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Effect of buffer layer on the growth of ZnO films on Si (111) substrates by sputtering via nitrogen mediated crystallization

RFマグネトロンスパッタ法を用いたSi(111)基板上でのZnO結晶成長における窒素不純物の効果

S. Miuraoka, J. Lyu, D. Yamashita, K. Kamataki, K. Koga, M. Shiratani and N. Itagaki
村岡宗一郎、呂佳豪、山下大輔、鎌滝晋礼、古閑一憲、白谷正治、板垣奈穂

Graduate School of Information Science and Electrical Engineering, Kyushu University
九州大学大学院システム情報科学府

ZnO has a large bandgap of 3.4 eV and a large exciton binding energy of 60 meV, making ZnO a promising material for various optoelectronic devices. Recently, we have developed a new growth method of ZnO, "nitrogen mediated crystallization (NMC)", where the crystal nucleation and the growth are controlled via absorption-desorption behavior of nitrogen "impurities" [1-4]. By utilizing the films grown via NMC as buffer layers, we succeeded in fabricating a high quality single crystal ZnO film on 18% lattice-mismatched c-sapphire substrates. Here, we employ 15%-lattice mismatched Si(111) substrates, taking the advantages of cost, wafer size, and electrical and thermal conductivity, where AlN layers is used for protecting Si surface against oxidation.

First, 1-nm-thick AlN layers were fabricated on Si(111) substrates at 600°C by RF magnetron sputtering in Ar/N_2 atmosphere. Al targets were used and the total gas pressure was 0.4 Pa. Next, 10-nm-thick NMC buffer layers were deposited on AlN layers by RF magnetron sputtering in Ar/N_2 atmosphere. The substrate temperature was 750°C, and the total gas pressure was 0.35 Pa. Finally, 1-μm-thick ZnO films were fabricated on NMC buffer layers by RF magnetron sputtering in Ar/O_2 atmosphere. The substrate temperature was 700°C, and the total gas pressure was 0.70 Pa. ZnO ceramic targets (2 inch, > 99.99% purity) were used for these films.

Figure 1 shows x-ray rocking curves for (002) planes of ZnO film on NMC-ZnO buffer layers. We observed NMC method leads to significant change in the grain size of buffer layers. The average grain size derived from AFM images jumps from 9.2 to 24 nm by adding N_2 gas into sputtering atmosphere. The analysis on height-height correlation function (HHCF) indicates that N_2 addition causes an increase in the lateral correlation length ξ, a measure of migration length of adatoms, from 15 to 29 nm. Such enhanced migration allows adatoms to reach the thermodynamically favored lattice positions, and thus leads to the large grain size as well as to high crystal quality of the films deposited on them. In fact, we observed high quality of ZnO film on NMC-ZnO buffer layer, where the full width at half maximum (FWHM) of (002) rocking curve is 0.67°, one-fourth of that for the films fabricated without buffer layers. The crystal quality has been further improved by introducing 1-nm-thick AlN layers prior to NMC-buffer layer deposition. The FWHM of ZnO film on AlN/NMC-ZnO double-layer is significantly small of 0.50°, attributed to AlN layer protecting Si surface against oxidation and thus promoting epitaxial growth of ZnO on the surface. We believe that the high-quality ZnO films obtained in this study will open up a new avenue for ZnO-based devices on Si substrates that would have a great impact on Si integrated circuit technology.

This work was supported by JSPS KAKENHI Grant Number 18H01206JP, Samco Science and Technology Foundation, and NTT collaborative research.

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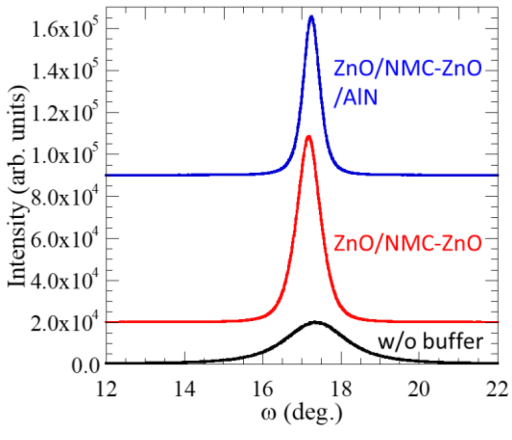

Fig.1 (002) rocking curves of ZnO films deposited on NMC-ZnO buffer layers.