# Fabrication of conductive AlN films by Pulsed Laser Deposition

Mitsuo Okamoto*, Yoke Khin Yap, Masashi Yoshimura, Yusuke Mori and Takatomo Sasaki

Department of Electrical Engineering, Faculty of Engineering,
Osaka University, 2-1 Yamada-Oka, Suita, Osaka 565-0871, JAPAN
Tel. +81-6-6879-7707    Fax. +81-6-6879-7708
e-mail: okamoto@ssk.pwr.eng.osaka-u.ac.jp

Currently, wide-band-gap semiconductors such as diamond, c-BN, and AlN are of great interest for various applications including electron-emitting devices, high-temperature devices, and light-emitting devices in the uv range. However, there is substantial difficulty in growing diamond and c-BN because their cubic crystal structure is metastable at low temperatures and pressures. On the other hand, it is relatively easy to grow AlN because its wurtzite crystal structure is a stable phase. For the purpose of electronic device, the control of conductivity of AlN films is required. Although its ability to accommodate both n- and p-type dopants has been proposed, conductive AlN crystal by impurity doping has not been reported. In this study, we try to fabricate doped AlN films by 2 beam pulsed laser deposition method with pure carbon or oxygen dopants and simultaneous incorporation of carbon and oxygen.

The fourth harmonics of a Nd: YAG laser ($\lambda$ = 266 nm) was employed to ablate the target. The laser beam was splitted by a half mirror and focused onto the targets by lenses. A polycrystalline, stoichiometric AlN target and a graphite target were mounted and ablated simultaneously. The concentration of carbon dopant in the fabricated film was controlled by the laser intensity and distance between target and substrate. The doped AlN thin films were grown on $Al_2O_3$(0001) substrate at a temperature of 1000°C for 2 h in $N_2$ background gas. The obtained AlN films were characterized by I-V measurement, X-ray photoelectron spectroscopy (XPS), cathodoluminescence (CL) and X-ray diffraction (XRD).

The undoped AlN films were insulator with resistivity too high to be measured. We tried to fabricate low-resistivity AlN film by incorporation impurity ranging from 1 at.% to 20 at.%. The dopant concentration of films was determined by XPS. As for pure carbon doping, the AlN:C films with more than 15 at.% carbon concentration indicated conductivity, but the films were brown in color. We couldn't obtain transparent and conductive AlN films by carbon doping alone. On the other hand, the AlN:O

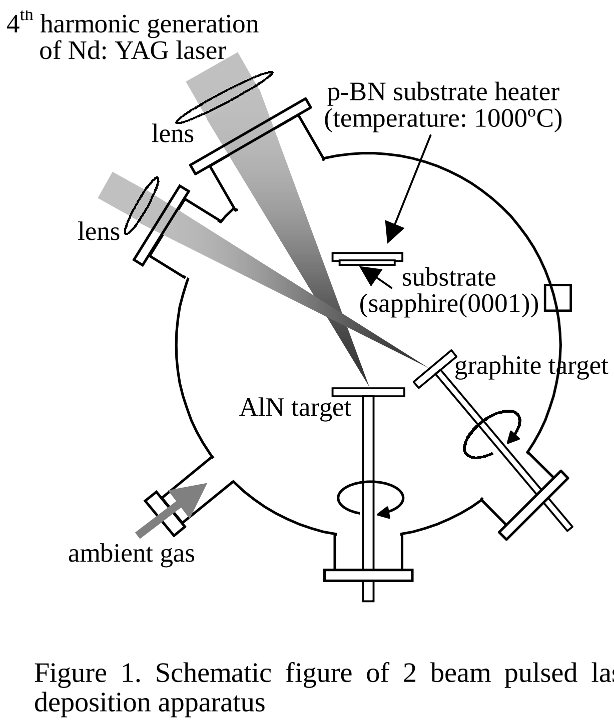


Figure 1. Schematic figure of 2 beam pulsed laser deposition apparatus

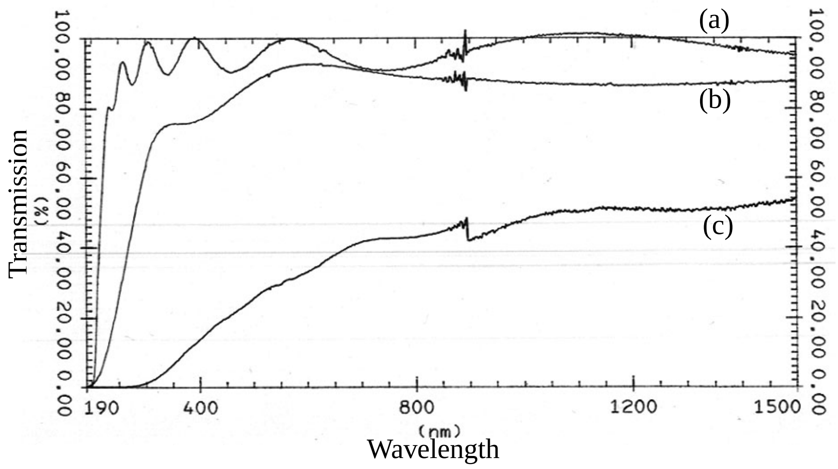


Figure 2. Transmission spectra of (a) undoped AlN film,
(b) AlN:C(5 at.%)+O(10 at.%) and (c) AlN:C 15 at.%.

films with oxygen concentration up to 30 at.% were insulator. At last we incorporated both carbon and oxygen impurity. The AlN:C+O films were conductive (~$10^3$ ohm cm) at concentration of 5 at.% carbon and 10 at.% oxygen. The AlN:C+O film is transparent. Figure 2 indicates the optical transmission spectra of the doped and undoped AlN films. Pure carbon doping causes degradation of the transmission. On the other hand, the band-gap energy of the AlN:C+O film as estimated from the absorption spectrum was ~5.4 eV. So the AlN:C+O film is a potential wide band-gap semiconductor. Further more, resistivity of the AlN:C+O film was increased with the increase of measurement temperature. The thermoelectromotive force measurement of the AlN:C+O film implied that the film has n-type conductivity. Figure 3 indicates the XRD profiles of the AlN films. As seen in figure 3, it is supposed that simultaneous incorporation of carbon and oxygen changed the crystalline structure of the film. So this doping might involve different doping mechanism. The details will be presented and discussed at the conference.

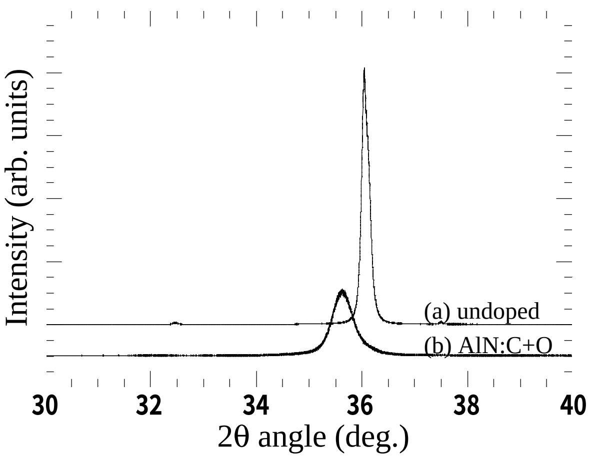


Figure 3. XRD profiles of (a) undoped AlN film, (b) AlN:C+Ofilm.