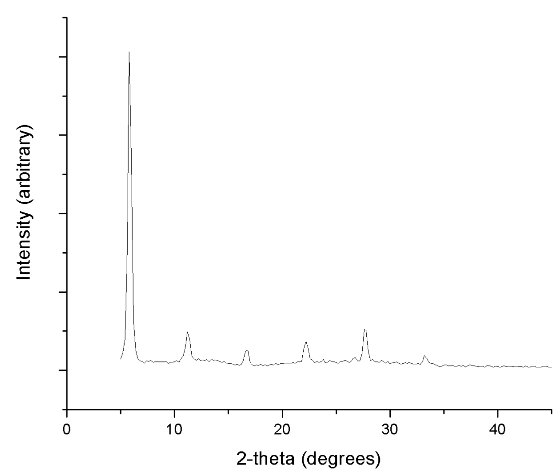

Figure 2. X-ray diffraction pattern of the spin-coated PEPI film. A large degree of texturing with the z-axis perpendicular to the substrate is observed.