Electronic conductivity of impurity-doped Zn$_3$N$_2$ thin films

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**INTRODUCTION:** Zn$_3$N$_2$ is an n-type nitride semiconductor. It has a relatively wide band-gap value of 3.26–2.30 eV [1] and a small electron effective mass of ~0.3m$_0$ ($m_0$ denotes free electron mass). Therefore, Zn$_3$N$_2$ is expected to be a transparent conductor with excellent conductivity. We have investigated electrical and optical properties of undoped Zn$_3$N$_2$ polycrystalline films fabricated by sputtering. Nitrogen-deficient Zn$_{3-x}$N$_2$ films showed low resistivities ($\rho$) of the order of 10$^{-3}$ Ω cm [2]. To establish Zn$_3$N$_2$ as a transparent conductor, further reduction of $\rho$ is still needed. One way to reduce $\rho$ is impurity-doping. Thus, we have tried impurity doping into Zn$_3$N$_2$. We found that oxygen is one of effective dopants to suppress $\rho$.

**EXPERIMENTS:** Oxygen-doped Zn$_3$N$_2$ thin films were deposited on glass substrates heated at 200 °C by reactive RF magnetron sputtering method using a metal Zn target. Film deposition was conducted in a mixture gas of Ar, N$_2$, and O$_2$ with various flow ratios of $f$(O$_2$) = O$_2$ / (Ar + N$_2$+ O$_2$) ranging from 0.0% to 0.5% at 0.1% interval. Meanwhile, $f$(N$_2$) = N$_2$ / (Ar + N$_2$+ O$_2$) was kept fixed at 80%.

**RESULTS & DISCUSSION:** X-ray diffraction (XRD) patterns shown in Fig. 1 indicate that all the films were phase-pure Zn$_3$N$_2$ polycrystalline films. Fig. 2 displays $\rho$, carrier density ($n_c$) and Hall mobility ($\mu_H$) as functions of $f$(O$_2$). The minimum $\rho$ value of 6.2×10$^{-4}$ Ω cm was obtained at $f$(O$_2$)=0.2%, where $n_c$ reached the maximum value of 1.2×10$^{20}$ cm$^{-3}$. From these results, we inferred that oxygen acts as an effective electron donor in the Zn$_3$N$_2$ films. As $f$(O$_2$) increased from 0.2% to 0.5%, $\rho$ increased as a result of a reduction of $n_c$. The $n_c$ reduction is probably due to the degradation of crystallinity as shown in Fig. 1. It should be noted that oxygen-doped Zn$_3$N$_2$ films have $\mu_H$ values larger than 60 cm$^2$ V$^{-1}$ s$^{-1}$. These values are 1.5 times larger than those of conventional transparent conductors like Sn-doped In$_2$O$_3$. Therefore, oxygen-doped Zn$_3$N$_2$ can be a high-mobility transparent conductor.

**REFERENCES**
