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PHOTOINDUCED RESTRUCTURING OF THE CURRENT-VOLTAGE CHARACTERISTICS OF NICKEL SILICIDE ON SILICON

M. Sh. Isaev
National University of Uzbekistan named after M. Ulugbek,
CYBER University State University of Uzbekistan

Abstract
This study investigates the effect of optical illumination on the current-voltage (I-V) characteristics of nickel silicide layers formed on p-type silicon. Experimental results show that illumination not only increases conductivity but also qualitatively modifies the charge transport mechanism. It was established that reducing the $NiSi_2$ layer thickness by 15 mkm increases the photocurrent by an order of magnitude due to reduced optical losses. At high reverse bias (100 V), an internal gain factor (M= 8-10) was observed, attributed to avalanche multiplication and barrier modulation at the silicide-silicon interface. The findings demonstrate the functional activity of nickel silicide in photovoltaic processes, expanding its application in photosensitive silicon structures.

Keywords: Nickel silicide, p-Si, I-V characteristics, photocurrent, internal gain, barrier modulation, photosensitivity, charge transport.

Introduction

Transition metal silicides are widely used in silicon micro- and nanoelectronics as contact and conductive layers due to their high thermal stability and low resistivity. Traditionally, such materials are considered electrically passive elements, making no significant contribution to photovoltaic processes in metal-silicon structures [1].

However, the research results presented in the literature, as well as experimental Data obtained for manganese silicides indicate a more complex nature of their electrical properties. In particular, the presence of a transition metal with a partially filled d -shell leads to the formation of local energy levels in the silicon band gap and to a modification of the barrier properties of the interface [2].

In this context, studying the current-voltage characteristics of nickel silicide on silicon under illuminated conditions is of particular interest. Analysis of the light-induced current-voltage characteristics allows us to identify the role of the silicide layer in photoinduced charge transfer processes and evaluate its potential functionality in photosensitive silicon structures [3].

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The effect of optical illumination on the current-voltage characteristics (I-V characteristics) of a nickel silicide layer formed on silicon was studied. It was shown that illumination not only increases the structure's conductivity but also leads to a qualitative restructuring of the charge transport mechanism, manifested in a change in the shape and asymmetry of the I-V characteristics. It was established that the system's photoresponse is due to the combined contribution of carrier generation in silicon and modification of the potential barrier at the nickel silicide-silicon interface. The obtained results demonstrate the functional activity of nickel silicide and expand our understanding of the role of transition metal silicides in photovoltaic silicon structures [4,5].

The aim of this work is to study the influence of optical illumination on the current-voltage characteristics of a nickel silicide layer formed on silicon and to identify the physical mechanisms of photoinduced charge transfer in the nickel silicide-silicon system.

Results and Discussion

To achieve this goal, the following tasks were formulated:

1. Analyze the current-voltage characteristics of the nickel-silicon silicide structure in the dark and under illumination.
2. To establish the relationship between the photoresponse of the structure and the barrier properties of the silicide-silicon interface.
3. To identify the role of nickel silicide in the photoconductivity processes of the system.

The structure under study was a contact $NiSi_2/p-Si$formed on psilicon-type surfaces by diffusion doping.

Main parameters:

Substrate type: $p-Si$, acceptor concentration: $N_A \approx 1x10^{16}см^3$,silicide phase: mono, -, di - and higher nickel silicides.

Initial thickness silicide layer: $30-35$μм, thickness after grinding: 15-20 мкм, contact area: 6 mm2 (0.06 cm2) , illumination wavelength: $\lambda = 0{,}63$мкм, illuminance: E=12 mW/cm2 · Direction of illumination: from the side of the silicide layer. Measurement mode: reverse bias up to 100 V.

After reducing the thickness of the silicide layer by 15 μm, the following photocurrent values were obtained:$I_Ф \approx 100$μA при $V_R = 50$ B;

$I_Ф \approx 1$ мА при $V_R = 100$ B.

At an illumination of 12 mW/cm2, the optical power incident on the contact is:

$$P = E \cdot S = 0.72 \text{ мВт}$$

Corresponding sensitivity:
a) when50 В: $R \approx 0.14$ А/Вт
b) when100 В: $R \approx 1.39$ А/Вт
The quantum sensitivity limit for $\lambda = 0{,}63$μмis about 0.32 A/W.
The photocurrent in the structure is described as a product of three factors:

$$I_\Phi(V,d) = K \cdot P \cdot e^{-\alpha d} \cdot \left(1 - e^{-W(V)/\delta}\right) \cdot M(V)$$

Where
$e^{-\alpha d}$– effective radiation losses in the silicide layer when illuminated from the silicide side;
W(V)- width of the depletion region in p - Si ;
$\delta \approx 3{,}2$мкм– absorption depth of silicon at 633 nm;
M(V)– internal gain coefficient;
K– coefficient taking into account reflection, interface losses and quantum efficiency.
It has been experimentally established that a decrease in the thickness of $NiSi_2$ At approximately 15 μm, the photocurrent increases by approximately an order of magnitude. This is well described by an exponential dependence $I_\Phi \sim e^{-\alpha d}$, indicating the dominant role of optical and energy losses in the thick silicide layer.
For $N_A \approx 10^{16}$см$^{-3}$the width of the depletion region is:

$$W(50B) \approx 2.6\text{мкм}, \qquad W(100B) \approx 3.6\text{мкм}$$

A sharp increase in photocurrent with an increase in voltage from 50 to 100 V requires the introduction of an internal gain factor M(V), reaching values of about 8-10 at 100 V. Possible physical reasons:
local avalanche multiplication of carriers in high-field regions; edge effects and electric field concentration; barrier modulation and field transport mechanisms.
Before polishing, the photocurrent is limited by exponential losses in the thick silicide layer, and internal carrier generation in silicon is virtually shielded. After reducing the thickness of the nickel silicide, the proportion of radiation reaching the nickel silicide- p - Si interface increases sharply . At high reverse voltages (approximately 100 V), the internal gain mechanism is activated, leading to a superlinear increase in photocurrent.

Conclusions

1. The photosensitivity of the nickel-silicon silicide structure when illuminated from the silicide side strongly depends on the thickness of the silicide layer.
2. Reducing the thickness of $NiSi_2$ by ~15 μm leads to an increase in photocurrent by approximately an order of magnitude.

3. At 633 nm and reverse voltages up to 100 V, the photocurrent reaches 1 mA at an illumination of 12 mW/cm^2.
4. Exceeding the quantum sensitivity limit indicates the presence of internal photocurrent amplification.
5. The obtained results are consistent with the model that takes into account exponential losses in the silicide and field enhancement at high voltages.

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