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# Al/$BaTa_2O_6$/GaN MIS 구조의 특성

## ( Characteristics of Al/$BaTa_2O_6$/GaN MIS structure )

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### 요 약

일반적인 산화 절연 게이트 대신 $BaTa_2O_6$를 사용한 GaN metal-insulator- semiconductor(MIS) 구조를 제작하였다. $Al_2O_3$(0001) 기판 위에서와 GaAs(001) 기판 위에서의 GaN 막의 누설 전류는 각각 $10^{-12}$ - $10^{-13}$ A/cm$^2$와 $10^{-6}$ - $10^{-7}$ A/cm$^2$로 측정되었다. 이 막의 누설전류는 각각 $Al_2O_3$(0001) 기판 위의 GaN인 경우는 45 MV/cm가 넘는 공간전하 제한전류에 의하여, GaAs(001) 기판 위의 GaN인 경우는 Poole-Frenkel 방출에 따른다는 것을 확인하였다.

### Abstract

A GaN-based metal-insulator-semiconductor (MIS) structure has been fabricated by using $BaTa_2O_6$ instead of conventional oxide as insulator gate. The leakage current of films are in order of $10^{-12}$ - $10^{-13}$ A/cm$^2$ for GaN on $Al_2O_3$(0001) substrate and in order of $10^{-6}$ - $10^{-7}$ A/cm$^2$ for GaN on GaAs(001) substrate. The leakage current of thses films is governed by space-charge-limited current over 45 MV/cm in case of GaN on $Al_2O_3$(0001) substrate and by Poole-Frenkel emission in case of GaN on GaAs(001).

**Keywords :** GaN, $BaTa_2O_6$, Poole-Frenkel emission, MISFET, Al/$BaTa_2O_6$/GaN

## I. INTRODUCTION

Gallium nitride (GaN) and III-N materials have been widely used in optoelectronic devices such as blue light-emitting diodes and laser diodes.[1] In addition, the electronic and structural properties of GaN and III-N materials also make it suitable for high-power and high-temperature electronic device application. During many years past, there have been many studies in the development of GaN based metal semiconductor field effect transistors (MESFETs), high electron mobility transistors (HEMTs) and heterojunction bipolar transistors (HBTs).[2] The performance of these devices was limited with many problem such as the lack of stable schottky contact which must have the low leakage current as well as the reproducible barrier height at the working temperature for MESFETs and HEMTs, difficult of p-type GaN with high conductivity due to low carrier concentration and a poor ohmic contact. These problems can be overcome by using a metal insulator semiconductor FET (MISFET) as the type of metal oxide semiconductor FET applied to silicon. A GaN MIS structure using a gate insulator comprised of deposited $Ga_2O_3(Gd_2O_3)$ has been reported by Ren et al. Since then, various GaN MIS structures have been investigated using insulator material such as $Ga_2O_3(Gd_2O_3)$, AlN, SiO2, $Si_3N_4$, $BaTiO_3$, $Pb(Zr,Ti)O_3$.[3,4] The insulating layer should have high dielectric reliability as well as a high charge storage capacitance in order to archive both the low power

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consumption and the stable operation of the device at normal situation or high temperature, power situation. Recently, some group used high dielectric materials such as $BaTiO_3$, Pb(Zr,Ti)$O_3$ as insulator on GaN.[5] In this work, we have used the $BaTa_2O_6$ which is high dielectric material as insulator for the first time to fabricate GaN MIS structure and its I-V characteristics is observed.

## Ⅱ. EXPERIMENTAL

The GaN samples were grown in a conventional Riber MBE-500 system equipped with a home made RF plasma cell for the activated nitrogen source on $Al_2O_3$(0001) and GaAs(001) substrate. The thickness and crystal structure of GaN were 1.83 um and cubic structure on GaAs(001), wurzite structure on $Al_2O_3$(0001). The $BaTa_2O_6$ thin films were prepared by a RF-magnetron sputtering technique on GaN thin films. The 4 inch diameter, 1/8 inch thickness $BaTa_2O_6$ ceramic disk(Cerac Co.) with 6N purity was used. The base pressure in the chamber was adjusted to $5 \times 10^{-5}$ Torr and the pressure during the deposition was maintained at $6 \times 10^{-3}$Torr of an Ar(6N) and $O_2$(4N) gas mixture. The ratio of Ar/$O_2$ is 3/2, which is controlled by mass flow controller (MFC). The density of RF power is 2.5W/$cm^2$ at 100℃ Figure 1 shows Cross-sectional diagram of MIS(Al/$BaTa_2O_6$/GaN) structure diode. The aluminum electrode of 1mm diameter was formed on 'the insulator layer by thermal evaporator. The thickness of the prepared thin film was measures by stylus of Tencor aa-200 model. The thickness of insulator and electrode is 3500Å, 1500Å, respectively. The current-voltage characteristic is investigated by KEITHLEY TEST SYSTEM UNIT.

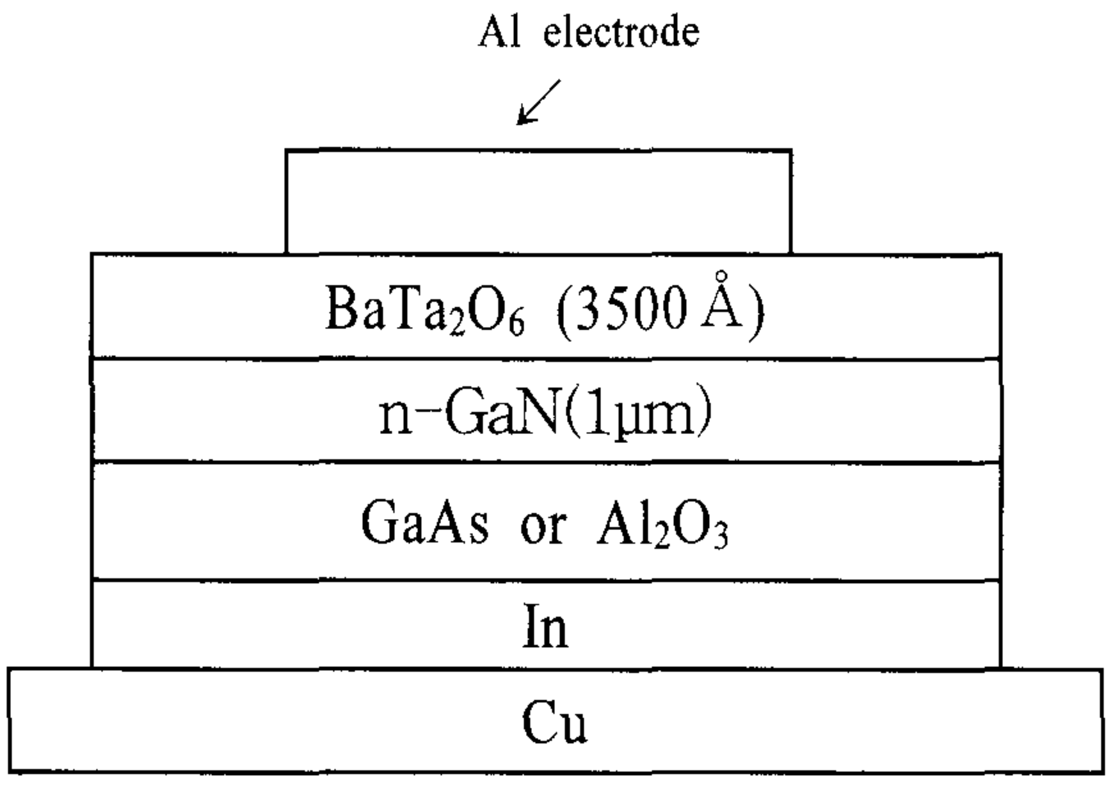


그림 1. MIS(Al/$BaTa_2O_6$/GaN) 구조의 단면 모식도
Fig. 1. Cross-sectional diagram of MIS (Al/$BaTa_2O_6$/GaN) structure diode.

## Ⅲ. RESULTS & DISCUSSIONS

The leakage current is a critical issue in the semiconductor device applications. Figure 2 shows leakage current versus electric field characteristics of Al/$BaTa_2O_6$/GaN structure on $Al_2O_3$(0001). The voltage is applied from 0V to 80V with a step of 0.1V. The leakage current of $BaTa_2O_6$ thin film is in the order of $10^{-12}$ - $10^{-13}$ A/$cm^2$ at the applied field of 1 MV/cm. This value is very lower than other insulator on GaN. The breakdown of insulator is occurred over 80 MV/cm. The leakage current in a dielectric film can be owing to several conduction mechanisms such as Schottky emission, Poole-Frenkel emission, Fowler-Nordheim tunneling, Space-charge limited current, Ohimic current, and Ionic conduction. When the conduction current in the film is governed by the Schottky emission, Poole-Frenkel emission and Fowler-Nordheim tunneling, the log($J/T^2$) versus $E^{1/2}$ for the Schottky emission, the log(J/E) versus $E^{1/2}$ for Poole-Frenkel emission and the log($J/E^2$) versus 1/E for the Fowler-Nordheim tunneling plots of the I-V data in Figure 3 should be a straight line over a wide range.[7,8] However, for the films the slopes, not presented here, gradually changed without any evidence of linearity but rather showed big curvatures. This suggested that the Schottky emission, Poole-Frenkel emission and Fowler-Nordheim tunneling is not responsible for the leakage current behavior in our films. When it is adjust the J versus $E^2$(space-charge-limited current) in our films, it shows linearity in high electric field( > 45 MV/cm) which presents Figure 3. Therefore, the leakage current of this films is governed by space-charge-

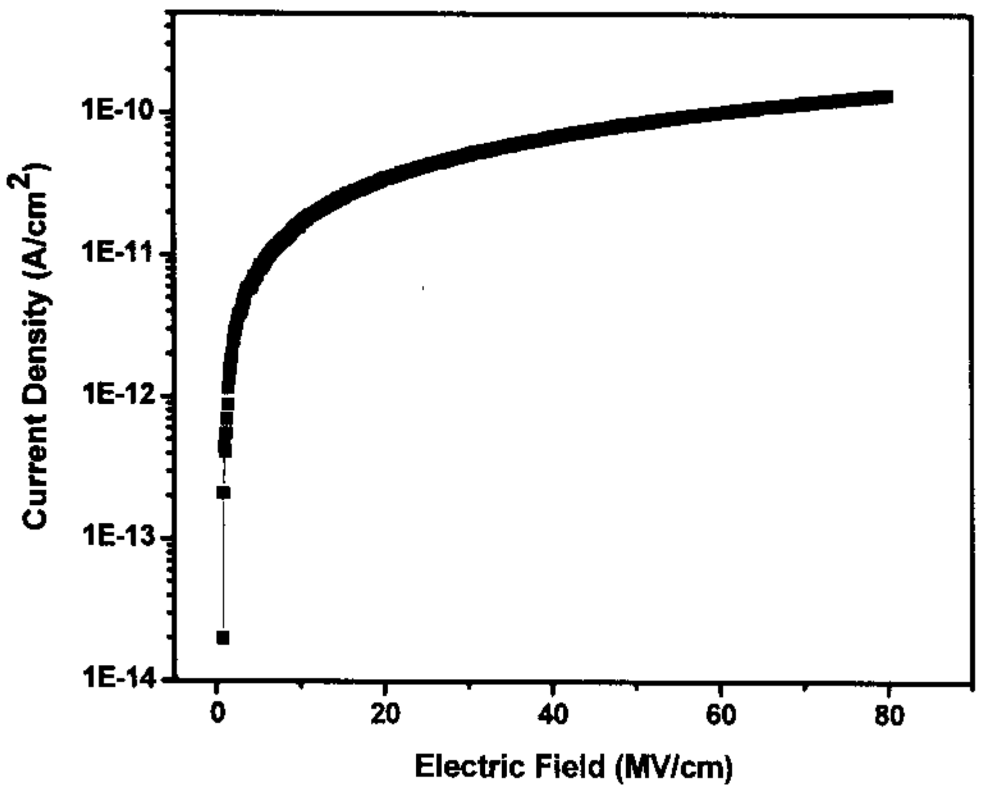


그림 2. $Al_2O_3$(0001) 위의 Al/$BaTa_2O_6$/GaN 구조의 전기장에 따른 누설전류

Fig. 2. Leakage current versus electric field characteristics of Al/$BaTa_2O_6$/GaN structure on $Al_2O_3$(0001).

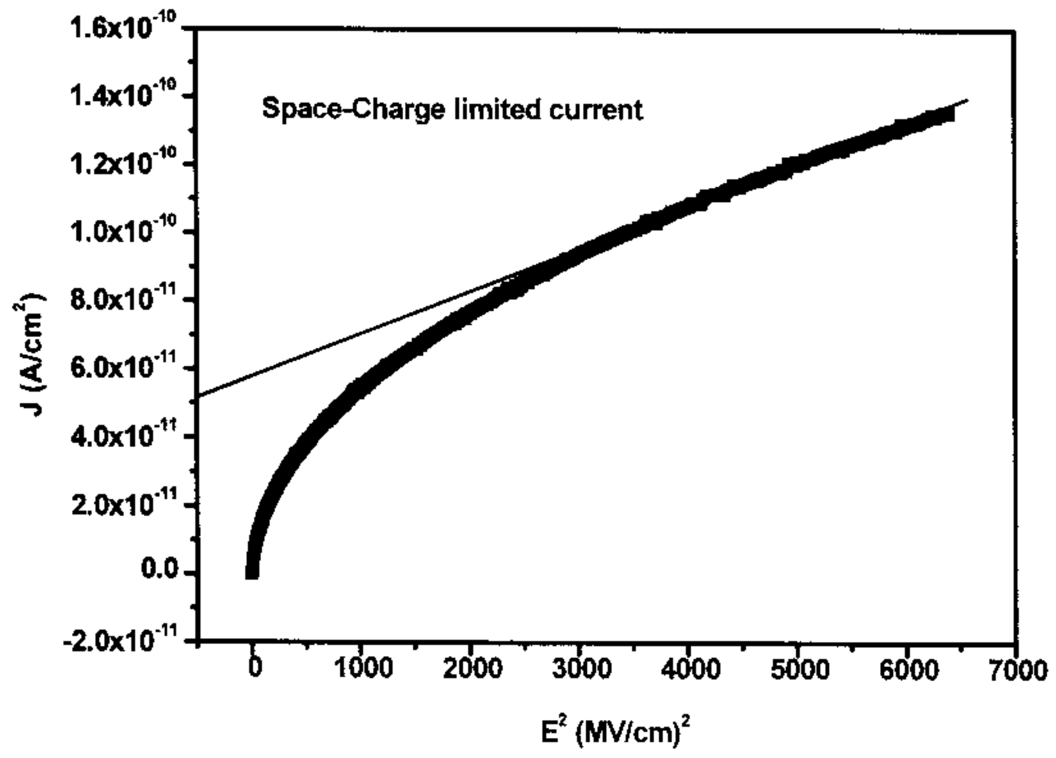


그림 3. 공간전하제한전류 특성 곡선 ($E^2$ 대한 J 특성곡성)

Fig. 3. Space-charge-limited current plots of J versus $E^2$.

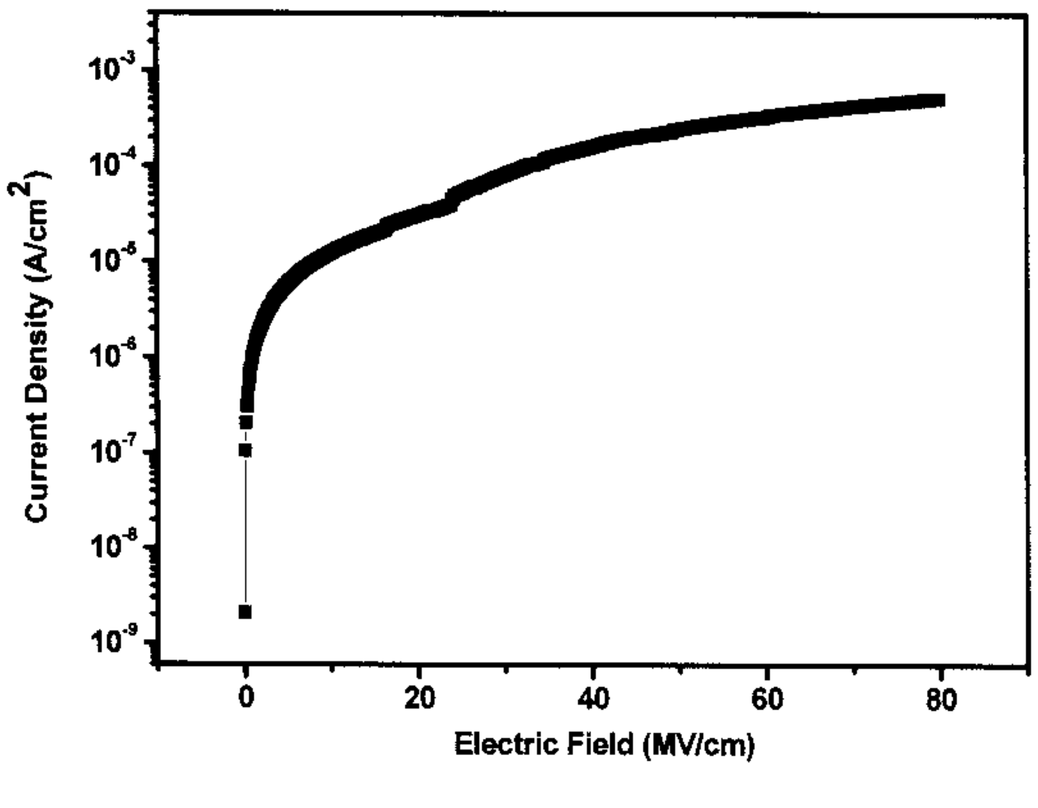


그림 4. GaAs(001) 위의 Al/$BaTa_2O_6$/GaN 구조의 전기장에 따른 누설전류

Fig. 4. The leakage current versus electric field characteristics of Al/$BaTa_2O_6$/GaN structure on GaAs(001).

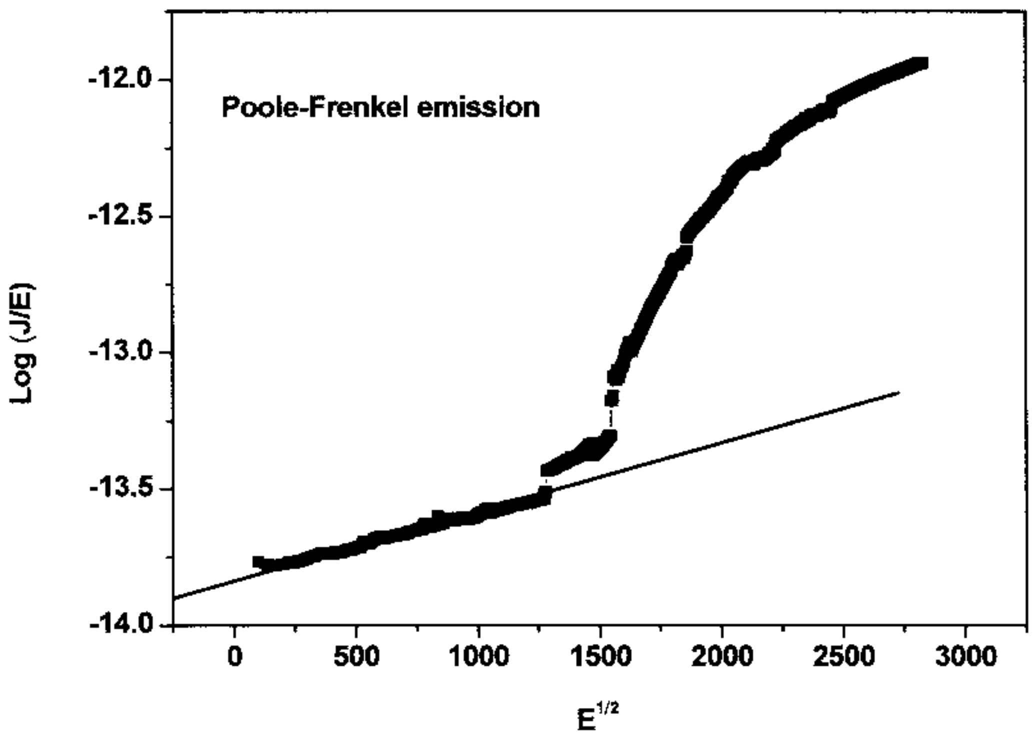
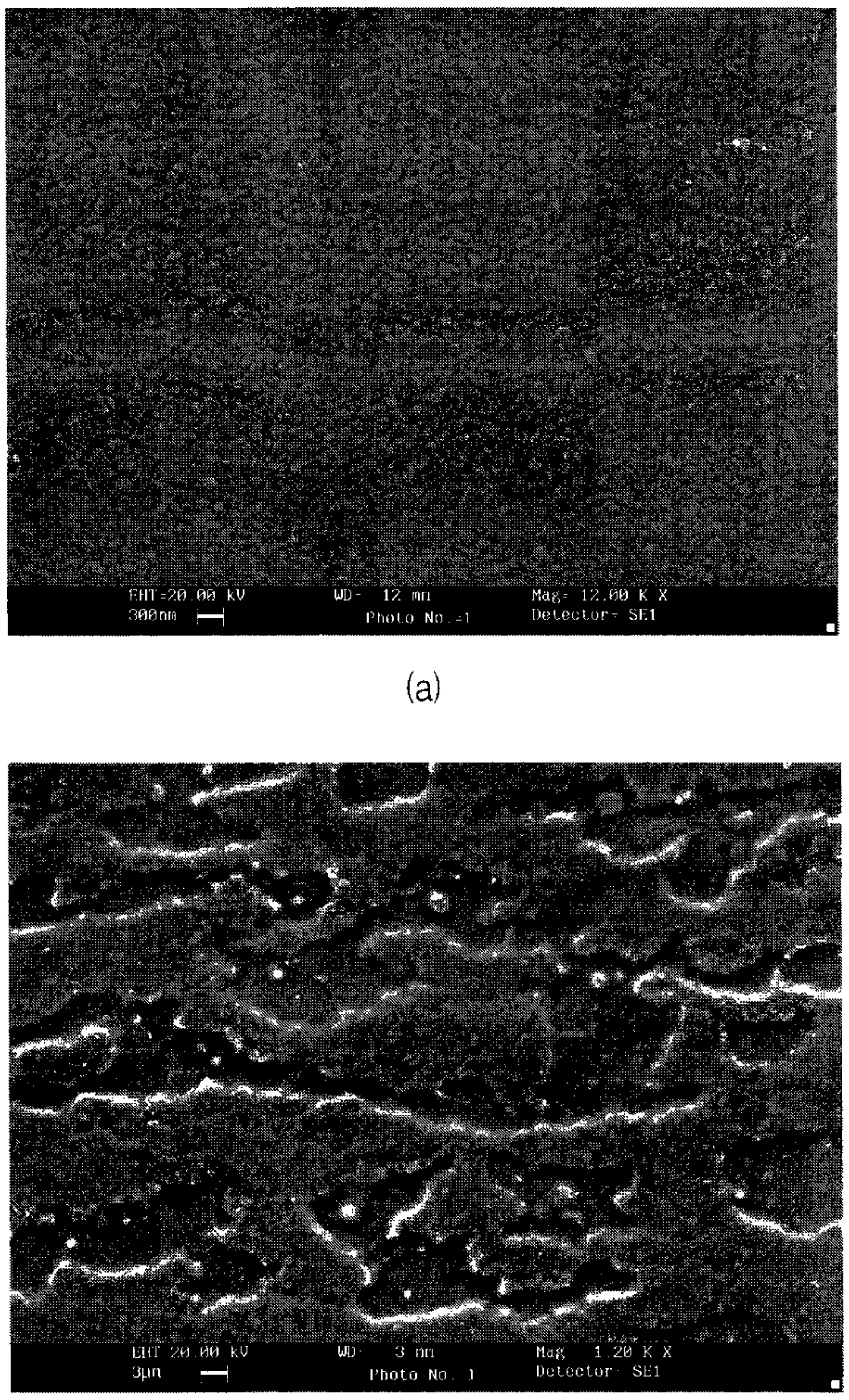


그림 5. Poole-Frenkel 전류방출 특성 곡선 ($E^{1/2}$ 에 대한 log(J/E) 특성곡선)

Fig. 5. Poole-Frenkel emission plots of log(J/E) versus $E^{1/2}$.



(a)

(b)

그림 6. SEM 사진 (a)GaN/$Al_2O_3$ 그리고 (b) GaN/GaAs

Fig. 6. SEM image of (a)GaN/$Al_2O_3$ and (b) GaN/GaAs.

limited current over 45 MV/cm. The space-charge-limited current resulted from a carrier injected into the insulator, where no compensating charge is present.[7] We need more study which is leakage current according to temperature to understand conduction mechanisms below 45 MV/cm.

Fig. 4 presents leakage current versus electric field characteristics of Al/$BaTa_2O_6$/GaN structure on GaAs(001). The leakage current of BaTa2O6 thin film is in the order of $10^{-6}$ - $10^{-7}$ A/cm$^2$ at the applied field of 1 MV/cm.

This leakage current is more higher than that of $Al_2O_3$(0001). The reason is high surface roughness that is caused by lattice mismatch and thermal expansion difference between GaN and substrate. The SEM images of GaN on $Al_2O_3$(0001) and GaAs(001)shows this at Figure 6. The rough surface may be caused by charge trap.

As a result, conduction mechanisms also is changed. When it plots the log(J/E) versus $E^{1/2}$ plot which shows Figure 5, the linearity shows below 20 MV/cm. Therefore, the leakage current of this films is governed by Poole-Frenkel emission.[7,8]

## Ⅳ. CONCLUSIONS

We have used the $BaTa_2O_6$ which is high dielectric material as insulator for the first time to fabricate GaN MIS structure and its I-V characteristics is observed. The leakage current of films are in order of $10^{-12}$ - $10^{-13}$ A/cm$^2$ for GaN on $Al_2O_3$(0001) substrate and in order of $10^{-6}$ - $10^{-7}$ A/cm$^2$ for GaN on GaAs(001) substrate. The leakage current of this films is governed by space-charge- limited current over 45 MV/cm in case of GaN on $Al_2O_3$(0001) substrate and Poole-Frenkel emission in case of GaN on GaAs(001).We have to more study to understand unknown conduction mechanisms.

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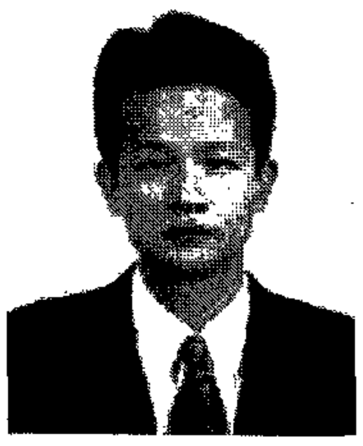
## 저자소개



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