Extended Abstracts of the 2008 International Conference on Solid State Devices and Materials, Tsukuba, 2008, pp. 296-297

F-3-1 (Invited)

Low Temperature Epitaxial Growth of Semiconductors on Metal Substrates

Hiroshi Fujioka

Institute of Industrial Science, The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
Phone +81-3-5452-6342 E-mail: hfujioka@iis.u-tokyo.ac.jp

1. Introduction

The use of metal substrates for epitaxial growth of semiconductors are quite attractive because of their excellent physical properties such as high thermal and electrical conductivities, which allow us to fabricate power devices with higher performance. The other advantage in the use of metal substrates lies in their availability with large sizes at low costs. This fact makes it possible to obtain inexpensive large area devices such as solar cells, which cannot be achieved by conventional semiconductor wafers. However, it is well known that the metals easily react with semiconductors at high temperatures during growth processes. This problem can be solved by development of a low temperature epitaxial growth technique for semiconductors. We have recently found that pulsed supply of film precursors for semiconductor films with high energies leads to formation of epitaxail films even at room temperature. [1]-[8] In this presentation, we will discuss properties of semiconductor films grown with this low temperature epitaxial growth technique called pulsed excitation deposition on metal substrates.

2. Experimental

Mirror polished single-crystalline BCC, FCC, and HCP metal plates (Fe, Mo, W, Ta, Rh, Cu, Ag, Ni, and Hf) with various surface orientations were used as substrates for epitaxial growth of semiconductor films which include GaN and Si. After polishing and degreasing, metal substrates were introduced into a vacuum chamber and annealed to remove the residual oxides on the surfaces. AlN barrier layers which should suppress the interfacial reactions between metals and semiconductors were grown by pulsed exitation deposition. Semiconductors such as GaN or Si were grown on the barrier layers and characterized by various techniques that include RHEED, EBSD (electron backscattering diffraction), XRD, GIXR (grazing incidence x-ray reflectometry), AFM, *in-situ* XPS, and PL.

3. Results and Discussion

Although the surfaces of metal substrates just after introduction into vacuum chamber shows halo RHEED patterns, they eventually changed into streaky patterns by the annealing. Surface reconstructions were also often observed in the patterns after annealing. This phenomenon can be interpreted as evaporation of native oxides, which was confirmed by *in-situ* XPS observations. AFM observations revealed formation of atomically flat terraces separated by bunched steps. Spotty RHEED patterns were seen during the growth of the AlN barrier layers, indicating the successful epitaxial growth. GIXR measurements revealed that heterointerface between the AlN barrier layer and the metal substrates prepared by the pulsed excitation deposition is atomically abrupt. Although we grew the AlN barrier films on the metal substrates with the various orientations, we found that high quality AlN films grew only on the most densely packed planes, which are (110), (111), and (0001) for BCC, FCC, and HCP, respectively. This phenomenon can be explained mainly by the fact that sparsely packed planes have higher reactivity. All the AlN

films have (0001) orientation and in-plane epitaxial relationships are AlN[11-20] // FCC[1-10], AlN[11-20] // BCC[001], and AlN [11-20] // HCP[11-20]. It should be noted that these relationships are unique to the crystalline structure of the metal substrates and do not depend upon lattice mismatches between the AlN films and the metal substrates. This fact implies that the in-plane epitaxial relationships are determined by adsorption processes at the initial stage of the film growth rather than by the strain energy stored in the nitride films. In fact, first-principle adsorption energy calculations showed that in-plane epitaxial relationship between the AlN films and the metal substrates are determined by the adsorption sites for the nitrogen atoms on the metal surfaces.

We found that GaN films grow on metal substrates show strong near band edge emission and its Schottky diodes have the good rectifying property. These results indicate that the use of metal substrates is quite promising for future large area low cost semiconductor devices.

4. Conclusions

We found that the use of pulsed exicitation deposition allows us to grow high quality semiconductor films even on metal substrates. GIXR measurements have revealed that heterointerface between the AlN barrier layer and the metal substrates prepared by this technique is atomically abrupt. We have found that high quality AlN films grow only on the most densely packed planes, which are (110), (111), and (0001) for BCC, FCC, and HCP, respectively. We have also found that in-plane epitaxial relationship between the AlN films and the metal substrates are determined by the adsorption sited for nitrogen atoms on the metal surfaces. Semiconductor films grown on metal substrates show strong near band edge emission and its Schottky diodes have good rectifying property. These results indicate that the use of metal substrates is quite promising for future large area low cost devices.

Acknowledgement

The author would like to express sincere thanks to Drs. A. Ishii, M. Oshima, J. Ohta, S. Inoue, and A. Kobayashi for the fruitful discussion and their experiments.

References

[1] K. Ueno, A. Kobayashi, J. Ohta, H. Fujioka, H. Amanai , S. Nagao , and H. Horie, Appl. Phys. Lett., 91, 081915 (2007).

[2] K. Ueno, A. Kobayashi, J. Ohta, and H. Fujioka, Appl. Phys. Lett., 90, 141908 (2007).

[3] A. Kobayashi, S. Kawano, Y. Kawaguchi, J. Ohta, and H. Fujioka, Appl. Phys. Lett., 90, 041908 (2007).

[4] K. Sakurada, A. Kobayashi, Y. Kawaguchi, J. Ohta, and H. Fujioka, Appl. Phys. Lett. 90, 211913 (2007).

[5] M.-H. Kim, J. Ohta, A. Kobayashi, H. Fujioka, and M. Oshima, Appl. Phys. Lett. 91, 151903 (2007).

[6] S. Inoue, K. Okamoto , T. Nakano , J. Ohta , and H. Fujioka, Appl. Phys. Lett. 91, 131910 (2007).

[7] S. Inoue, K. Okamoto , T. Nakano , J. Ohta , and H. Fujioka, Appl. Phys. Lett. 91, 201920 (2007).

[8] A. Kobayashi, S. Kawano, K. Ueno, J. Ohta, H. Fujioka, H. Amanai , S. Nagao , and H. Horie, Appl. Phys. Lett. 91, 191905 (2007).