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論文 / 著書情報
Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子 系 電気電子 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （工学）
学生氏名： Student's Name	片岡 淳司	指導教員（主）： Academic Supervisor(main)	角嶋 邦之
		指導教員（副）： Academic Supervisor(sub)	

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

$Al_{1-x}Sc_xN$ films are attractive materials for high-sensitive piezoelectric sensors and filters because of their high piezoelectric coefficient with a high-temperature tolerance. Besides, recent works have experimentally demonstrated that the $Al_{1-x}Sc_xN$ films exhibit ferroelectric properties with a high remnant polarization (P_r) of over 100 μC/cm^2.The bandgap of the $Al_{1-x}Sc_xN$ film which shows the ferroelectricity is from 3.0 to 6.0 eV, indicating that the $Al_{1-x}Sc_xN$ films can be considered as one of the nitride semiconductors. Once we can control the carrier charge types of the $Al_{1-x}Sc_xN$ films for source and drain, complementary metal-oxide-semiconductor (CMOS) thin-film transistors (TFT) with ferroelectric $Al_{1-x}Sc_xN$ channel can be realized, which opens a wide range of unique applications. One of the issues for using the $Al_{1-x}Sc_xN$ film as a channel of the TFT is the formation of contacts with low Ohmic contact resistance (ρ_c). The key to achieving the low ρ_c is lowering the Schottky barrier height (ϕ_B) and/or increasing the carrier concentration (N) of the $Al_{1-x}Sc_xN$ film. The purpose of this thesis is the extraction of band alignment of metal/$Al_{1-x}Sc_xN$ interface and propose a guideline to reduce the ϕ_B, and to demonstrate n-type conduction to increase in the N for low ρ_c. In chapter 1, the feature of $Al_{1-x}Sc_xN$, the proposal of a new device using $Al_{1-x}Sc_xN$ as the channel, and how to realize it are summarized. In chapter 2, the physical and electrical characterization methods are described. In chapter 3, the extraction results of the band alignment at the metal/$Al_{0.78}Sc_{0.22}N$ are described. In chapter 4, the achievement of n-type conduction of $Al_{1-x}Sc_xN$ by Si ion doping and the properties of n-type $Al_{1-x}Sc_xN$ are described. In chapter 5, the issue of Si-doped $Al_{1-x}Sc_xN$ films, "sheet resistance instability" is described and its solution is proposed. In chapter 6, the summary and the future perspective of this thesis are described.

The band alignment was extracted by leakage current analysis of the metal/ferroelectric/metal (MFM) capacitors with either TiN or W electrode. The electron conduction through the $Al_{0.78}Sc_{0.22}N$ film followed the Schottky emission model with an initial ϕ_B of 0.46 and 0.55 eV for TiN and W electrodes, respectively. During the first ferroelectric polarization switching, a gradual shift in the leakage current was observed, changing the effective ϕ_B to 0.36 eV for both electrodes. After the initial polarization switching, the current level kept the same level during the further positive/negative sweeping, indicating that the ϕ_B for both polarization states (metal-face, N-face) was the same. The formation of an interface dipole layer possibly formed by nitrogen vacancies (V_N) at the metal interface can be deduced from the modeling of the Richardson constant (A^*). With the obtained results, a small ϕ_B to reduce the ρ_c can be achieved by forming the interface dipole layer at the interface. The demonstration of the n-type conduction in the $Al_{0.78}Sc_{0.22}N$ film was achieved by Si ion doping followed by activation annealing. The activation of Si atoms was found above an annealing temperature of 800°C. Under a dose of 2×10^{15} cm^{-2} with an activation annealing at 900°C, n-type conduction was obtained with Hall mobility and a carrier concentration of 8.6 cm^2/Vs and 8.9×10^{18} cm^{-3}, respectively. The Si atom concentration in the $Al_{0.78}Sc_{0.22}N$ film was 4.1×10^{20} cm^{-3} by secondary ion mass spectroscopy. Therefore, the activation ratio can be deduced to be 2.2%. The activation annealing temperature of implanted Si atoms in $Al_{0.78}Sc_{0.22}N$ film is relatively low for those implanted to AlN or AlGaN. The n-type conduction was realized in a relatively low-temperature process. This can be an advantage for applications such as the ferroelectric semiconductor-FET. The surface of the n-type $Al_{0.78}Sc_{0.22}N$ film turned out to be sensitive to exposure to air, and two orders of magnitude increase in the sheet resistance (R_s) were measured. The mechanism of the increase in R_s was explained by H_3O^+ molecules adsorption by self-ionization of water in the air to the Si-doped $Al_{0.78}Sc_{0.22}N$ surface. With the adsorption, a depletion region from the backside of the $Al_{0.78}Sc_{0.22}N$ film is formed, caused by the balance between the spontaneous polarization and surface charges. To overcome this issue, it is necessary to coat a proper passivation layer on the n-type $Al_{0.78}Sc_{0.22}N$ film, or either thicken the n-type $Al_{0.78}Sc_{0.22}N$ film or increase the carrier concentration of n-type $Al_{0.78}Sc_{0.22}N$ film.

Based on the obtained results, the remaining issues of $Al_{1-x}Sc_xN$ films for TFT application are summarized. Considering other n-type semiconductors used for TFT, the ρ_c needs to be further reduced to increase the current density. Therefore, it is essential to increase the carrier concentration of the $Al_{1-x}Sc_xN$ film. Secondly, the demonstration of p-type conduction by impurity doping is required for CMOS application. Also, a carrier conduction model between the ferroelectric and doped regions needs to be constructed.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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