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Formation Peculiarities and Properties of Ohmic Contacts to *n*-GaN(AlN) and Artificial Diamond

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Abstract—The paper considers ohmic contacts of Au–TiB_x–Al–Ti–*n*–GaN, Au–Pd–Ti–Pd–*n*–AlN and Au–Pd–Ti–*n*–C to the promising for use in microelectronics wide-gap semiconductors. Ohmic contact formation takes place after sequential layering of metal with further fast thermal processing, which leads to solid-phase reactions between the semiconductor and metal. It is shown that the use of X-ray amorphous TiB_x layer in ohmic contact as the diffusion barrier allows for creating thermal stability contacts up to $T = 900$ °C. Current flow in the considered ohmic contacts is described using a model with current flow along metal shunts considering diffusion limitation on the charge carrier supply.

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INTRODUCTION

Increase of power and frequency of semiconductor microelectronic devices is impossible to imagine without the introduction of new semiconductor materials. The most suitable ones for this purpose are wide-gap semiconductors such as GaN, AlN and C, that possess strong fields of avalanche breakdown and as a consequence high operating temperatures and powers of devices designed on their basis.

Properties of some semiconductor materials [2, 3] are presented in Table 1. The most studied one is GaN, which is widely used in optical electronics. However realization of all its promising properties in microelectronics as well as in the cases of AlN and C, has not been achieved. The possibility of designing optical electronics devices using AlN and C, which may allow for creating a laser operating in the deep ultraviolet frequency range (~200 nm), is still under investigation.

High temperature conductivity of AlN and C, which in the case of C exceeds that of SiC, allow for efficient heat removal without the use of a heat sink. Epitaxial layers of aluminum and gallium nitrides for better heat removal may be grown on the SiC substrate.

Complexity of growing and obtaining bulk materials with stoichiometric content due to high atom connection energy, which in the case of GaN amounts to 9.12 eV/atom [1], is a limiting factor for using all these materials in microelectronics. Due to these difficulties GaN, AlN and C often get grown on foreign substrates (Al_2O_3, SiC, Si), which leads to a significant defect density in a semiconductor due to relaxation of intrinsic mechanical stresses that arise because of mismatches in lattice properties and thermal expansion coefficients of a semiconductor and a substrate.

One of the principal limiting factors appears to be the absence of thermally stable reliable ohmic contacts. As results prove [4–9] in order to form such contacts stability of their layered structure and absence of uncontrolled mass flow under the impact of degradation factors such as temperature increase, electromagnetic fields and ionizing radiations play a major role. To achieve this one should use multi-layered contact structures with a contact forming layer, a diffusion barrier made of refractory metals or their alloys and a contact layer used for interfacing the conductors such as gold [4, 8, 9].

This paper considers the process of forming ohmic contacts to wide-gap semiconductors like A^3N and C as well as current flow mechanisms in the obtained contact structures. The studied processes get complicated due to growing the studied semiconductors on foreign substrates.

FORMATION OF OHMIC CONTACTS TO WIDE-GAP SEMICONDUCTORS

An ohmic contact is a non-injecting contact between a metal and a semiconductor with linear symmetrical current-voltage characteristic (CVC) and negligibly small resistance compared to that of a bulk semiconductor.