# Investigation of AuGeNi Ohmic Contact to *n-i*-GaAs Deposited by Different Methods

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**Abstract – The comparative analysis of parameters of ohmic contacts to *n-i*-GaAs deposited by the thermal evaporation of Au–Ge–Ni alloy or layer by layer deposition of Ge, Au, and Ni films is carried out. That has been shown the values of the specific contact resistance of the layer by layer deposited ohmic contacts are more reproducible and the surface morphology of this contacts is smoother than in the case of contacts deposited by the Au–Ge–Ni alloy evaporation.**

## 1. Introduction

Ohmic contacts parameters define characteristics of MESFET and *p*-HEMT transistors as well as parameters of the MIMIC based on these transistors. At the technology node reduction the requirements to parameters of ohmic contacts, to their thermal stability and lifetime are increase [1]. In this connection the searching of the contact metallization optimal composition as well as effective deposition method is staying an actual problem.

The work purpose is analysis of parameters of ohmic contacts to *n-i*-GaAs deposited by the thermal evaporation of the Au–Ge–Ni alloy or layer by layer deposition of Ge, Au, and Ni films.

## 2. Experimental techniques

Samples of the Si-doped *n-i*-GaAs ($n \cong 4 \cdot 10^{17}$ cm$^{-3}$, $d = 0.12$ μm) and $n^+$-GaAs ($n \cong 10^{18}$ cm$^{-3}$) were used in experiments. The two-layer resist mask with TLM patterns was produced by standard photolithographic techniques.

For the GaAs native oxides removal samples were processed in $H_2SO_4$ (1 : 10) water solution within 3 min. After the treatment, samples were rinsed in deionized (DI) water and drying in $N_2$ flow.

The AuGeNi film (0.15 μm) was deposited by the thermal evaporation of the alloy AuGe (88% / 12% wt) + Ni (10% wt) and by layer by layer deposition of Ge (40 nm), Au (80 nm) and Ni (20 nm) films at the pressure $2 \cdot 10^{-6}$ Torr. The total thickness of films was ≅ 150 nm. The topology of the contact pads was formed by the lift-off process. Samples were annealed in nitrogen environment in furnace at temperature $T = 350$–$460$ °C during time $t = 5$ min.

Surface morphology of the annealed contact pads was examined by methods of the scanning electronic and the atomic force microscopy. The specific contact resistance ρ was measured by the TLM and Cox-Strack methods. The accuracy of the specific contact resistance measurement was 30%.

## 3. Results and discussion

In Figure 1, the SEM surface images of annealed ohmic contacts, deposited at the basic pressure $2 \cdot 10^{-6}$ Torr by the thermal evaporation of Au–Ge–Ni alloy and layer by layer deposition of Ge, Au, and Ni films are presented.

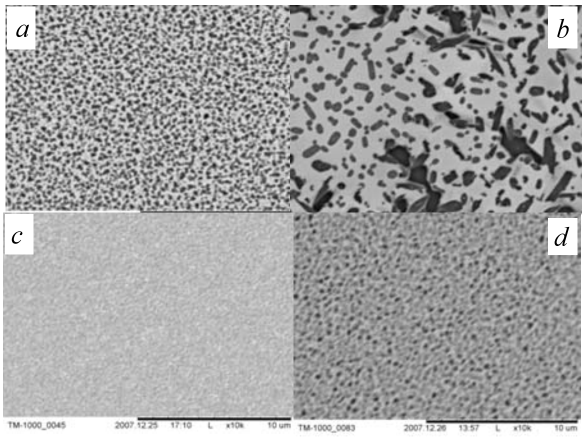


Fig. 1. SEM images of the AuGeNi (*a*, *b*) and Ge/Au/Ni (*c*, *d*) ohmic contacts surface annealed at the optimal temperature (*a*, *c*) and at 460 °C (*b*, *d*)

Both types of the contact metallization were deposited on *n-i*-GaAs samples. From the analysis of the grey contrast distribution along of the contact pad follows, that contact Ge/Au/Ni has homogeneous distribution of specific contact resistance and smoother morphology of the surface, than contact deposited by the thermal evaporation of AuGeNi alloy. It is correct for annealing at the optimal temperature (temperature which corresponds to minimal ρ value), and for higher temperature ($T = 460$ °C) too.

In Figure 2, the AFM surface morphologies of annealed ohmic contacts both types are shown. These images are adjusting with the Fig. 1 data and testify that contacts Ge/Au/Ni have smoother surface morphology at all annealing temperatures.

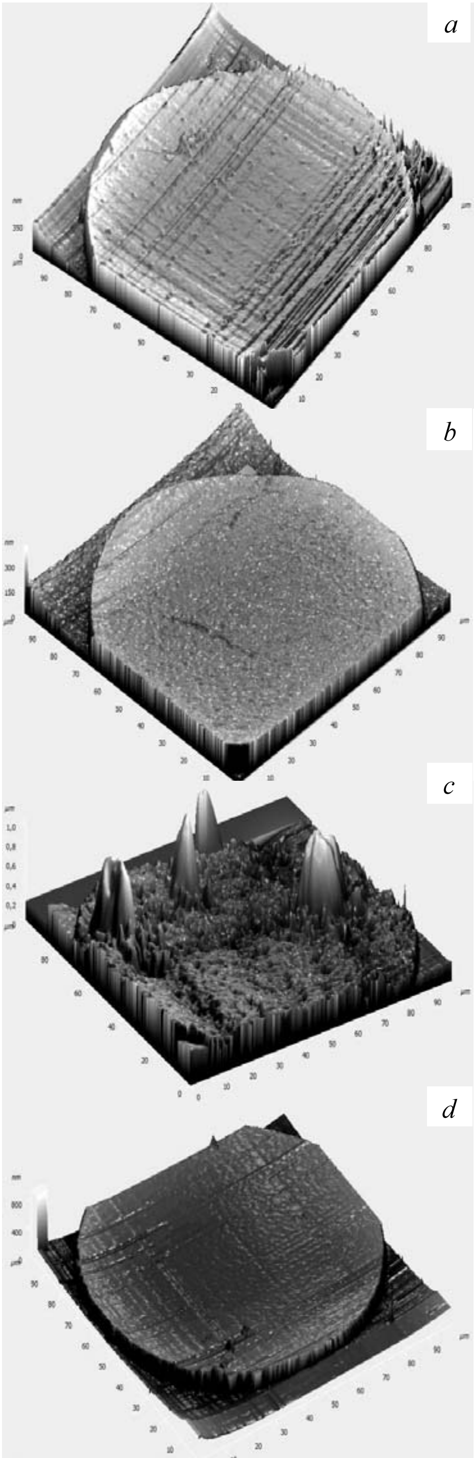


Fig. 2. AFM images of the AuGeNi (*a*, *c*) and Ge/Au/Ni (*b*, *d*) surface of ohmic contacts annealed at the optimal temperature (*a*, *b*) and at 460 °C (*c*, *d*)

In Figure 3 the measurement results of the specific contact resistance of the AuGeNi and Ge/Au/Ni ohmic contacts, deposited on *n*-GaAs and $n^+$-GaAs and annealed are presented. The temperature dependences has a traditionally curves shape with the ρ value minimum. With the increasing of the annealing temperature the decreasing of the specific contact resistance is observed.

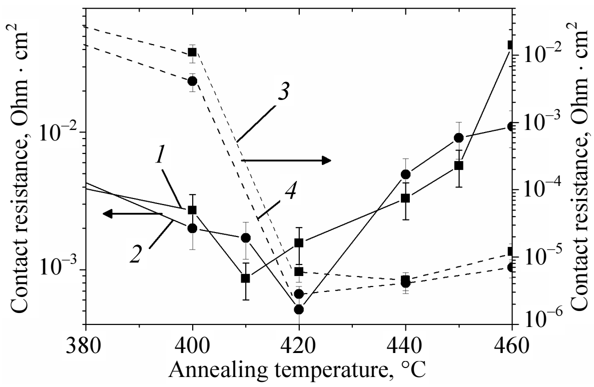


Fig. 3. Dependence of the specific contact resistance of AuGeNi (*1*, *3*) and Ge/Au/Ni (*2*, *4*) ohmic contacts to *n*-*i*-GaAs (*1*, *2*) and $n^+$-GaAs (*3*, *4*) versus annealing temperature

This is the result of the interdiffusion between ohmic contact metallization and GaAs and the formation doping interface layer. The increasing of the temperature leads to ρ growth as result of the high-resistance intermetallic AuGa phase formation [2].

The minimal value of the specific contact resistance for Ge/Au/Ni contacts to *n*-*i*-GaAs, deposited by layer-to-layer method is $5 \cdot 10^{-4}$ Ohm · cm$^2$ at $T = 420$ °C. The Au–Ge–Ni ohmic contact, deposited by alloy evaporation in a point of a minimum has higher resistance $\rho = 8.5 \cdot 10^{-4}$ Ohm · cm$^2$ at $T = 410$ °C.

In case of $n^+$-GaAs samples, minimal values of the specific contact resistance are $\rho = 2.8 \cdot 10^{-6}$ Ohm · cm$^2$ for layer-by-layer deposited Ge/Au/Ni ohmic contact and $\rho = 4.5 \cdot 10^{-6}$ Ohm · cm$^2$ for Au–Ge–Ni contact, deposited by alloy evaporation.

The degreasing of the specific contact resistance by factor 100 at increase GaAs doping level by factor 2 is a result of high influence of the doping concentration on ρ.

A series of the experiments devoted to research of reproducibility of contacts to *n*-*i*-GaAs parameters has shown, that layer by layer contacts achieves the minimal contact resistance $\rho = (4.2 \pm 1.4) \cdot 10^{-4}$ Ohm · cm$^2$ at temperature $T = (420 \pm 5)$ °C, while for Au–Ge–Ni contact achieves $\rho = (5 \pm 2) \cdot 10^{-4}$ Ohm · cm$^2$ at $T = (430 \pm 30)$ °C. It is testifies that the layer by layer technology allows producing contacts with lowered contact resistance and also to higher reproducibility of their parameters.

## 4. Conclusions

That has been shown that layer by layer deposited Ge/Au/Ni ohmic contacts has the reduced, more reproducible the specific contact resistance and smoother surface morphology at all annealing temperatures, in compare with contacts deposited by Au–Ge–Ni alloy evaporation.

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