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Features of the formation super C45-RuO_2-based planar supercapacitor structures

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Abstract. A method for forming electrodes of a planar supercapacitor based on Super C45 and RuO_2 by electrophoretic deposition is considered. The possibility of controlling the sediment composition by changing the composition of the initial suspension is shown. The suspension was subjected to dispersion, after which electrophoresis was performed in an electrophoretic cell consisting of two electrodes and a power source. The features of electrophoretic deposition and the influence of the main technological regimes on the morphology and composition of the formed layers of electrode materials are considered. A technological route was developed for manufacturing prototypes of planar supercapacitors using laser engraving to apply a topological pattern. The dependence of the specific capacitance on the electric field strength during electrophoretic deposition has been studied. Thus, it became possible to create designs of planar supercapacitors for a wide range of applications in microelectronics.

Keywords: planar supercapacitor, laser engraving, electrophoretic deposition, suspension, electrode material

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Материалы конференции
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Особенности формирования структур планарного суперконденсатора на основе super C45-RuO_2

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Аннотация. Рассмотрен способ формирования электродов планарного суперконденсатора на основе Super C45 и RuO_2 методом электрофоретического осаждения. Изучены особенности электрофоретического осаждения и влияние основных технологических режимов на морфологию и состав формируемых слоев электродных материалов. Был разработан технологический маршрут изготовления прототипов планарных суперконденсаторов с применением лазерной гравировки для нанесения топологического рисунка. Таким образом, стало возможным создание конструкций планарных суперконденсаторов для широкого спектра применений в микроэлектронике.

Ключевые слова: планарный суперконденсатор, лазерная гравировка, электрофоретическое осаждение, суспензия, электродный материал

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Introduction

Composite materials based on various modifications of carbon with a large surface area and transition metal compounds have become quite promising due to their unique properties: high specific capacity and power due to fast redox reactions [1–2]. This increases the demand for various power sources, including supercapacitors. The main efforts of researchers were aimed at maximizing their productivity, increasing their specific capacity and energy density. In this work, we study the manufacturing technology of planar supercapacitor structures by laser engraving. As the electrode layer, we used a composite based on Super C45 and RuO_2, formed by electrophoretic deposition (EPD), which makes it possible to form multicomponent materials and create nanostructured coatings of a given composition at room temperature [3–5].

Materials and Methods

Sital plates were used as substrates, on which a nickel layer 300 nm thick was deposited by means of magnetron sputtering. For the manufacture of electrodes, as the main material, we used Super C45 and RuO_2. All components (Super C45, RuO_2*xH_2O, cellulose and iodine) were mixed in a test tube with a mixture of acetone and isopropyl alcohol (Table 1).

Dispersion of the resulting solution was carried out by submersible ultrasonic disperser. The electrode material was deposited in an electrophoretic cell consisting of two electrodes: a cathode (sitall with nickel coating) and an anode (gold electrode). Electrophoretic deposition of composite materials was carried out in a potentiostatic mode at an electric field strength of 50 and 100 V/cm. The duration of the process was 60 seconds. To determine the mass of the deposit, the substrate was weighed before and after the deposit. After electrophoretic precipitation using laser engraving on a CNC machine, a layer of the structure of a planar supercapacitor was formed, which is an interdigital comb, nested on top of each other. With the help of laser engraving, not only the electrode composite material was locally removed, but also the nickel layer, which ultimately made it possible to electrically isolate the electrodes from each other (Fig. 1).

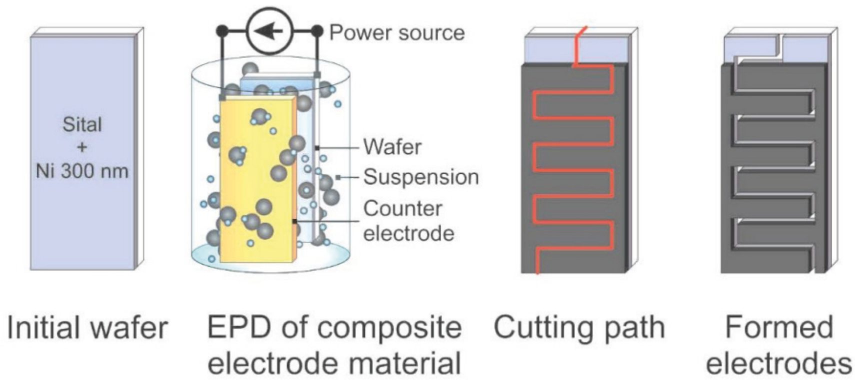

Fig. 1. Schematic representation of the route for creating a planar supercapacitor with composite electrodes based on Super C45-RuO_2

Table 1

Suspension composition

Super C45, (g)	RuO_2*xH_2O, (g)	Cellulose, (g)	Iodine, (g)	Acetone, (l)	Isopropyl alcohol, (l)
0.01	0.01	0.01	0.02	0.025	0.025

The morphology and composition of the surface of the resulting coatings were studied by scanning electron microscopy. To study the electrophysical characteristics, supercapacitors were placed in a beaker with a 1 M KOH solution, and their capacitance characteristics were measured using an Elins-45X potentiostat with the supplied ES8 software for PC.

Results and Discussion

Electrophoretic deposition is a technique that can not only deposit multi-component materials and locally deposit on a conductive pattern, but also control the composition, thickness, and porosity of the layer. Samples after composite deposition by this method were examined using a scanning electron microscope (SEM).

SEM images of samples based on Super C45 and RuO_2 at 50 V/cm and 100 V/cm deposition show differences in the morphology of the composite layers (Fig. 2). The sample deposited at 100 V/cm has a more distinct uniform, porous and rough structure compared to the sample deposited at 50 V/cm. This feature can make a positive impact on the capacitive characteristics of a supercapacitor, since the effective electrode-electrolyte contact area will be larger, and, hence, the contribution to the total capacity of the electric double layer.

For two samples formed at field strengths of 50 and 100 V/cm, cyclic sweeps were taken at different scanning rates from 10 to 500 mV/s. Based on the data obtained, the values of the specific capacity of the samples were calculated, after which the dependences of the capacity on the scanning speed for both samples were plotted, which are shown in Fig. 3.

There is a tendency for capacitance to decrease as sweep speed increases. It can be seen from the dependence graphs that the specific capacitance of the sample deposited at 50 V/cm is almost 2,5 times less than that of the sample deposited at 100 V/cm. At an electric field strength of

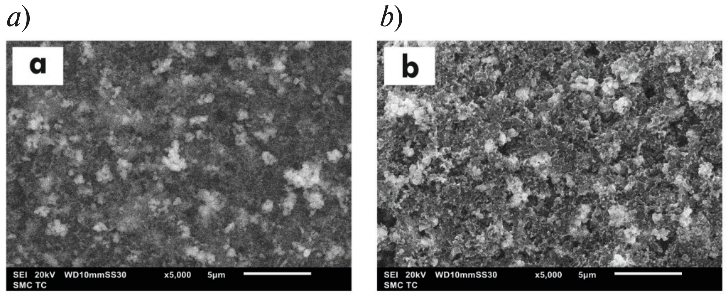

Fig. 2. SEM images of samples based on Super C45-RuO_2 at 50V (*a*) and 100V (*b*)

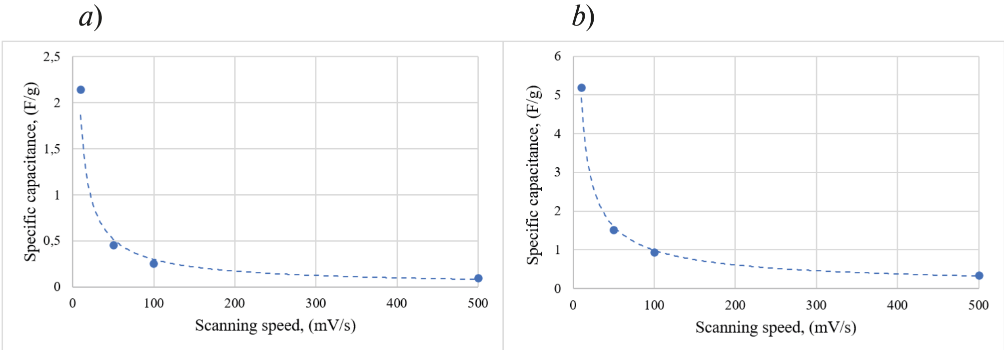

Fig. 3. Dependence of the scanning speed on the specific capacitance of the samples upon deposition of 50 V/cm (*a*) and 100 V/cm (*b*), respectively

100 V/cm, compared to 50 V/cm, the composite clings better and is more uniformly distributed on the substrate surface, which has a good effect on the contribution of redox reactions.

With an increase in the sweep rate on both samples, one can see a decrease in the capacitive characteristics of the planar supercapacitor. This may be due to the low rate of redox reactions compared to the rate of potential change in the cell. The higher it is, the smaller the contribution of Faraday processes and the greater the contribution due to the formation of a double electric layer. As the sweep rate increases, the resistance to internal diffusion of the active material may increase.

Conclusion

In this work, we studied planar supercapacitors with composite electrodes based on Super C45 and ruthenium oxide. The electrode materials were formed using electrophoretic deposition, and the planar power supply structure was formed using laser engraving. The technology for manufacturing structures of planar supercapacitors was worked out, and the modes of laser engraving were optimized. The dependence of the capacitive characteristics of planar supercapacitors on the measurement modes is also studied. A maximum capacitance of 5.2 F/g was found with a minimum sweep rate of 10 mV/s at 100 V/cm deposition and 2.15 F/g at 50 V/cm deposition.

Super C45 and RuO_2 are materials whose measured parameters have good prospects, and the proposed planar supercapacitor assembly option can allow it to be widely used on various electronic devices, and EPD will bring the deposition process to a new level of application when creating functional layers with various required characteristics.

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