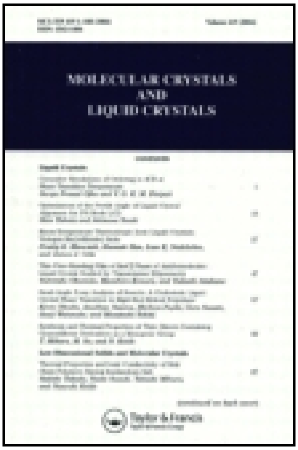

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Vaculjm Vapor Deposition of C_{60} Thin Films and Their Lateral Photoconductivity

Nobutsugu Minami[a]

[a] Research Institute for Polymers and Textiles, AIST 1-1-4 Higashi, Tsukuba, Ibaraki, 305, JAPAN

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VACUUM VAPOR DEPOSITION OF C_{60} THIN FILMS AND THEIR LATERAL PHOTOCONDUCTIVITY

NOBUTSUGU MINAMI
Research Institute for Polymers and Textiles, AIST
1-1-4 Higashi, Tsukuba, Ibaraki 305, JAPAN

Abstract Thin films of C_{60} are fabricated by vacuum vapor deposition and their lateral photoconductivity is measured. We found unusual temperature dependence of photocurrents, the cause of which is so far unknown. From the comparison of photocurrent and absorption spectra it is shown that photocarrier generation efficiency is higher around absorption edge (600 nm). Photocurrents are found to increase in proportion to the square root of light intensity.

INTRODUCTION

For the realization of electronically functional molecular systems, it is essential to accumulate the basic knowledge about their structure and electronic properties and the mutual correlation between them. Spheric carbon cluster (C_{60}), a new allotropic form of carbon,[1] can be considered a promising candidate for an organic electronic material due to its extended π electron system. This expectation was substantiated by the recent discovery that alkali metal doped C_{60} became superconductive at rather high temperature.[2-3] The potential of carbon cluster, however, is not confined to this; we found the considerable photoconductivity of C_{60}/C_{70} thin films possibly exceeding that of phthalocyanine (Pc), a representative organic photoconductor.[4] In the present study, we extended our work to the preparation of pure C_{60} thin films and investigated their lateral photoconductivity under various conditions.

EXPERIMENTAL

Purified C_{60} from a commercial source (Texas Fullerene Corporation) was used as received. Evaporation was carried out in a vacuum of $4\text{-}6\times10^{-5}$ Pa. Controlling the temperature to 380°C of an aluminum crucible containing C_{60} powder yielded an evaporation rate of about 0.05 nm/min. Compared with C_{60}/C_{70} mixture, pure C_{60} appeared easier to evaporate.

A system and method for the measurement of lateral photocurrent was detailed in a previous publication.[5] A pair of coplanar interdigitated gold electrodes deposited on a fused quartz plate was used as a substrate for C_{60} deposition. The electrodes were separated by 0.1 mm with high voltage (typically 1000 V) applied between them. Our experimental system allowed us to carry out the measurements in a high vacuum without exposing the samples to air.

A monochromator (Nikon G-250) combined with a neutral density (ND) filter servo control system (Optel Corporation) was used for the measurement of photocurrent spectra. By the computer-controlled rotation of the ND filter, this system kept the incident photon number constant irrespective of used wavelength.

RESULTS AND DISCUSSION

First, photocurrent was measured during thin film deposition. Similar to what we reported earlier for C_{60}/C_{70} thin films,[4] we observed the emergence and increase in the photocurrent as films thickened. However, the increase rate was very slow and occasionally it decreased back to almost zero. The behavior of C_{60} appeared different from that of C_{60}/C_{70}, the reason of which is unknown. In the previous experiments for Pc thin films, we observed a very clear change of slope in photocurrent increase curves; this was attributed to the coverage of the entire surface of substrate by very thin Pc layer (thickness:5-6 nm).[5] In the present study, the irregular behaviors of photocurrent made it difficult to analyze the change of slope, though we could barely observe one.

We found that the photoconductivity of C_{60} films has rather unusual temperature dependence. A small drop of temperature from 25°C

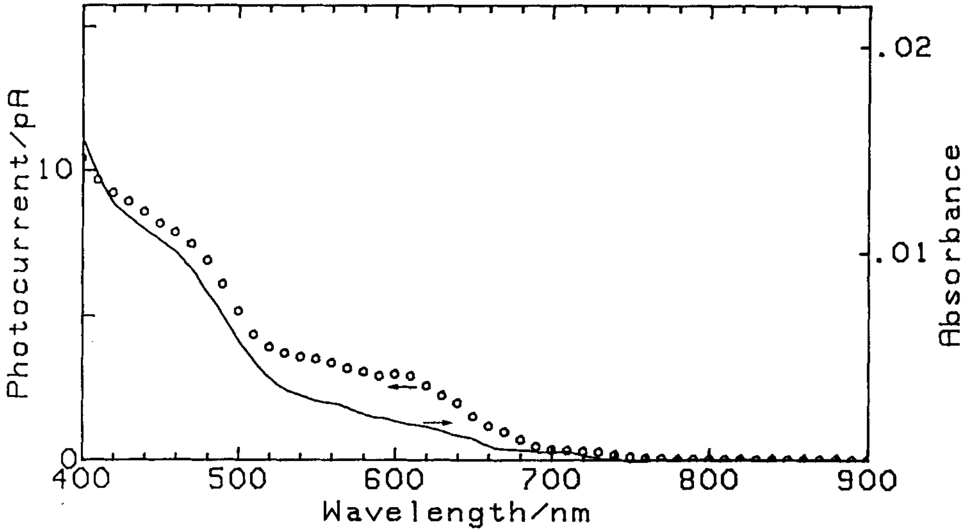

FIGURE 1 Photocurrent action spectrum (O) and absorption spectrum (——) of a 3 nm thick C_{60} film.

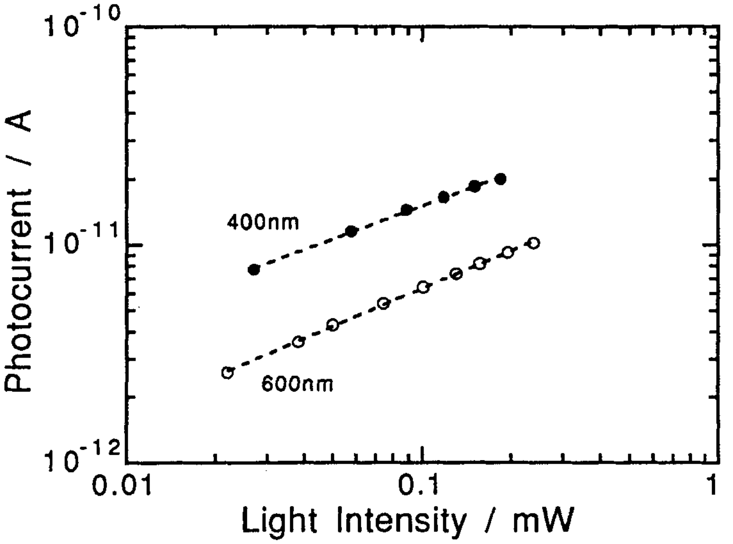

FIGURE 2 Light intensity dependence of photocurrents at 400 nm and at 600 nm.

to 15°C brought about a huge increase in the photocurrent approaching two orders of magnitude. On the other hand, the heating of samples only to 40°C quenched the photocurrent almost completely. The irregularity of the photocurrent increase mentioned above appears to be derived from this temperature dependence, since thermal radiation from the evaporation source was found to raise the temperature of samples. We are now investigating the cause of this unusual behavior.

Figure 1 shows the photocurrent spectrum of a 3 nm thick C_{60} film at 19°C together with its absorption spectrum. Compared with C_{60}/C_{70} mixture,[4] a shoulder in the photocurrent spectrum at 600 nm is more clearly observed here. The absorption spectrum, however, failed to detect such a weak structure. In this sense, the sensitivity of the photocurrent spectroscopy is remarkable and can be applied to investigate the excited state of carbon clusters.

The spectral measurements have shown that an excited state associated with the 600 nm shoulder is more efficient in photocarrier generation compared with other excited states. We ascribe this tentatively to the forbidden nature of the optical excitation at the absorption edge.[6] The lifetime of the excited state can be longer because radiative decay is forbidden. This increases the chance of electron-hole charge separation, leading to more efficient photocarrier generation.

Figure 2 shows the light intensity dependence of photocurrent at 400 nm and 600 nm. At both wavelengths, photocurrents are near proportional to the square root of light intensity. This suggests that the concentration of photocarrier is controlled by bimolecular recombination.

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