Morphology of thin films containing Ni-Ga intermetallic compounds formed on GaN(0001)

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Studies of catalytic systems, which with high efficiency convert carbon dioxide into liquid fuel, have grown rapidly in the past few years. It is caused by increasing amount of carbon dioxide in the earth atmosphere and the global demand for fuel. Due to its good activity and selectivity Ni-Ga intermetallic compounds are important catalysts, which could be used for the development of low-pressure small-scale devices for CO_2 reduction to CH_3OH [1]. In order to increase catalytic efficiency of the compounds their highly dispersed form fixed on an unreactive support is required.

Gallium nitride (GaN) is a wide band-gap semiconductor which surface is very resistive chemically and can withstand relatively high temperature. Under annealing above 500 ^{0}C the surface enriches with Ga. Annealing of thin Ni films deposited on GaN results in Ni-Ga intermetallic compounds formation [2]. The alloying is accompanied by coalescence of the deposit into 3D islands of nanometer dimensions.

Herein we report the results of our *in situ* STM studies on the influence of deposition conditions on the morphology of thin films containing Ni-Ga intermetallic compounds formed on GaN(0001) surface. The films were engineered in two different ways. The first way (a post-deposition annealing), in which Ni was deposited in doses under UHV on the substrate kept at RT and obtained film was afterwards annealed first at 650 ^{0}C and next at 800 ^{0}C after each deposited dose, resulted in a wetting layer of 2D Ni-Ga surface alloy formation on which 3D islands developed. The {111}-oriented Ni crystallites initially formed on top of the wetting layer following the subsequent deposition and annealing cycles became enriched with Ni-Ga intermetallic compounds phases. The dominating phase was Ni_3Ga. Growth of the rich with the Ni-Ga compounds 3D grains was accompanied by their coalescence. Coalesced grains of average diameter of 10 – 20 nm and height of about 2 nm crated meandering chains on the surface. Average area of a single coalesced chain amounted to about 900 nm. The second way of engineering the films containing Ni-Ga compounds was direct deposition of Ni on GaN(0001) surface kept at 650 ^{0}C. The obtained films have a grainy morphology. Grains of irregular polygonal (mostly hexagonal) shape were uniformly distributed over the surface. They grew steadily following the Ni deposition; creating eventually film consisted of grains with diameters ranging from 14 to 20 nm and average height equal to about 1.5 nm. Coalescence of the grains was observed rarely. Both used procedures give highly dispersed films that should be suitable for catalytic applications.

[1] I. Sharafutdinov, C.F. Elkjaer, H.W. Pereira de Carvalho, D. Gardini, G.L. Chiarello , C.D. Damsgaard, J.B. Wagner, J.D. Grunwaldt, S. Dahl, I. Chorkendorff, *J. Catal.* **320** (2014).
[2] M. Grodzicki, P. Mazur, S. Zuber, J. Pers, J. Brona, A. Ciszewski, *Appl. Surf. Sci.* **304** (2014).