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Fabrication of TTF-TCNQ Molecular Wires Using Applied Electric Field Deposition

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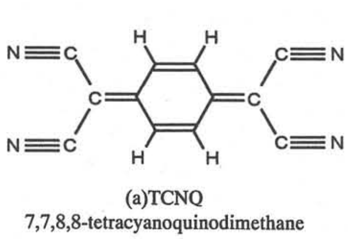
1. Introduction

Organic molecules are interesting materials having a potential to be used in next-generation nano-devices. It is important to prepare highly oriented molecular wire since the optical and electrical properties of the organic films strongly depend on the molecular orientation. The organic compound tetrathiafulvalene-tetracyanoquinodimethane (TTF-TCNQ) has been widely studied due to its quasi-one-dimensional conductivity. It consists of homologous stacks of cations (TTF) and anions (TCNQ) along the *b*-axis and shows one-dimensional metallic conductivity due to a charge transfer between the two different types of molecules. In the previous study, it was found that the molecular orientation of TTF-TCNQ complex films could be controlled using the co-evaporation technique with an applied electric field [1,2].

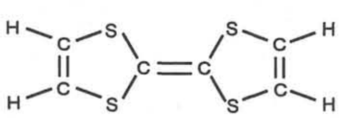
In this study, we have fabricated highly oriented TTF-TCNQ wires using the applied electric field deposition technique.

2. Experimental

Figure 1 shows the chemical structures of TCNQ (acceptor) and TTF (donor) molecules. Fabrication system of TTF-TCNQ wire using applied electric field deposition are shown in Fig. 2. The Au/Cr electrodes were formed on the glass substrate. The electrode gap was 20 or 100 μm. TTF-TCNQ wires were fabricated by using a co-evaporation system with two separated sources (TTF and TCNQ). The electric field between the electrodes was varied from 0 to 35 kV/cm. TTF and TCNQ were deposited in the vacuum chamber with the substrate temperature of 42 ℃. The morphology of the TTF-TCNQ wires on the substrates was observed using an optical microscope.



(a)TCNQ
7,7,8,8-tetracyanoquinodimethane



(b)TTF
tetrathiafulvalene

Fig. 1 Chemical structures of a) TCNQ, b) TTF.

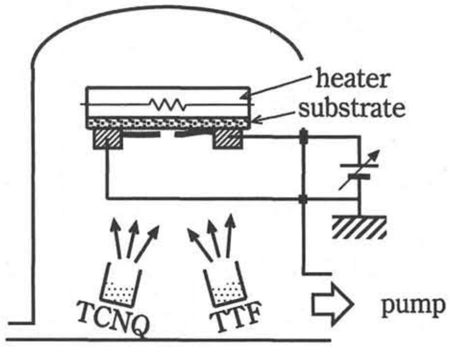


Fig. 2 Applied electric field deposition method.

3. Results and discussion

Figure 3 shows surface morphology of the TTF-TCNQ films with zero electric field. Whisker-like micro-crystals of TTF-TCNQ were formed on the substrate surface. Highly oriented wires are not formed under the zero electric field.

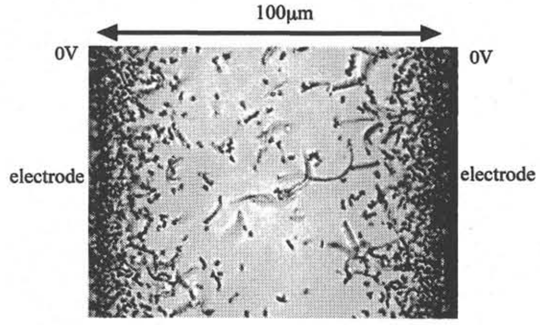


Fig. 3 Optical microscope image of the TTF-TCNQ grains formed by co-evaporation technique with zero electric field.
(Electrode gap was 100 μm.
Substrate temperature was 42 ℃).

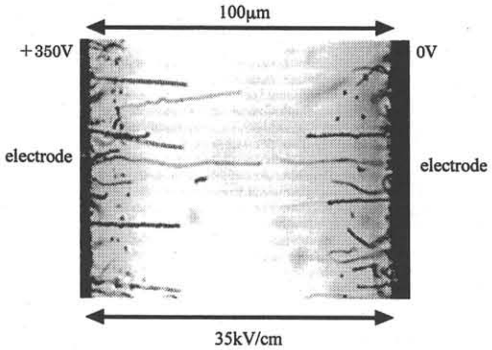


Fig. 4. Optical microscope image of TTF-TCNQ wires formed with applied electric field deposition. (Electrode gap was 100 μm. Substrate temperature was 42 ℃)

Figure 4 shows TTF-TCNQ wires formed on a substrate with applied electric field of 35 kV/cm (350V). Many TTF-TCNQ wires longer than 30 μm were observed. TTF-TCNQ wires grow the along applied electric field.. These results demonstrate that the electric field is essential to fabricate the molecular wires.

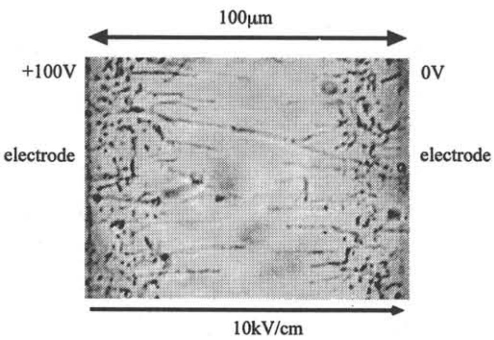


Fig. 5. Optical microscope image of TTF-TCNQ wires formed by applied electric field deposition. (Electrode gap was 100 μm. Substrate temperature was 42 ℃)

Figure 5 shows the surface morphology of TTF-TCNQ wires formed on a substrate with applied electric field of 10 kV/cm (100V). Although TTF-TCNQ wires grown from both electrodes were able to contact at medium electric field of 10 kV/cm (Fig. 5), the connected wire was not achieved at lower and higher electric fields (Fig. 3 and Fig. 4).

A similar experiment was performed using the electrode with a gap of 20 μm. Optical microscope images of TTF-TCNQ wires are shown in Fig. 6 and 7. Reducing the electrode gap, TTF-TCNQ wires connecting the electrode gap were obtained at a lower voltage of 12V (6 kV/cm : Fig. 7). However, the connection of TTF-TCNQ wires was difficult at a high voltage of 70 V (35 kV/cm :

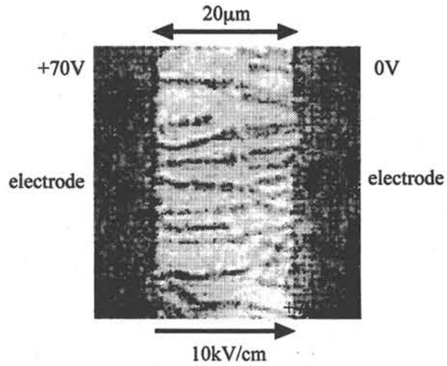


Fig. 6. Optical microscope image of TTF-TCNQ wires fabricated by applied electric field deposition. (Electrode gap was 20 μm. Substrate temperature was 42 ℃)

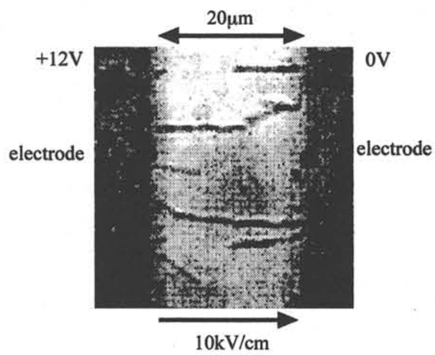


Fig. 7. Optical microscope image of TTF-TCNQ wires fabricated by applied electric field deposition. (Electrode gap was 20 μm. Substrate temperature was 42 ℃)

Fig. 6). These results indicate that the TTF-TCNQ wire formation strongly related to the electric field strength. The difficulty of the wire connection is mainly due to the Joule heating with a large current flow just after the wire connection.

4. Conclusions

We have fabricated TTF-TCNQ molecular wires using the co-deposition technique with applied electric field. The formation of TTF-TCNQ conducting wires was controllable by choosing the condition of the applied electric field deposition.

References

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[2] T. Sakabe, M. Iizuka, S. Kuniyoshi, K. Kudo and K. Tanaka, Mol. Cryst. Liq. Cryst. **349**, 367 (2000).