

during the rapid oxidation of droplets of the material melt. That is, when the surface is treated with a laser in air, the metal drops knocked out by the laser beam are oxidized, that is, a parallel process of material consumption occurs, which reduces the efficiency of obtaining a developed surface.

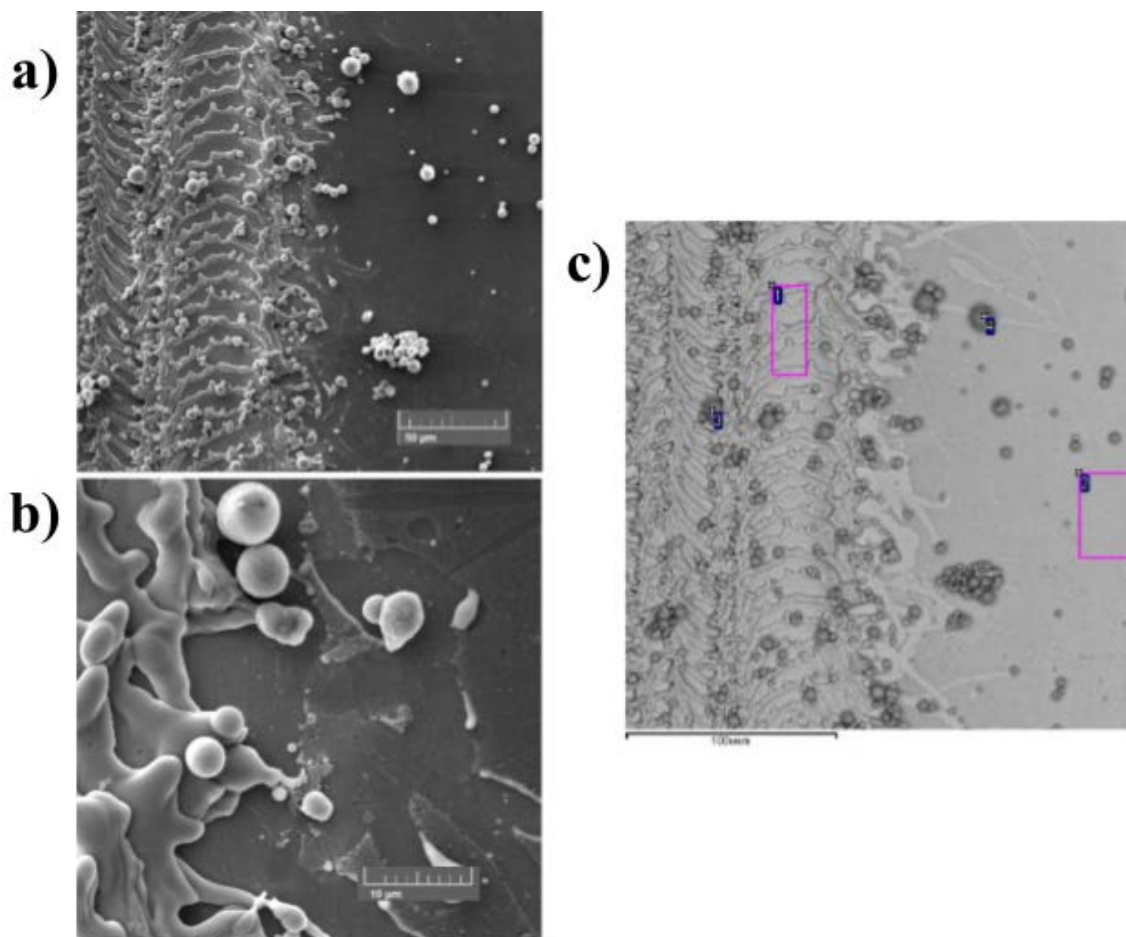


Fig. 6. (a, b) SEM images of the steel electrode surface at the border of the treated and untreated areas at different magnifications, c – indication of the areas of study of the composition

In the case of a steel electrode, Raman spectroscopy turned out to be less informative (Fig. 5). The spectrum of black color, obtained on an untreated steel plate, demonstrates the absence of any response, this form of the spectrum is typical for this material [19]. Violet and green spectra of the processed sample also contain peaks associated with carbon (green peaks), but of much lower intensity, which may indicate a smaller thickness of the grown layer of the same carbon. An exception is a peak at 674 cm^{-1} , which may correspond to iron oxide Fe_3O_4 [20].

Thus, laser-driven alteration on copper, nickel, and steel occurs in different ways, due to differences in the thermal conductivity of materials. The results indicate the fundamental suitability of the method of laser-driven alteration of various metal foils for the formation of electrodes for the electrochemical determination of glucose in solution since they make it possible to quickly and reproducibly obtain a developed metal surface. Of the materials considered, the nickel surface treatment is the most promising, since it is not accompanied by the formation of additional parasitic phases.

To study the sensitivity of the formed electrodes to the presence and concentration of glucose in the solution, a technique that allows electrochemically investigating the ongoing

processes was developed. At the first stage, the behavior of nickel foil in a 0.1 M NaOH solution was under investigation. It was found that in the case of using an untreated nickel substrate as a working electrode, the characteristic peaks of the Ni(III)/Ni(II) transition at about 0.4 V [21] are not observed. Additional electrochemical treatment (cathodic and anodic), etching, and mechanical activation of the surface of the initial foil also did not lead to the appearance of a corresponding peak in CV. In the case of using a preliminarily laser-altered nickel foil as a working electrode (Fig. 7), characteristic peaks of the Ni(III)/Ni(II) transition are observed for all rates of potential change. The formation of hydroxide on the treated surface most likely occurs during contact of the material with the solution.

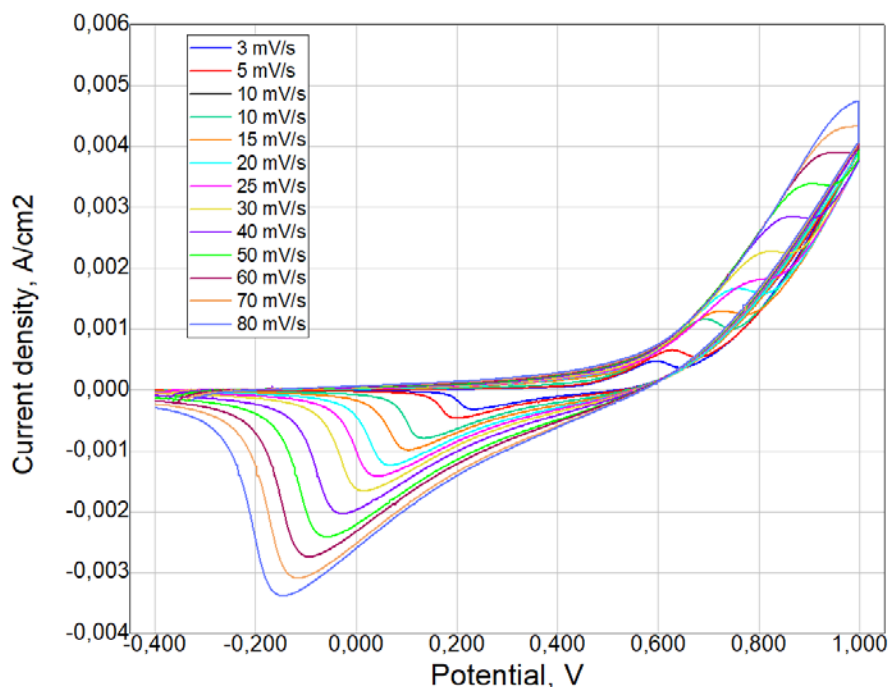


Fig. 7. Cyclic voltammograms of laser-altered nickel foil

In the case of adding 0.1 mM glucose to the working solution, a peak of about 0.4 V is also observed, the intensity of which is higher than for the case of CV without glucose (Fig. 8a). This result unambiguously indicates that electrodes for the electrochemical determination of glucose in the solution can be obtained by the method of laser-driven alteration of nickel foils. The areas of linear dependence of the current on the sweep speed will allow in the future to select the most convenient areas of the device operation parameters (Fig. 8b). The increase in the current of characteristic peaks on CV can be associated with surface glucose oxidation to form gluconate ion and hydronium ion [22-25].

During potentiostatic measurements (Fig. 9): 0-30 sec – the electrochemical circuit is open, the current is 0; at 30 seconds, a potential is applied and a current is recorded, when the circuit is closed, a sharp increase in current occurs; the system is turned off for 150 seconds. It can be seen that the introduction of glucose immediately provokes an increase in the current. The calculated values of the sensitivity are higher than $10 \mu\text{A}/(\text{mM}\cdot\text{cm}^2)$, the detection limit is not less than $5 \mu\text{M}$, the signal-to-noise ratio is 5.

Thus, the proposed technique of laser-driven alteration of nickel foils for electrochemical determination of glucose in solution electrode formation makes it possible to form active parts of sensors that are sensitive to glucose in the concentration range from 100 to 1500 μM with sufficient sensitivity and reproducibility.

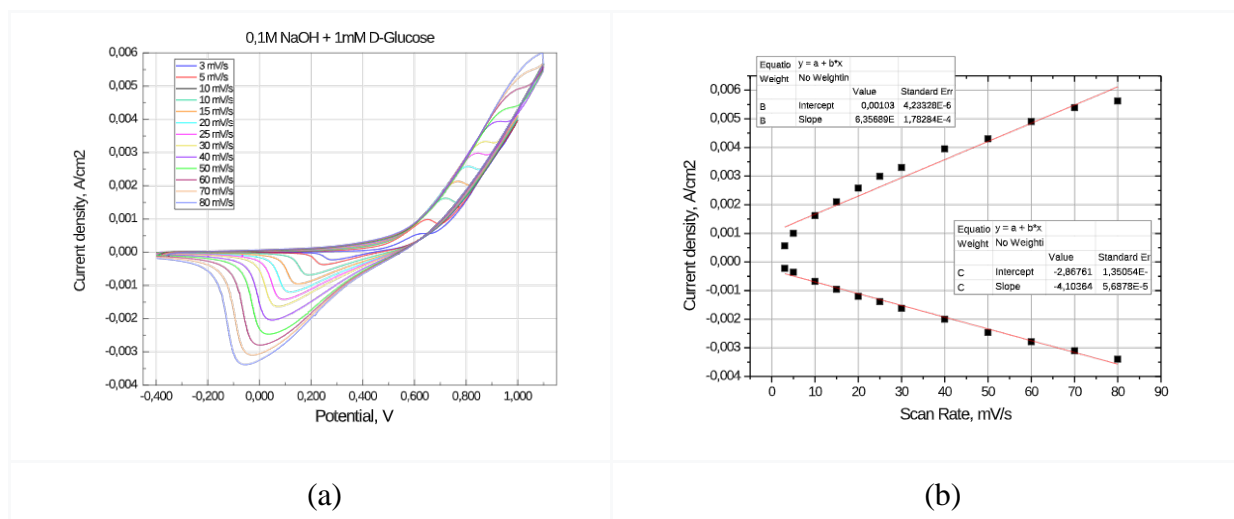


Fig. 8. (a) Cyclic voltammograms of activated nickel foil and (b) currents of the anode and cathode legs at different rates of change in the scan potential

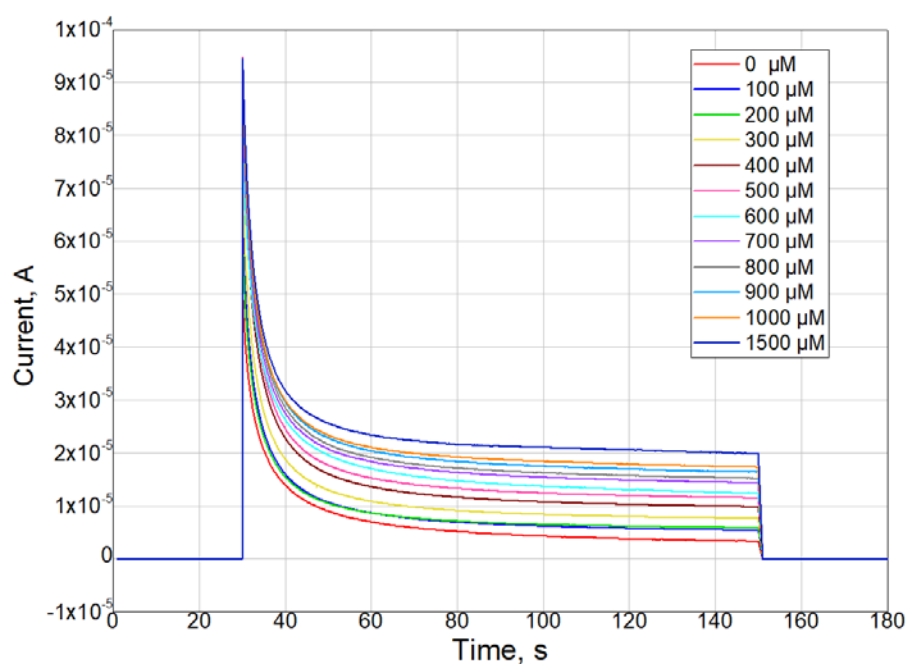


Fig. 9. Results of potentiostatic measurements (current response) at different glucose concentrations

4. Conclusions

The manufactured active layer of the sensor made of nickel oxide allows the amperometric determination of glucose in the concentration range from 10 μM to 1.5 mM, the sensitivity is higher than 10 $\mu\text{A}/(\text{mM} \cdot \text{cm}^2)$, the detection limit is not less than 5 μM , the signal-to-noise ratio is 5.

The method of laser-driven modification of a metal surface can be used to manufacture active elements of a non-enzymatic glucose sensor. The ease of scaling the results is due to the ease of observing the geometry of the device and the absence of complex technological operations during its manufacture. The next stage in the development of the prototype will be the development of a test system and a system for removing and processing signals.

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