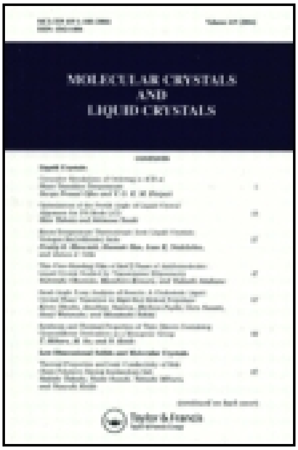

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

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

Effect of the Intercalation of Ne on Electronic Properties of C_{60} Solids

Shinji Bitoh [a] , Takashi Itoh [a] , Shigeru Yoshida [a] , Shoji Nitta [a] & Shuichi Nonomura [b]

[a] Department of Electrical Engineering, Gifu University, 1-1 Yanaido, Gifu, 501-1193, Japan

[b] Environment and Renewable Energy Systems, Graduate School of Engineering Gifu University, 1-1 Yanaido, Gifu, 501-1193, Japan

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 340, pp. 655-660
Reprints available directly from the publisher
Photocopying permitted by license only

Effect of the Intercalation of Ne on Electronic Properties of C_{60} Solids

SHINJI BITOH[a], TAKASHI ITOH[a], SHIGERU YOSHIDA[a], SHOJI NITTA[a] and SHUICHI NONOMURA[b]

[a]*Department of Electrical Engineering, Gifu University, 1-1 Yanaido, Gifu 501-1193, Japan and* [b]*Environment and Renewable Energy Systems, Graduate School of Engineering Gifu University, 1-1 Yanaido, Gifu 501-1193, Japan*

(Received May 30, 1999; In final form July 8, 1999)

The intercalation of Ne in C_{60} solids has been studied. Gas effusion spectrum of C_{60} powder exposed to Ne at 100°C, three evolution peaks of Ne are found near 100, 200 and 250°C. Electrical resistivity of a C_{60} film increases by the exposure to Ne at 100°C. Electron spin density of a C_{60} film does not vary by the exposure to Ne. The intercalation of Ne and its effect on electronic properties of C_{60} solids are discussed.

Keywords: C_{60} solids; intercalation of Ne; electron spin resonance; gas effusion spectroscopy; electrical resistivity

INTRODUCTION

It is well known that the electronic properties of C_{60} solids are not stable in air, because C_{60} solids intercalate O_2. Therefore it is important to protect the intercalation of O_2 into C_{60} solids in order to apply to electronic devices for C_{60} solids. It was reported that rare gas such as Ne and Ar were intercalated into C_{60} solids by exposure to rare gas at high pressure [1-3]. There is possibility that the intercalation of O_2 into C_{60} solids is protected by the occupation of the interstitial sites with rare gas. Then the electronic properties of C_{60} solids will be stable in air. However the effect of the intercalation of rare gas on the electronic properties of C_{60} solids is not known. In this report, the intercalation of Ne and its effect on the electronic properties of C_{60} solids have been studied by gas effusion spectroscopy, electron spin resonance and electrical resistivity.

EXPERIMENT

C_{60} powder (Term Co.) was used in gas effusion spectroscopy and as a source material on preparation of C_{60} films. The nominal purity was 99.98%. C_{60} films were prepared by a vacuum evaporation method in the vacuum of ~2.0×10^{-5} Torr. The C_{60} source powder was sublimated at 400~450℃ onto sapphire substrates. The substrate temperature was 250℃. The film thickness of samples used in electron spin resonance (ESR) and electrical resistivity were ~5.0 and ~3.0μm, respectively.

Gas effusion spectroscopy was measured at a heating ratio of 5°C/min as described previous report [4]. C_{60} powder was exposed to Ne of 1.0 atm. at 100℃ to intercalate Ne after annealing at ~350℃ in vacuum of ~10^{-5} Torr for 8 hours. The purity of Ne was 99.999%. Electron spin density of a C_{60} film was obtained by ESR. The electrical resistivity was measured in a vacuum of ~7×10^{-5} Torr. In this work, Au was evaporated as gap electrode with a gap of 60μm. In these measurements, C_{60} films were exposed to Ne of 1.0 atm. at 100℃ after annealing at 200~250℃ in vacuum of ~10^{-5} Torr for 8 hours.

RESULTS AND DISCUSSION

Figure 1 shows a gas effusion spectrum of Ne for C_{60} powder exposed to

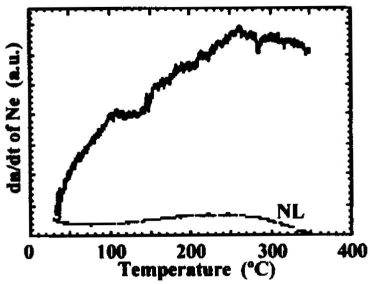

FIGURE 1 Gas effusion spectrum of Ne for C_{60} powder exposed to Ne at 100°C for 24 hours.

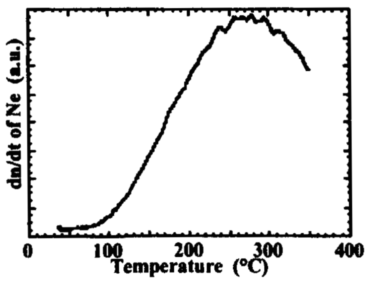

FIGURE 2 Gas effusion spectrum of Ne for C_{60} powder exposed to Ne at 100°C for 24 hours.

Ne at 100°C for 24 hours. The curve NL shows the noise level. In this spectrum, three evolution peaks of Ne are found near 100, 200 and 250°C. It is found by cyclic experiments that the absorption and desorption of Ne in C_{60} powder are reversible phenomena. Therefore this result indicates that C_{60} solids intercalate Ne by exposure to Ne at 100°C. From figure 1, it was found that Ne intercalated in C_{60} solid should be annealed out at ~250°C. Figure 2 shows a gas effusion spectrum of Ne for C_{60} film exposed to Ne at 100°C for 24 hours. The spectra in figures 1 and 2 are those for samples held in vacuum for 3 and 13 hours after exposure to Ne, respectively. In figure 2, the evolution peak of Ne near 100°C is not found. From these results, the origin of Ne evolved near 100°C and above 200°C would be estimated as Ne adsorbed on the surface or in grain boundaries and Ne intercalated in C_{60} solids, respectively. C_{60} solids have octahedral sites (O sites) and tetrahedral sites (T sites) as a interstitial site. Ne would be intercalated into O sites, because Ne is smaller than a size of O site and larger than a size of T site.

Figure 3 shows the dependence of the electrical resistivity of a C_{60} film on the exposure time to Ne at 100°C. The electrical resistivity of the sample

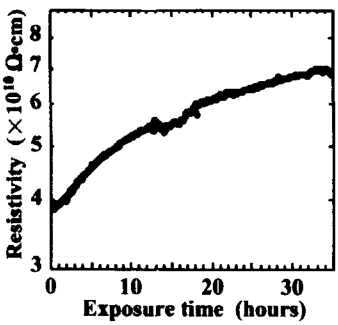

FIGURE 3 Dependence of electrical resistivity of C_{60} film on exposure time to Ne at 100°C.

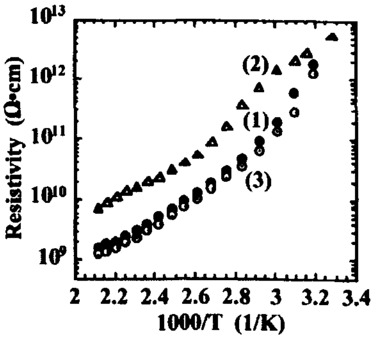

FIGURE 4 Temperature dependence of electrical resistivity of C_{60} film.

increases with the exposure time to Ne. This result indicates that the electrical resistivity of a C_{60} film increases by the intercalation of Ne. Figure 4 shows the temperature dependence of the electrical resistivity of the C_{60} film. Solid circles (1) show the electrical resistivity of the sample annealed at 200°C in vacuum for 12 hours. Open triangles (2) show the electrical resistivity of the sample, which was exposed to Ne at 100°C for 40 hours after annealing at 200°C in vacuum for 12 hours, with increasing temperature from room temperature to 200°C. Open circles (3) show the electrical resistivity of the sample annealed at 200°C in vacuum for 12 hours after exposure to Ne at 100°C. From this result, the electrical resistivity of the sample exposed to Ne at 100°C recovers by annealing at 200°C in vacuum. Comparing with the result of gas effusion spectroscopy, this recover would be caused by annealing out Ne from the sample.

Figures 5 and 6 show the dependence of the electron spin density and the g-value of a C_{60} film on the exposure time to Ne, respectively. The electron spin density of the sample does not vary by the exposure to Ne. The g-value

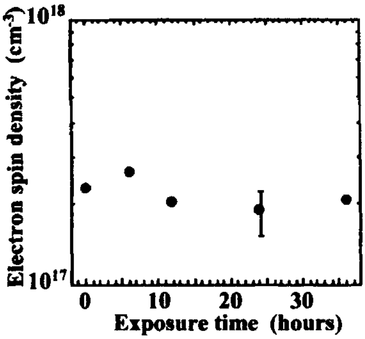

FIGURE 5 Dependence of electron spin density of C_{60} film on exposure time to Ne.

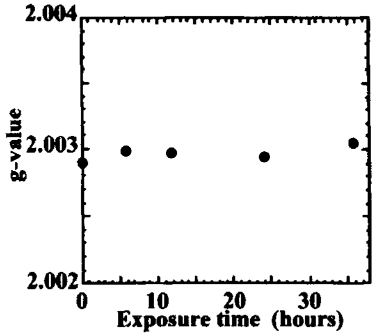

FIGURE 6 Dependence of g-value of C_{60} film on exposure time to Ne.

of the sample also does not vary by the exposure to Ne. These results indicate that the intercalation of Ne does not affected the electronic property of C_{60} solids. Both the electron spin density and the electrical resistivity of a C_{60} solid increase by the intercalation of O_2 [5,6]. Therefore the effects of the intercalation of Ne and O_2 on the properties of C_{60} solids are different. This difference in the effect of the intercalation of Ne and O_2 on the properties of C_{60} solids would be explained as follows. The g-value of O_2-intercalated C_{60} solids is ~2.003. The g-values of C_{60}^+ and C_{60}^- are 2.00221 and 2.00056, respectively [7]. Therefore there is a possibility that the intercalated O_2 could accept electron from C_{60} solids. The increase of the electrical resistivity by the intercalation of O_2 could be caused by the electron acceptance of O_2 from C_{60} solids, because a C_{60} solid is an n-type semiconductor. On the other hand, the intercalated Ne could not accept electron from C_{60} solids, because the electron spin density does not vary by the intercalation of Ne. It was reported that the lattice parameter of C_{60} solids was expanded by the intercalation of Ne [3]. Therefore the increase of the electrical resistivity of the sample by the intercalation of Ne could be caused by the expansion of the lattice parameter.

SUMMARY

In gas effusion spectrum of C_{60} powder exposed to Ne at 100°C, three evolution peaks of Ne are found near 100, 200 and 250°C. C_{60} solids intercalate Ne by exposure to Ne at 100°C. Electrical resistivity of a C_{60} film increases by the intercalation of Ne. Electron spin density of a C_{60} film does not vary by the intercalation of Ne. Comparing with the results of the O_2-intercalated C_{60} solids, the increase of electrical resistivity of C_{60} film by the intercalation of Ne could be caused by the expansion of lattice parameter.

Acknowledgments

This work was supported partly by the Grant in Aid of Encouragement of Young Scientist from the Ministry of Education of Japan and the Program "Research for Future" from the Japan Society for Promotion of Science.

References

[1] B. Morosin, J.D. Jorgensen, S. Short, G.H. Kwei and J.E. Schirber: Physical Review B, **53**, 1675 (1996).

[2] G.E. Gadd, M. James, S. Moricca, P.J. Evans and R.L. Davis: Fullerene Science & Technology, **4**, 852 (1996).

[3] J.E. Schirber, G.H. Kwei, B. Morosin, J.E. Schirber and R.L. Hitterman: Physical Review B, **51**, 12014 (1995).

[4] T. Itoh, S. Nitta and S. Nonomura: Journal of Physics and Chemistry of Solids, **58**, 1741 (1997).

[5] T. Arai, Y. Murakami, H. Suematsu, K. Kikuchi, Y. Achiba and I. Ikemoto: Solid State Commun., **84**, 827 (1992).

[6] T. Itoh, R. Yasuda, T. Go, S. Nitta and S. Nonomura: Abstracts of 10th International Conference on Intercalation Compounds, in print.

[7] M.S. Dresselhaus, G. Dresselhaus and P.C. Eklund: *in Science of Fullerenes and Carbon Nanotubes* (Academic, San Diego, 1996), Chaps. 16, p.674.