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Electroluminescent edge emission from poly(phenylene vinylene) films

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Abstract

Edge emission has been demonstrated from an ITO/poly(phenylene vinylene)/In–Mg electroluminescent device. Room temperature emission saturated at 0.6 mA mm^{-2}, 14 V, and 9.6 cd m^{-2} approximately 35 times brighter than face emission from the same device.

Keywords: Electronic devices; Luminescence; Polymers

Light emission from poly(phenylene vinylene) (PPV) and related organic films is now well established, following the initial reports of Burroughes et al. [1] The typical device configuration tested up to this time is a multilayer structure consisting of (from bottom to top) a transparent substrate, a transparent ohmic electrode, the polymer film, and a rectifying electrode. The light emitted by the polymer film is then observed through the transparent electrode and substrate (face emission). The objective of the present work is to determine whether this type of polymer film would also emit light from the edge of the film. Experience with inorganic electroluminescent materials suggests that edge emission could be considerably brighter than face emission [2]. Increased brightness of 100 × can be obtained by using the extra film depth of edge emission. However, the emitting material must also serve as a low attenuation waveguide [3]. Thus the material should have a low absorption coefficient and a high refractive index relative to the substrate. This then produces a high intensity, directed light source. Moreover, while there are many applications for materials exhibiting face emission, the most significant being flat panel displays, there are also many applications for materials exhibiting edge emission, including electrophotographic printers, heads-up displays, and photonics.

For the current work, PPV was prepared from a solution of a precursor polymer according to the method of Lenz et al. [4], with some modifications. The precursor polymer was obtained in aqueous solution from p-xylene-bistetrahydrothiophenium chloride by base-initiated polymerization. The precursor polymer was subsequently purified by dialysis and stabilized in pyridine. The PPV was obtained by the elimination of the corresponding bis-sulfonium salt from the precursor polymer at 250 °C under vacuum for 17 h.

Test devices were fabricated on glass substrates coated with indium–tin oxide (ITO, 3200 Å, Donnelly Type 5005 FW). A 2000 Å PPV film was deposited by multiple spin coats of the precursor polymer under nitrogen and converted thermally as described above. Finally, a 2000 Å electron-injecting In/Mg electrode was evaporated on the polymer film.

The luminous brightness of emitted light from these devices was determined using a Pritchard 1980A-PL photometer having a MC-80-10 × microscope lens. The diameter of the image spot was 0.100 mm, based on a viewing aperture of 20 min and a zero neutral density filter (open) and no color filters (open). In face emission, the glowing region completely filled the aperture. The sample was then cleaved and tested in edge emission. For edge emission, an area correction was used since the image is thin. During measurements the ITO electrode was connected to the positive terminal of a Hewlett-Packard 6289A current control power supply. Current density was then determined by measuring the electroded area under an optical microscope.

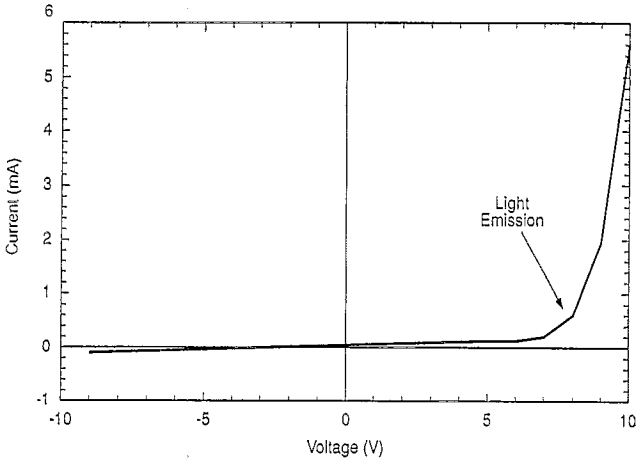

Fig. 1. Diode characteristics of a PPV light-emitting diode.

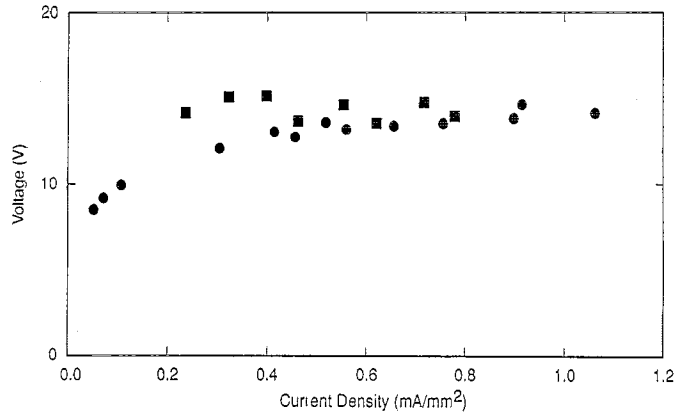

Fig. 3. Voltage/current density curve recorded in face (●) and edge (■) emission modes.

Under d.c. voltage, the threshold for substantial charge injection occurred at approximately 10 V, while opposite biasing exhibits current blocking (Fig. 1). This type of behavior is typical for PPV-based diodes [1]. Waveguiding can be expected in this polymer film due to the high refractive index of the polymer (2.10 at 632.8 nm, as determined by ellipsometry) and low refractive index of the glass substrate (1.5). Face emission of the device was observed to saturate at 0.27 cd m^{-2} at a current density of 0.6 mA mm^{-2} and a voltage of 14 V (Figs. 2 and 3). Edge emission results for the same device are also shown in the figures. The brightness of edge emission at saturation is 20–35 times greater than the brightness of face emission.

The quantum efficiency closely parallels the brightness–current density curve, saturating near 10^{-6}. Similarly the power efficiency shows the same behavior, saturating near 10^{-7}.

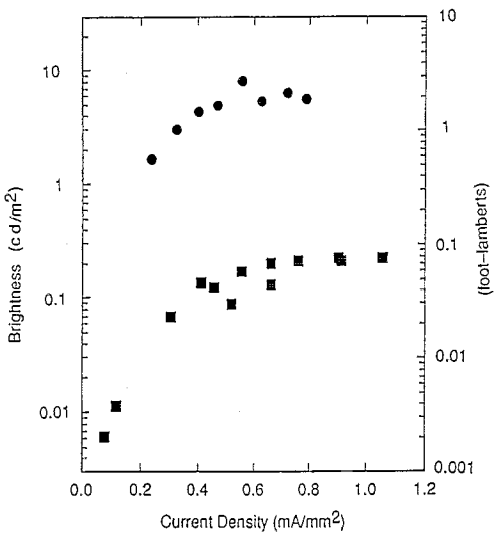

Fig. 2. Brightness/current density characteristic of a PPV diode in face (■) and edge (●) emission.

A comparison can be made with the work of Hiramoto et al. [5], who found edge emission and conclusively determined the existence of waveguiding behavior in a light emitting diode using a bilayer of films of organic small molecules. Their device used tris(8-hydroxyquinoline) aluminum (Alq_3) as the emitter layer and *N,N,N′,N′*,tetrakis(m-methylphenyl)-1,3-diaminobenzene as the hole transport layer between Mg/Ag and Au/Ag electrodes. These films were deposited by vacuum evaporation at room temperature. Measurements were made at 0.1 Pa and −140 °C. When a negative voltage was applied they observed light emission from the edge of their device, with the λ_{max} determined by the thickness of the Alq_3 layer. They attributed the variation to the waveguiding at certain wavelengths between two parallel mirrors at particular separations. At a current density comparable with that used in our work, they report an edge brightness of approximately 4100 cd m^{-2} (1200 foot-lamberts) at −140 °C. Direct comparison to the 9.6 cm m^{-2} (2.8 foot-lamberts) we observed (Fig. 2) is difficult because our measurements were made at room temperature on a device having carrier generation and transport in a single layer.

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