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Study of the formation and degradation of intermetallics formed by solid-state reaction of Ni on InGaAs

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In order to push the boundaries of the actual CMOS devices performances, it is vital to seek for new materials to replace silicon, as this material reaches its limit as a channel material for the transistors [1]. III-V materials and especially InGaAs represent serious candidates for this task due to their high carrier mobility. To achieve a fully functioning device, it is important, among others key processes, to properly study and develop the metal/semiconductor contact issues. Silicide processes have been widely investigated during the last 20 years, but interest began to rise in III-V based contacts that are formed in the silicide way: by means of solid-state reaction to form a self-aligned contact. Different materials have been assumed as contact materials to achieve III-V contacts ([2][3]). Ni or Ni-alloys thin films remain one of the promising options as a contact material, but only few papers investigate Ni-based intermetallic on InGaAs ([4][5]).

The first part of this abstract is focused on the 3D Full Reciprocal Space Mapping (3D-RSM) [6] results. The use of 3D-RSM and careful data treatment is crucial in order to have the complete diffraction pattern of the intermetallic compound and to ensure that no reflection was omitted. The initial stack is illustrated at Fig. 1. At 250 °C, Ni is completely consumed and no corresponding Bragg peak was detected. The intermetallic is formed exhibiting two different orientations with two azimuthal variants each [7] (see Fig. 2). We could determine the space group of the intermetallic as the $P6_3/mmc$ by studying the systematic extinctions of *hkl* planes. This result is coherent with the studies of Guivarc'h et al. on the similar compound Ni_3GaAs [8]. The unit cell of the hexagonal structure contains two formulas units (see Fig. 3); the metal atoms occupy the (2a) sites and the non-metal atoms occupy the (2c) sites. Moreover there are two additional sites (2d) for the metal which can be partially, fully or non-occupied. In this case Ni atoms occupy the (2a) and potentially (2d) sites, while In, Ga and As occupy the (2c) sites. Fig. 4 shows the evolution of the c/a ratio of the intermetallic according to temperature with two major limits: NiAs at 1.4 and $Ni_3InGaAs$ at 1.3. According to Fig. 2 we can assume that the intermetallic hexagonal structure unfolds from a $Ni_3InGaAs$ composition into NiAs composition.

In this second part we describe the EDX results done on samples annealed at 300 °C and 550 °C (see Fig. 5). The EDX spectra reconstruction shows that at low annealing temperatures, In, Ga and As are nearly at their nominal stoichiometry inside the intermetallic compound. On the contrary, at higher annealing temperatures the proportion of these elements inside the intermetallic lattice is no longer the same as their nominal composition. This could be explained by the out-diffusion of Ga and In during the thermal annealing and the formation of NiAs at higher temperature. Moreover the film is highly agglomerated suggesting important structural changes. Similar degradation process of germane-silicides was discussed by T. Jarmar et al [9]. Further, XRD establishes significant evolution of the lattice parameters and texture of the intermetallic along with the emergence of superstructures.

Given the X-Ray diffraction, 3D-RSM and EDX/TEM results, we will suggest and discuss a model that describes the formation and degradation mechanisms of the intermetallic and its influence on the orientations of the intermetallic at higher temperatures.

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References:

1. Int. Techn. Roadmap for Semiconductors, 2013
2. Eugene Y.-J. Kong et al., *ISDRS* 2011
3. J. C. Lin et al., *J. Appl. Phys.,*114, 044504,2013
4. Ivana et al., J. Vac. Sci. Technol., B, 31, 012202, 2013.
5. P. Shekhter et al., J. Vac. Sci. Technol., B, vol. 31, no. 3, p. 031205, 2013
6. Thanh, T.Nguyen et al., *IITC/MAM*, *2015 IEEE*, pp.53-56, 18-21 May 2015
7. S. Zhiou et al. *IITC/MAM, 2015 IEEE*, pp.63-66, 18-21 May 2015
8. Guivarc'h, A. et al., Journal of Applied Physics, vol.66, no.5, pp.2129,2136, Sep 1989
9. T. Jarmar et al. J. Appl. Phys., 92 (2002), p. 71

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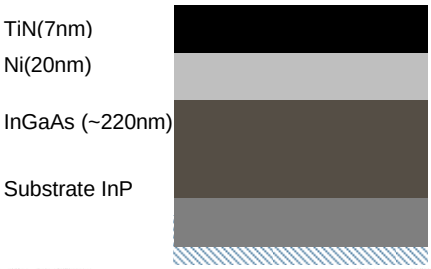

Figure 1. Illustration of the as-deposited stacks of the prepared samples: Ni/InGaAs/InP

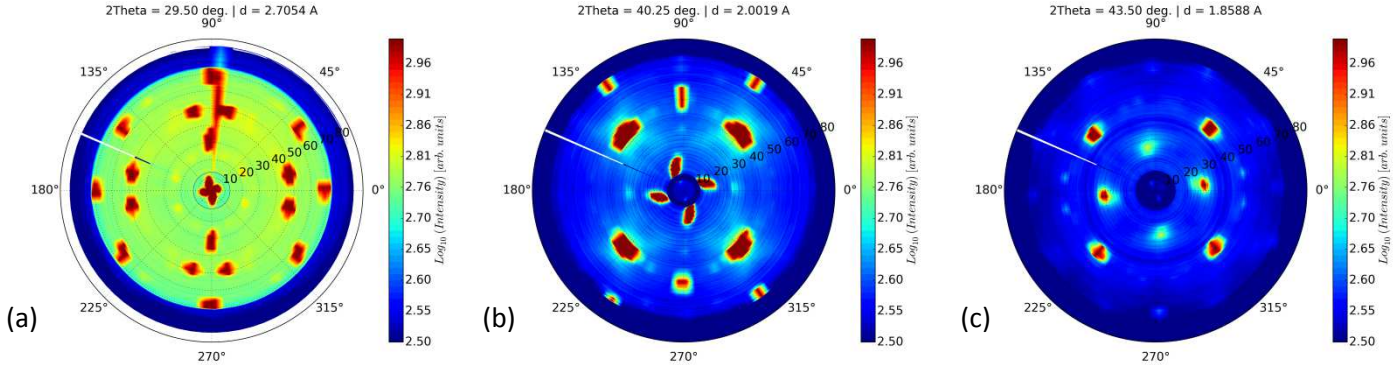

Figure 2. Pole figures of several planes of the intermetallic : (a) {10-11} Pole figure (b) {10-12} Pole figure (c) {11-20} Pole figure. Orientation and texture were discussed in [7]. The pole figure measurements were carried at the ESRF at an energy of 10keV

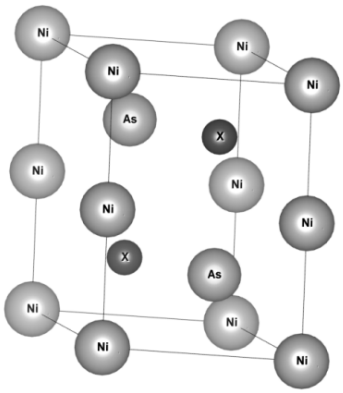

Figure 3. Reduced lattice of the NiAs hexagonal structure. Atom position marked by X correspond to (2d) sites

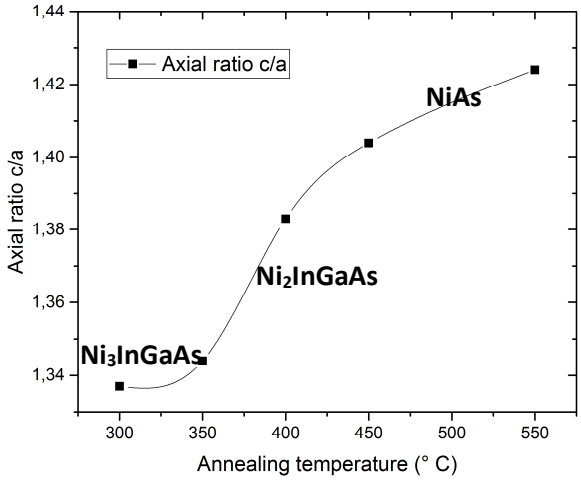

Figure 4. Evolution of the c/a lattice parameters ratio of the intermetallic according to temperature

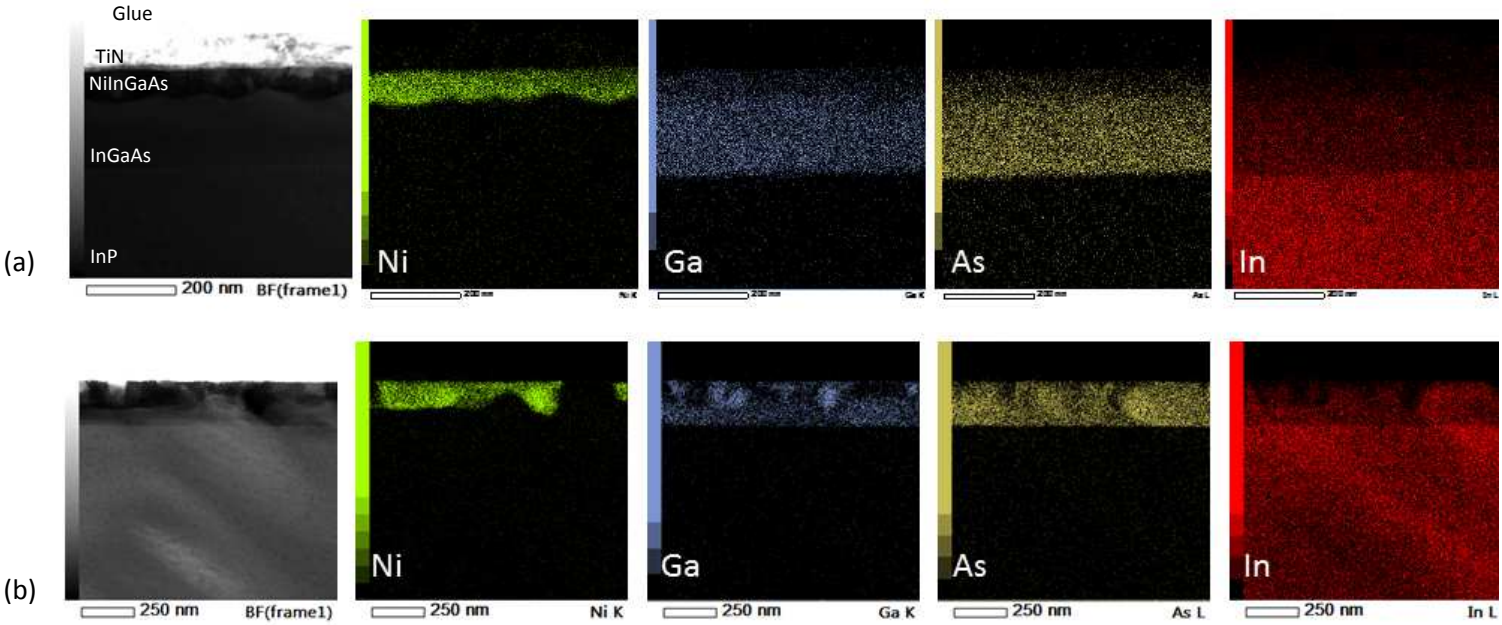

Figure 5 : (a) TEM and EDX images of the sample annealed at 300 °C (b) TEM and EDX images of the sample annealed at 550 °C