# Pre-amorphization implantation (PAI) process assessment for GaN contact technologies

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Ohmic contacts are used in many technologies to connect active parts of electronic devices to back-end circuits. However, achieving low contact resistances on GaN substrates and related materials remains a challenge [1]. Several process steps are required to form a contact, generally including surface preparation, metal deposition, and annealing. In silicon technologies, several levers such as pre-amorphization by implantation (PAI) have been proposed in order to tune the properties of the silicide layer and the associated NiSi/Si interface obtained by silicidation [2]. In such processes, the substrate is amorphized over a few nanometers prior to metal deposition, which affects the subsequent silicide formation mechanisms. Typically, crystalline phase formation temperatures can be modified to induce metallic alloy formation at relatively low temperatures [3]. If such a trend could be obtained on GaN, adapted intermetallic alloys could be developed, with the advantage of mitigating the difficulties of preparing the GaN surface prior to metal deposition.

In this work, the potential of using PAI processes on GaN for power electronic applications is evaluated by implanting non-intentionally doped GaN samples with a single Al shot at 4 keV and 1E16 at.cm$^2$ (VIISTA HCP implanter from Applied Materials). The sequential deposition of a 30 nm metal (Ni or Ti) layer and a 10 nm TiN capping layer is then performed without air break using an Endura 200mm integrated platform from Applied Materials. Depending on the sample, different thermal budgets are then applied (see Table 1). The resulting samples are characterized by high-angle annular dark-field (HAADF) scanning transmission electron microscopy (STEM) and corresponding energy dispersive spectroscopy (EDS) spectra, out-of-plane (θ-2θ) and in-plane reciprocal space map (IPRSM) X-ray diffraction.

For Ni-based samples, Fig. 1 shows that the use of a pre-implantation step changes the morphology of the contact obtained after annealing at 600 °C. Indeed, while a $Ni_{1-x}Ga_x$ layer (i.e. Ni-rich NiGa) is obtained for both samples, most likely by diffusion of Ga atoms into the Ni layer, only the sample where the substrate was amorphized shows additional areas where Ni atoms seem to have diffused into the GaN substrate. The associated alloy is found to be about 40 nm thick and has a stoichiometry close to NiGa. This difference between samples annealed at 600 °C is confirmed by XRD analysis in Fig. 2. For the reference sample, the obtained IPRSM is composed of a series of epitaxial-like spots consistent with $Ni_4Ga$, as confirmed by θ-2θ measurements (see Fig. 2.a and Fig. 2.b, respectively). For the sample with PAI, the resulting alloys show a fiber texture, with the presence of $Ni_4Ga$ and NiGa related components (see Fig. 2.c). More importantly, the system evolution is accelerated when the substrate surface is amorphous: for samples annealed at 500 °C, the GaN 002 to $Ni_4Ga$ 111 diffraction line intensity ratio is higher for the reference sample (see Fig. 2.b) than for the implanted one (see Fig. 2.d).

The results described above indicate a promising use of PAI processes for GaN technologies, as will be discussed in detail in this paper. Results for Ti-based samples, which also show differences whether or not a PAI step was used prior to metal deposition, will be presented.

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**References:**

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| PAI conditions | Metallization | Annealing condition |
|---|---|---|
| None (Ni based samples ref.) | Ni(30nm)/TiN(10nm) | Ar, 3min, 500°C and 600°C |
| Al: 4keV, 1.10$^{16}$ at/cm² | Ni(30nm)/TiN(10nm) | |
| None (Ti based samples ref.) | Ti(30nm)/TiN(10nm) | |
| Al: 4keV, 1.10$^{16}$ at/cm² | Ti(30nm)/TiN(10nm) | |

Table 1: Studied samples

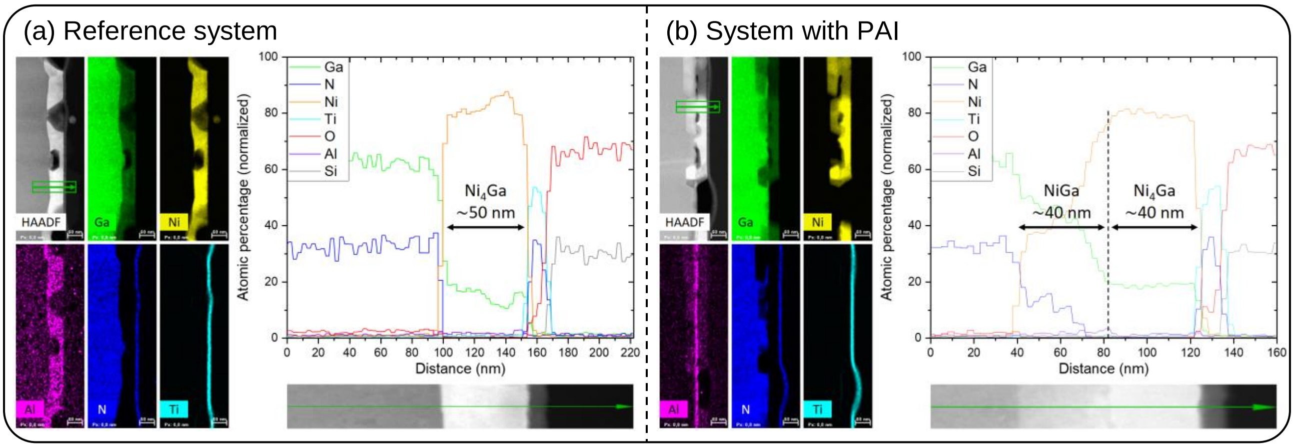


Fig. 1: HAADF-STEM image and corresponding EDS-STEM elemental mappings of the Ni-based system after annealing at 600 °C (a) without and (b) with PAI. For each sample, the composition profile across the stack measured by EDS along the green arrow (see HAADF image) is shown on the right.

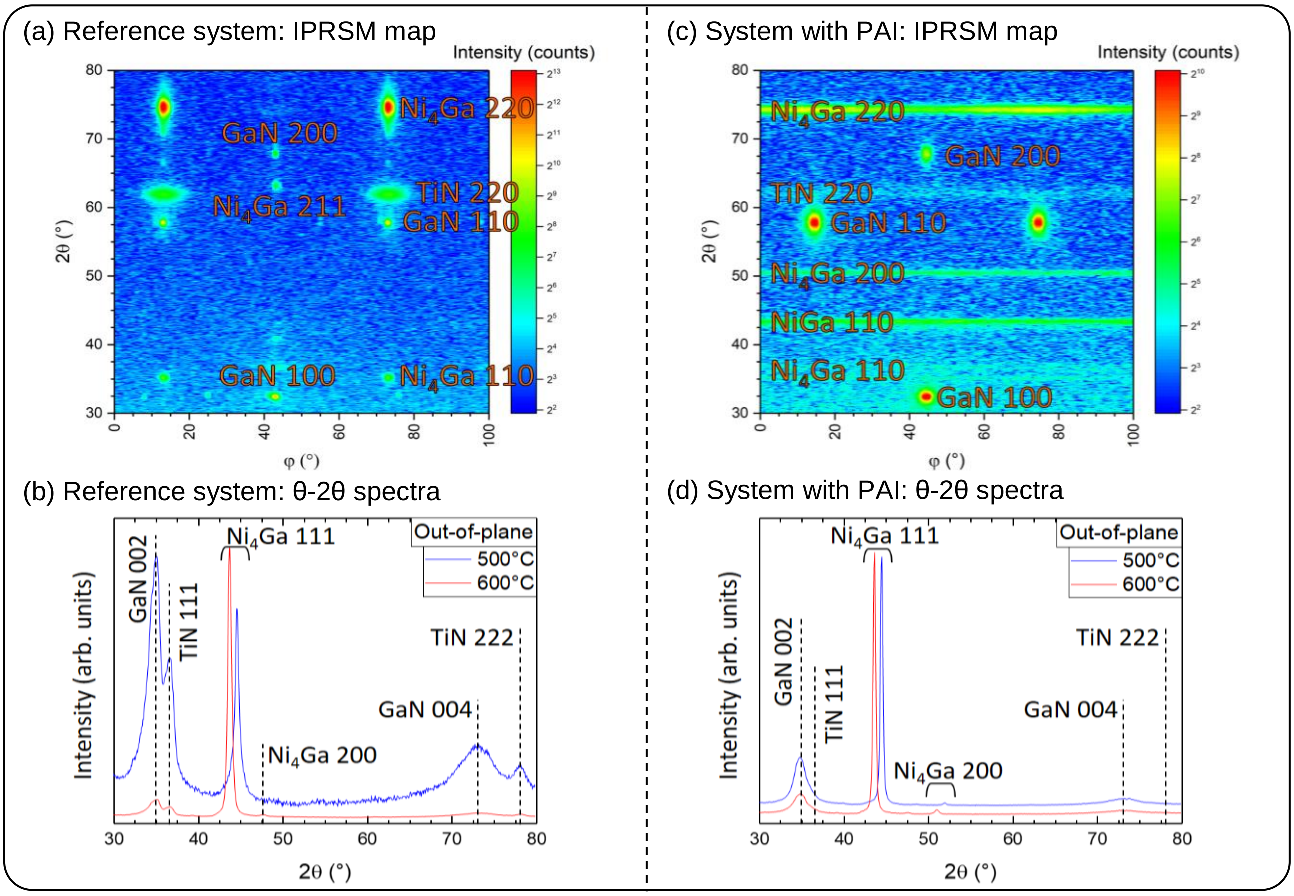


Fig. 2: XRD analysis of the Ni-based system. Figures on the left side (a, b) correspond to the reference sample while those on the right side (c, d) correspond to the system with PAI. (a) and (c) show IPRSM maps after annealing at 600 °C while (b) and (d) show out-of-plane θ-2θ results for two annealing temperatures, 500 °C in blue and 600 °C in red.