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Article / Book Information

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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	電子物理工学　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（工学）
学生氏名： Student's Name	河村　哲史	指導教員（主）： Academic Advisor(main)	波多野　睦子　教授
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

A flexible wireless communicating device will be a key device in the coming era of "Internet of Things." A sheet device such as a plastic film equipped with communicating function is light, thin and flexible and thus attachable on to a curved surface or bending part of things. Wireless connection to a network avoids a mess due to the wirings. Such a wireless communicating device requires a technology to fabricate a power source, an antenna and electrical circuits on a flexible substrate.

Against this background, this study was targeted at the development of the flexible passive-type RFID tag with monolithic antenna that can be operated by 13.56-MHz RFID reader. Though RFID does not contain sensors on it, it equips the basic elements for the wireless communication and hence it is an adequate target for the first step. The passive-type operation was selected since the on-board battery is not suitable with the flexibleness and also the replacement of the battery is almost impossible when thousands of RFID tags are distributed. The antenna should be fabricated monolithically with the RFID circuit to increase the resistance to bending and also to reduce the production cost. The device should be operated by the 13.56-MHz RFID reader since this frequency band is most widely used for the wireless communication devices such as RFIDs and thus the reader is in widespread use.

In order to achieve the target, three element technologies were developed in this study; (1) low-voltage operating transistor that can be fabricated on a flexible substrate, (2) rectifier that can convert 13.56-MHz radio wave into a DC power, and (3) logic gate that enables the internal data-processing circuits to operate within the power supplied through the rectifier and with the frequency accepted by the reader terminal. With these threes studies, the feasibility of the flexible passive-type RFID tag was demonstrated.

In chapter 1, the foresight of the connected devices, the necessity of the flexible passive-type RFID and the basics of oxide semiconductor (especially a-InGaZnO), are described.

In chapter 2, the concept, fabrication and experimental results of a low-voltage operating fully-depleted (FD) type a-InGaZnO TFT, which is proposed in this study, are described. The fully-deplete type a-InGaZnO TFT was proposed and 1.5-V operation was demonstrated. This TFT utilizes the FD state for the off state of an nMOS TFT that uses an accumulation layer formed in an n-type semiconductor channel layer. The operation model and the designing strategy of the TFT were also proposed. Thanks to the FD state, a small off current and a small subthreshold slope (*SS*) were achieved; the smallest *SS*, 62 mV/decade, was close to the theoretical limit of the *SS* for a transistor. The dependence on (a) the thickness of the channel layer, (b) oxygen partial pressure during the sputtering of a-InGaZnO, (c) the type of the gate insulator, (d) the thickness of the gate insulator, (e) operation temperature, and (f) the length of the channel were analyzed. The operation mechanism of the FD a-InGaZnO TFT was discussed and theoretical expressions for *SS*, source-drain current and threshold voltage of the TFT were proposed. Furthermore, the maximum operation frequency of the FD a-InGaZnO TFT was estimated. A TFT promising for the flexible wireless communicating devices was achieved.

In chapter 3, the designing, fabrication and experimental results of a rectifier circuit using the above FD a-InGaZnO TFT were described. A four-TFT rectifier that operates with 13.56-MHz band, which is the frequency band widely used for wireless devices such as RFID was developed. A simulation model of the TFT based on a model for poly-crystalline silicon TFT was developed and the rectifier circuit was designed by using this model. The structure and the fabrication process of FD a-InGaZnO were modified in order to apply it to a circuit. The four-TFT rectifier was fabricated and the wired operation up to 25 MHz and the wireless operation up to 13.56 MHz were demonstrated. The dependence of the output voltage on (a) input voltage, (b) input frequency and (c) transmittance distance were discussed.

In chapter 4, the designing, fabrication and experimental results of a capacitive-coupling type logic gate that satisfies both the operation frequency and the consumption power required for the wireless operation of the RFID were described. A novel logic gate using the FD a-InGaZnO TFTs was proposed. Since p-type a-InGaZnO is not available, logic gates need to be formed only with nMOS TFTs. However, it is not easy to form logic circuits for RFID that satisfy both the frequency and the consumption power required for the operation with a reader terminal compliant with ISO/IEC 15693 standard by using conventional logic gates. Therefore, a novel logic gate named "capacitive-coupling type" was proposed and an operation with the required frequency and consumption power was demonstrated.

In chapter 5, the final chapter, conclusion and the foresight are described. The main remaining issues, which will surely be solved, are further lowering of the fabrication temperature and the addition of the sensing function onto the flexible RFID platform.