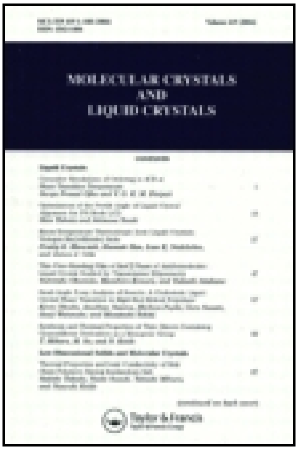

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

AC-Photoconductivity of C_{60} by Molecular Beam Epitaxy

Takeshi Ohgami [a], Yoichi Shimada [a], Hiroshi Kubota [a], Yoshitomo Yamasaki [b], Takahiro Tomiku [b], Susumu Matsuzaki [b] & Masanori Nagata [c]

[a] Faculty of Engineering, Kumamoto University, Kumamoto, JAPAN

[b] Faculty of Science, Kumamoto University, Kumamoto, JAPAN

[c] Kumamoto Industrial Research Institute, Kumamoto, JAPAN

Version of record first published: 04 Oct 2006

Mol. Cryst. Liq. Cryst., 1997, Vol. 295, pp. 59–62
Reprints available directly from the publisher
Photocopying permitted by license only

AC-PHOTOCONDUCTIVITY OF C_{60} BY MOLECULAR BEAM EPITAXY

TAKESHI OHGAMI, YOICHI SHIMADA, HIROSHI KUBOTA
Faculty of Engineering, Kumamoto University, Kumamoto, JAPAN

YOSHITOMO YAMASAKI, TAKAHIRO TOMIKU, SUSUMU MATSUZAKI
Faculty of Science, Kumamoto University, Kumamoto, JAPAN

MASANORI NAGATA
Kumamoto Industrial Research Institute, Kumamoto, JAPAN

Abstract Band gap structure of C_{60} epitaxial film is reported by using AC-photoconductivity measurement. The measurement clarify gap states by analyzing spectra two components of photocurrent and phase shift. A bias operation through semi-transparent Au electrodes has verified existence of Schottky barrier of about 2V. The temperature dependence of the spectra indicate that tail states correspond to structure change of C_{60} at around 250K.

INTRODUCTION

Since the discovery[1] of C_{60}, the fundamental phenomena such as optical absorption, electronic band gap for application to electronic and optical devices have been widely reported, where C_{60} films indicate the band gap at 1.6-2.0eV by optical studies for application to electrical process[2,3,4]. There is, however, no study of impurity level, localized states in the band gap related to semiconductor crystal quality, which grade is necessary to recognize whether localized states expand over soccer balls or not.

We observed band gap structure of C_{60} epitaxial film by using AC-photoconductivity measurement[5,6] with focusing tail states. The measurement under bias field has succeeded to obtain the barrier height between Au electrode and the sample.

EXPERIMENTAL PROCEDURE

The C_{60} films in this study were prepared by molecular beam epitaxy (MBE) systems equipped by K-cell evaporation source in a vacuum at the range of 10^{-10}Torr and grown on MoS_2 substrate with Au precoated electrode. Substrate temperature and deposition rate were set up 120°C and 1Å/min, respectively. The sample has finally sandwiched structure by top semi-transparent Au electrode. The electrode deposited on the upper side has been formed right after the C_{60} deposition and without exposing the sample to the air. Figure 1 shows the configuration of the sample and the direction of light incident.

Block diagram of the experimental set of AC-photoconductivity is shown is figure 2. The sample is irradiated by monochromatic light chopped from halogen light source. The modulated frequency was 270Hz at this time. Reference signal is introduced by photo-detector to lock-in amplifier. The detected photocurrent is converted by transformer and low noise preamplifier into the voltage signal.

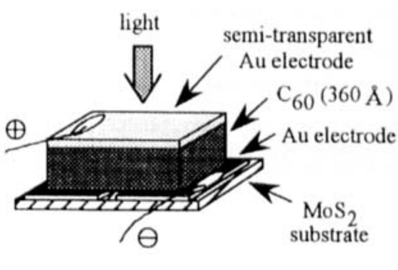

Fig.1. Configuration of C_{60} sample.

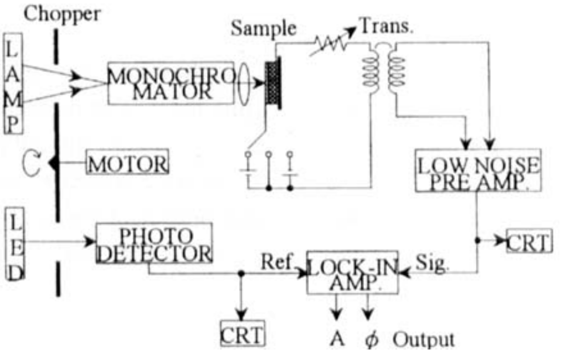

Fig.2. Block diagram of AC-photoconductivity measurement.

RESULTS AND DISCUSSION

Dark current and voltage characteristic of C_{60} sandwiched by Au electrodes indicated weak rectifying effect in both forward and backward bias. The rectification is originated to a Schottky barrier layer, which made by different work functions of Au and C_{60}.

Figure 3 shows the spectra of photocurrent and phase shift as functions of photon energy at various applied bias voltage. The spectrum of the phase at 0V (no-bias) spectra shows gradual change around 1.65-1.85eV. The result is described that C_{60} has mobility edge around 1.85eV. In the range above 1.85eV light absorption occurred at the surface, where photocarriers were created and moved into the sample by the surface

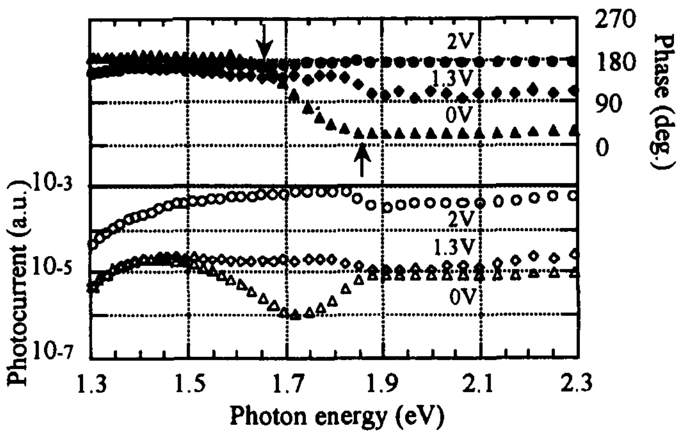

Fig.3. Spectra of photocurrent and phase shift as function of photon energy at various bias voltage.

potential of Schottky barrier between Au electrode and C_{60} film. In the equal absorption range below 1.65eV, photocarrier of electron flowed against under another Schottky potential between the bottom electrode and C_{60} film. The photocurrents in cases of surface and equal absorption conditions, flows against each other. The phenomena were observed as 180° phase change. The decrease of photocurrent below 1.7eV under no-bias is described due to the change of direction of photocurrent. Photocurrents below 1.4eV reflects the localized states in the gap. Applied bias voltage works reduction of Schottky barrier at 2V, which is 2V magnitude of Schottky barrier height verified.

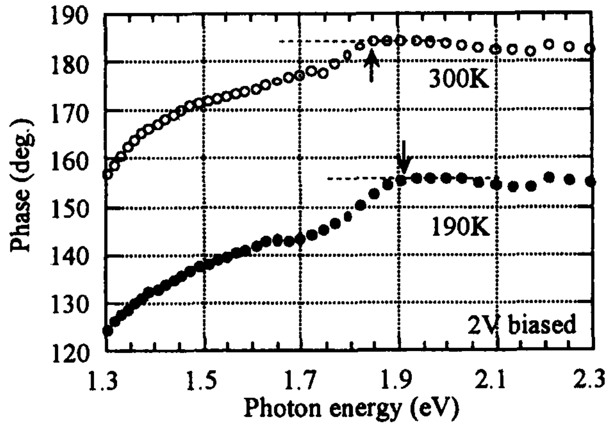

Fig.4. Spectra of phase shift as function of photon energy at 300K and 190K.

Measurement of the AC-photoconductivity has been carried out under 2V bias voltage at 300K and 190K is shown in figure 4. In the case of 300K, phase keeps constant for high energy region, but decreases with decreasing photon energy below 1.85eV. In the case of 190K, energy gap is estimated 1.91eV in the same way. The difference between two cases will be described due to reduction of edge states related to bridge over soccer balls induced by structure change around 250K.

SUMMARY

In summary, Schottky surface potential of about 2V exists in the C_{60} thin films sandwiched by Au electrodes. According to AC-photoconductivity measurement without the Schottky barrier effect, the value of mobility edge has been obtained at 1.85eV at 300K. The edge states distributed over 0.06eV is related to the structure change of C_{60} at around 250K.

REFERENCE

1. H.W.Kroto, J.R.Heath, S.C.O'Brien, R.F.Curl and R.E.Smalley, Nature, 318, 162 (1985).
2. H.Yamaguchi and T.Masumi, Journal of The Physical Society of Japan, 61, 4279 (1992).
3. M.Hosoya, K.Ichimura, Z.H.Wang, G.Dresselhaus, M.S.Dresselhaus and P.C.Eklund, Physical Review B, 49, 4981 (1994).
4. S.Hasegawa, T.Nishiwaki, H.Habuchi, S.Nitta and S.Nonomura, Fullerene Science & Technology, 3, 313 (1995).
5. H.Oheda, Solid State Communications, 33, 203 (1979).
6. M.Yamaguchi and K.Morigaki, Japanese Journal of Applied Physics, 20, 677 (1981).