Lattice Constants of Quaternary Nitride Alloys

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New Electronic devices based on group-III-nitrides, especially light emitting devices, have been succesfully launched on the semiconductor market. However the electronical as well as the structural quality is still much lower than that of Si, GaAs and other semiconductors used by the industry.

One of the major problems in semiconductor heterostructures is strain introduced by the difference of the lattice constants of the respective layers. It is expected, that reduced stain in heterostructures will lead to better structural properties and thus to improved electronic behavior [1]. Therefor it is desirable to grow heterostructures without any lattice mismatch between the layers. For the group-III-nitrides this can be achieved by using the quaternary alloy AlGaInN. The bandgap of a AlGa nN layer grown without lattice mismatch on GaN can be varied from 3.4 eV to 5.4 eV, by adjusting the In and Al content.

To be able to grow lattice matched heterostructures the exact dependency between the composition of the alloy and its lattice constants must be known. It could already be shown, that for AlGaN Vegard's law is valid [2], which is in good agreement with theory [3]. However only little is known for GaInN. For the quaternary alloy AlGaInN only few measurements have been published [1]. Especially for alloys with a composition that is close to the inmiscibility region for the group-I I-nitrides a deviation from Vegard's law seems likely [4].

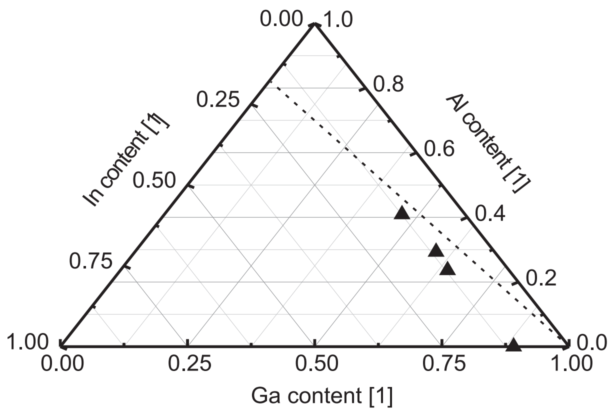

Fig. 1: H_2 Measured a-lattice constant compared to a-lattice constant as calculated from the composition using Vegardś Law

A series of $Al_xGa_{1-x-y}In_yN$ samples with an In content of about $y = 0.12$ and Al contents between $x = 0$ and $x = 0.41$ were measured (Fig. 1). The lattice constants were obtained from HRXRD (High Resolution X-Ray Diffraction). The compositions were measured with ERD (Elastic Recoil Detection). The ERD was done using a $170 MeV$ ^{197}Au beam and a monitor detector [5] under a scattering angle of $\phi = 35$. The experimental setup allowed the detemination of all the major cons ituents (N, Al, Ga, In) in separation simultaneously. In addition impurities, mainly H and O were measured, however their effect on the lattice constants were not taken into account. The relative error of the ERD measurement was below 2%.

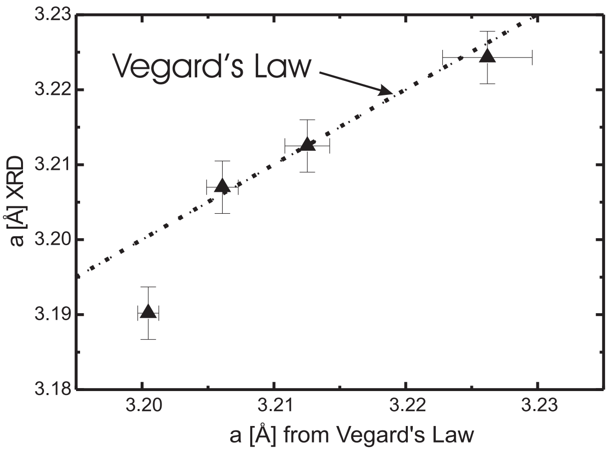

Fig. 2: H_2 Composition of the measured samples, the dotted line represents lattice matched composition on GaN

A comparison of the actual lattice constants and the lattice constants derived from Vegard's Law using the composition obtained from ERD shows good agreement. However the sample with the highest Al content ($x = 0.41$) exhibits a deviation from Vegard's Law towards smaller lattice constants. As the HRXRD measurements show no phase mixing, this can be taken as a first sign of a non-linear component of the dependence between the composition and the lattice constants of the alloy.

The results suggest, that Vegard's law is a good estimation for alloys with amounts of Al and In of up to $x = 0.25$ and $y = 0.12$. Further measurements are necessary for compositions with higher Al and In content.

References

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