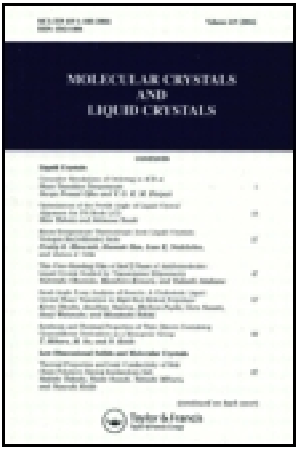

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# Bipolar Carrier Behavior in a Near Ultraviolet Electroluminescent Silicon Polymer: Poly[Bis (p-n-butylphenyl)silane]

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# Bipolar Carrier Behavior in a Near Ultraviolet Electroluminescent Silicon Polymer: Poly[Bis(p-n-butylphenyl)silane]

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Bipolar carrier behavior in a near ultraviolet electroluminescent polymer, poly[bis(*p*-*n*-butylphenyl)silane], was investigated by means of time-of-flight measurements. We observed a hole drift mobility of about $10^{-4}$ $cm^2V^{-1}sec^{-1}$ at room temperature and a clear trace of electron migration. This unique electron behavior is an essential factor as regards observing efficient electroluminescence from the polymer.

*Keywords:* polysilane; drift mobility; hole; electron; electroluminescence

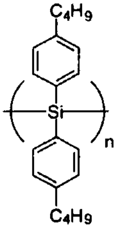
## INTRODUCTION

Polysilanes are polymers with a linear silicon–silicon backbone. They exhibit one-dimensional semiconducting properties, which originate in the delocalization of $\sigma$-electrons along the main chain. Polysilanes have a drift mobility of $\sim 10^{-4}$ $cm^2V^{-1}sec^{-1}$ for holes but none has been observed for electrons. Recently, electroluminescence (EL) has been reported from several polysilanes.[1] They exhibit EL in the ultraviolet or near ultraviolet region which corresponds to photoluminescence from the exciton levels of their silicon backbone. Poly[bis(*p*–*n*–butylphenyl)silane] (PBPS) is unique among them in that it exhibits intense EL at room temperature with a lower turn–on voltage than the other polysilanes so far studied.[2] This implies effective electron injection into a PBPS film or possible electron transport in the film.

In this paper, we report the bipolar carrier behavior of PBPS studied by means of the time-of-flight technique.

## EXPERIMENTS

PBPS was synthesized by a previously reported method.[3] PBPS film was bar-coated on an Al substrate from a toluene solution. A semi-transparent Au electrode was vacuum–deposited on this 6.0 $\mu$m–thick film. A conventional time-of-flight setup, as illustrated in Fig. 1, was used for the drift mobility measurements. A 387 nm pulse laser with a duration of 0.6 ns (BBQ pumped by an $N_2$ pulse laser) was used for carrier generation. The penetration length for 387 nm light was estimated to 400 nm.



**PBPS**

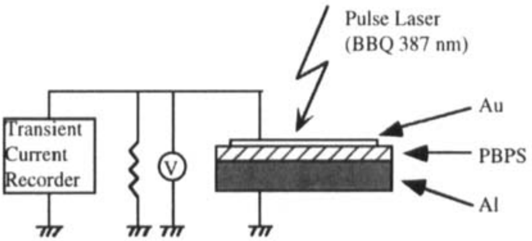


FIGURE 1 Experimental setup for time–of–flight measurements.

## RESULTS AND DISCUSSION

Typical transient curves at 293 K under a variety of applied electric fields, including those with negative signs, are shown in Fig. 2. They show a typical hole–transport behavior for polysilanes under positive electric fields which correspond to the application of a positive bias voltage at the Au electrode. The curves are dispersive at low electric fields and/or at low temperatures, although they become non-dispersive with a plateau and a tail under high electric fields. Log–log plots of these curves were employed to determine the transit time. The hole mobility was calculated to be 8.0 x $10^{-5}$ $cm^2V^{-1}sec^{-1}$ under an electric field of 4.2 x $10^5$ $Vcm^{-1}$ at 293 K. This value is comparable to those for typical polysilanes such as poly(methylphenylsilane)

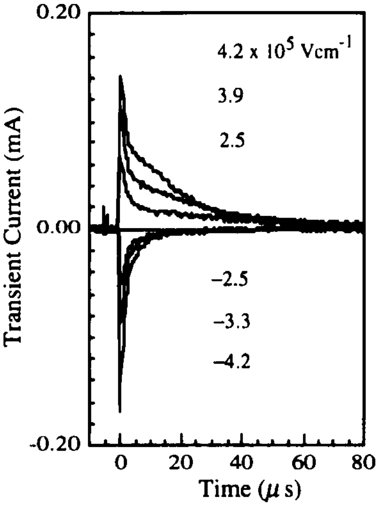


FIGURE 2 Transient current curves for PBPS at 293 K.

(PMPS). Temperature-dependent hole drift mobilities are plotted against 1000/T in Fig. 3. In accordance with Gill's formula, mobility $\mu_0$ at critical temperature $T_0$ and zero-field activation energy $E_0$ are $\mu_0 = 1.8 \times 10^{-4}$ cm$^2$V$^{-1}$sec$^{-1}$, $T_0 = 376$ K, and $E_0 = 0.22$ eV, respectively. The activation energy is smaller than those for the other polyalkylarylsilanes (0.26–0.39 eV) and comparable to those for polydialkylsilanes (0.21–0.26 eV). Further analysis by using Baessler's formula yields parameters $\sigma$ and $\Sigma$, which represent energy and position disorders, and which have respective values of 0.075 eV and 2.3. Both these parameters are relatively small for polysilanes, which is explained by the homogeneity of the rigid PBPS.

When a negative electric field (negative bias voltage at the Au electrode) was applied, a negative transient current was observed which remained for 10 μsec (Fig. 2). The absolute value of the initial transient current was the same as that observed under the same positive electric field. This is in marked contrast to PMPS, which shows almost no signal under a negative electric field. Although the curves did not provide a clear trace of electron transport through the PBPS film, the intense initial transient current indicated

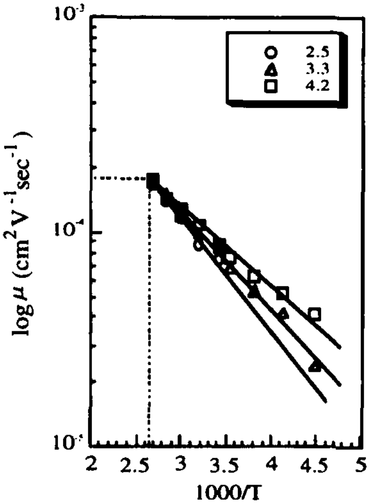


FIGURE 3 Arrhenius plot for PBPS under a variety of applied electric fields (x $10^5$ $Vcm^{-1}$).

that electrons were mobile during a certain period of time in the PBPS film.

Finally, we would like to address the mechanism of efficient EL from PBPS in terms of the bipolar carrier dynamics elucidated in this study. In a polysilane single layer device, electrons injected from an electron injection electrode (EIE) are recombined with holes, which are provided in excess from the opposite electrode, to form a radiative singlet exciton near the polymer–EIE interface. This singlet exciton, however, can relax by energy transfer to the EIE. It is advantageous for PBPS to avoid this nonradiative process, because electrons can migrate deeper into a PBPS layer than into the other polysilanes so far studied. We thus conclude that electron migration in PBPS is one of the essential factors leading to the observation of intense EL at room temperature.

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