Formation of a Ti_2AlN layer on GaN for contact applications

M.A. Borysiewicz[1], B. Pecz[2], L. Tóth[2], E. Kaminska[1], A. Piotrowska[1], I. Pasternak[1], R. Jakieła[3], E. Dynowska[3]

1. Institute of Electron Technology, Al. Lotników 32/46, 02-668 Warsaw, Poland
2. Research Institute For Technical Physics And Materials Science, Hungarian Academy of Sciences, Konkoly Thege Miklós út 29-33, H-1121 Budapest, Hungary
3. Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland

mbory@ite.waw.pl
Keywords: MAX phases, TEM, ohmic contacts, GaN

The development of specialised electronics drives the need for materials that can operate in conditions that cannot be met by Si-based devices. Such harsh conditions can be defined by high temperature, high reactivity environments or high power load on the device. Due to their wide band gap, semiconductors from the III-N group are seen as promising candidates for such applications. Nevertheless, a device itself is not only composed of the semiconductor and one has also to take into account the issues of electric contacts, heat dissipators, packaging etc. This work concerns studies on phase formation of thermally stable, oxidation-resistant ohmic contacts to n-type GaN.

An ohmic contact to n-GaN conventionally used is a Ti/Al Bilayer [1]. The idea behind this study was to replace this bilayer with a Ti-Al-N MAX phase. The MAX phases are material phases exhibiting both metallic (good thermal and electrical conductivity) and ceramic (high hardness, oxidation resistance) properties [2,3]. Their hexagonal elemental cells are constructed of transition metal atoms (M), a IIIA or IVA-group element (A) and nitrogen or carbon (X) and have a $M_{N+1}AX_N$ stoichiometry, where N=1,2 or 3. The unique material properties of the phases arise from their nanolaminate structure (see fig. 1).

The samples were prepared using sputter deposition by two methods. First: TiN, Ti and Al multilayers were deposited on GaN (0001) substrates and subsequently annealed in Ar flow in 600^{o}C Second: several Ti/Al bilayers were deposited on a GaN (0001) substrate and annealed in a N_2 flow at 600^{o}C.

Phase transformations in the interface region were characterised by conventional and high resolution transmission electron microscopy (TEM) in cross-section. Transparent TEM specimens were prepared by Ar+ ion milling at 10 keV, and finished at 3 keV in order to decrease the ion beam damage. Conventional TEM images were taken on a Philips CM20 transmission electron microscope working at 200 kV, while high resolution images were taken on a JEOL 3010 operating at 300 kV. Elemental maps of the areas were also measured.

Secondary Ion Mass Spectrometry depth profiles (CAMECA IMS6F) and X-Ray Diffractometry (Phillips X'Pert) were performed for complementary characterisation.

The results obtained show that in some of the samples a new material phase forms on the interface with the substrate (see fig.2 and fig.3). A HR-TEM image shown on fig. 2.b. shows the laminar structure of this phase and the spacing between the layers to be equal to 0.75 nm. When assumed that this spacing is between two subsequent layers of MX and A atoms it is seen that for a Ti_2AlN unitary cell the cell parameter c is equal to two times this value giving 15 Å. From the XRD measurements for this sample a c = 13.9 Å is obtained. A c = 13.6 Å value is given by Barsoum [2]. Based on these figures one can identify the phase observed in the samples as the Ti_2AlN phase.

W. Grogger, F. Hofer, P. Pölt (Eds.): MC2009, Vol. 3: Materials Science,
DOI: 10.3217/978-3-85125-062-6-394 , © Verlag der TU Graz 2009

1. M.E. Lin et al., *Appl. Phys. Lett.* **64**, 1003 (1994).
2. M.W. Barsoum, *Prog. Solid St. Chem.* **28**, 201 (2000).
3. J. Emmerlich et al., *Acta Materialia*, **55**, 1479 (2007).
4. This study was partially supported by the EC under the project "Materials for Robust Gallium Nitride" CP-IP 214610-2 MORGaN.

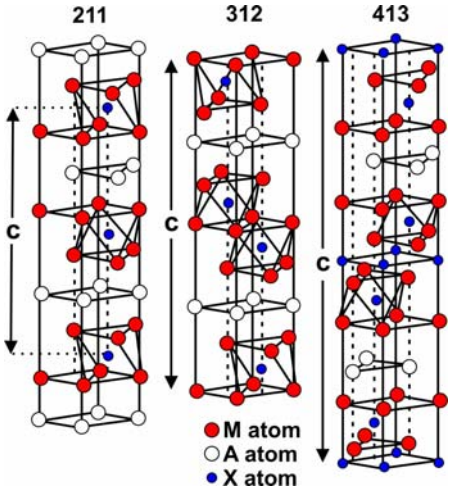
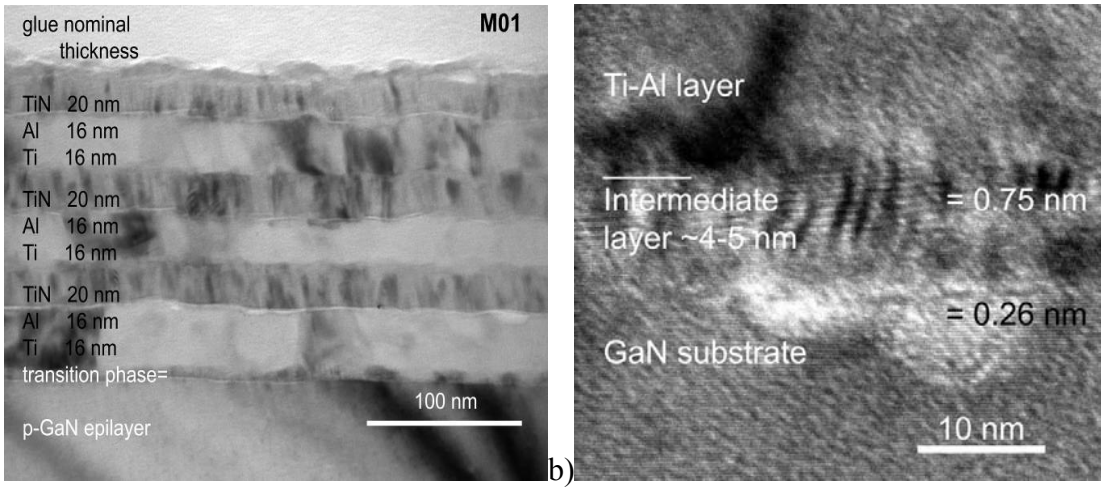


Figure 1. MAX phase cell.



a) b)

Figure 2. (a) TEM image of sample M01, (b) HR-TEM image of the interface region

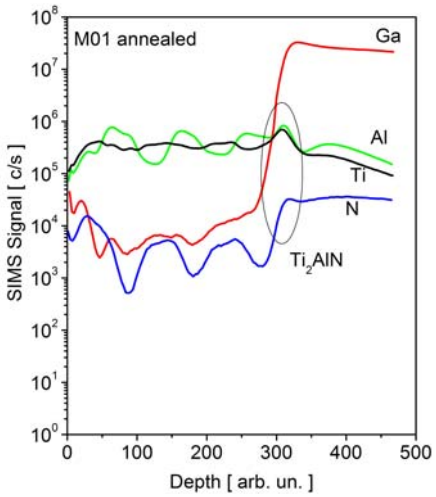


Figure 3. SIMS depth profile of sample M01

DOI: 10.3217/978-3-85125-062-6-394 , © Verlag der TU Graz 2009