論文 / 著書情報
Article / Book Information

題目(和文)	高性能有機トランジスタの電荷輸送と接触抵抗の温度依存性解析
Title(English)	Low temperature analysis of charge transport and contact resistance in high performance organic transistors
著者(和文)	Cho Joung-Min
Author(English)	Joung-Min Cho
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10123号, 授与年月日:2016年3月26日, 学位の種別:課程博士, 審査員:森 健彦,石川 謙,道信 剛志,松本 英俊,早水 裕平
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10123号, Conferred date:2016/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	有機・高分子物質　専攻	申請学位（専攻分野）： Academic Degree Requested	博士　（　工学　） Doctor of
学生氏名： Student's Name	Cho Joung-min	指導教員（主）： Academic Advisor(main)	森 健彦
		指導教員（副）： Academic Advisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis deals with variable temperature analysis of charge transport and contact resistance in organic field-effect transistors. Various n-channel and p-channel organic semiconductors are used for active layers of transistors, and the thin-film and single-crystal devices are attained by vacuum evaporation and solution process. By electrically characterizing organic transistors at variable temperatures, the fundamental physics of charge transport at the interface between the organic semiconductor and the gate insulator is revealed. In addition, gated four-probe measurements offer the understanding of contact resistance, which is caused by carrier injection/extraction between the contact electrode and the organic semiconductor, and afford information of the intrinsic charge transport not hindered by the contact resistance.

This thesis is organized as follows: in Chapter 1, general introduction for the present work is given. In Chapter 2, the basic knowledge on organic transistors used in this work is introduced. An overview over organic transistors, from a brief introduction of organic transistors to the microscopic mechanism of charge transport, is given. In Chapter 3, materials and experimental methods used in this work are described. In Chapter 4 – 6, main results of the present work are described. Finally, general conclusion is made in Chapter 7.

Trap density of states (DOS) in n-channel organic thin-film transistors based on cyclohexyl naphthalenetetracarboxydiimide (Cy-NDI) and dimethyldicyanoquinonediimine (DMDCNQI) is investigated in Chapter 4. A new method is proposed to extract trap DOS from the Arrhenius plot of the temperature-dependent transconductance. Double exponential trap DOS is observed, in which Cy-NDI has considerable deep trap states, by contrast, DMDCNQI has substantial tail states. In addition, numerical simulation of the transistor characteristics has been conducted by assuming an exponential trap distribution and the interface approximation. Temperature dependence of transfer characteristics is well reproduced only using several parameters, and the trap DOS obtained from the simulated characteristics is in good agreement with the assumed trap DOS, indicating that our analysis is self-consistent. Finally, band transport is explored from the simulation having a small number of traps. A crossing point of the transfer curves to negative activation energy is observed above a certain gate voltage in the simulated

characteristics, where the critical V_G above which band transport is realized is determined by the sum of the trapped and free charge states below the conduction band edge.

Band-like transport has been realized down to 20 K in solution-processed single-crystal transistors based on dioctyl-benzothienobenzothiophene (C8-BTBT) in Chapter 5. The high-quality single crystals are grown by the solvent vapor annealing method, and utilized as transistors by using carbon contacts. The organic transistors show clear band-like transport accompanied by the power law of $\mu \sim T^{-n}$ and as high mobility as 10 cm^2/Vs at room temperature. In the best device, the mobility increases from 16 to 52 cm^2/Vs as the temperature is lowered from 300 to 80 K. An abrupt mobility drop is observed around 80 K, but even below 80 K, gradually increasing mobility is restored again down to 20 K instead of thermally activated transport. From the observation of a shoulder structure in the transfer curve, it is concluded that the mobility drop is attributed to a discrete trap state.

The mobility drop in single-crystal transistors based on C8-BTBT is analyzed from the appearance of discrete trap states based on the shoulder structure in the transfer curve, but the real origin is uncertain because the contact effect cannot be eliminated in two-probe transistors. Thus, the four-probe measurement is conducted in Chapter 6. A crystalline film of phenyldecylbenzothienobenzothiophene (Ph-BTBT-10) having a large domain is fabricated by the blade-coating method, and the four-probe configuration of transistor is made on the film. The resulting transistors exhibit as large four-probe mobility as 34 cm^2/Vs at room temperature, though the contribution of contact resistance is significant. In the variable temperature measurement, band-like transport is observed with the four-probe mobility increasing up to 157 cm^2/Vs at 80 K. At 60 K the two-probe mobility drops abruptly by about 40%, but the mobility drop is mostly attributed to the increase of the source resistance. The carrier transport in the present single crystalline film is regarded as essentially band-like down to 30 K.

In conclusion, the present thesis proposes valuable findings on fundamental charge transport and device operation in organic transistors. In thin-film transistors based on n-channel molecules, the trap DOS is determined and the influence on transistor characteristics is systematically analyzed by simulation. In single-crystal transistors based on p-channel semiconductors, the excellent transistor performance is achieved showing mobility over 10 cm^2/Vs, and it is found that charge transport is essentially band-like down to 20 K. The effect of discrete trap levels on a transfer curve is examined by an analytical method, and the contact resistance is intensively studied by the gated four-probe measurement. The author believes that the present work provides important knowledge on intrinsic charge transport and the relationship to the device performance in organic transistors.