DEVELOPMENT AND APPLICATION OF METAL CONTACTS ON POLYCRYSTALLINE DIAMOND FILMS USING COMBINATION OF HF AND ARC PLASMA SOURCES

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In this paper, the technology of application of ohmic contacts using arc discharge assisted by HF field was developed for semiconductor radiation detectors production. Polycrystalline diamond material for production of detectors was synthesized by chemical vapor deposition method (CVD) in NSC KIPT. Bilayer contacts were deposited on polycrystalline CVD (pCVD) diamond films, where the first layer was chromium, and the second layer – copper or stainless steel respectively. Electro-physical characteristics of pCVD diamond detectors with different contact materials were studied.

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INTRODUCTION

In recent years, the problem of the development of highly portable dosimeters and spectrometric instruments for radiation monitoring is extremely important. Semiconductor materials are being increasingly used as sensitive elements in such devices instead of scintillation and gas detectors [1-3].

Detecting and electrical characteristics of such structures depend on the properties of the semiconductor material, and the properties of the metal-semiconductor layer as well as of the manufacturing method.

The semiconductor detector consists of two metal contacts applied on its opposite sides forming metal-semiconductor-metal structure. Electro-physical and detecting characteristics of such structure depend both on properties of the semiconductor material, metal-semiconductor layer and the method of contact deposition. Ohmic contacts are intended for connection of the semiconductor to readout electronics, therefore they have to possess continuous and extremely low resistance.

Thus, research of possibility of improvement of the electro-physical and detecting characteristics of metal-semiconductor-metal structures with ohmic contacts is an actual task for effective registration of irradiations. Metal contacts also carry out a sheeting role and they have to be almost pore-free. In the present activity, the coatings on the basis of Cr, Cu and stainless steel were applied to metal contacts.

In this paper, the technology of application of ohmic contacts using arc-discharge assisted by HF field was developed for semiconductor detectors production.

1. EXPERIMENTAL SETUP

The application of coatings was carried out on Bulat-6 type device, additionally equipped with a high-frequency generator [4]. Fig. 1 schematically shows the device for HF-cleaning and ion-plasma assisted deposition.

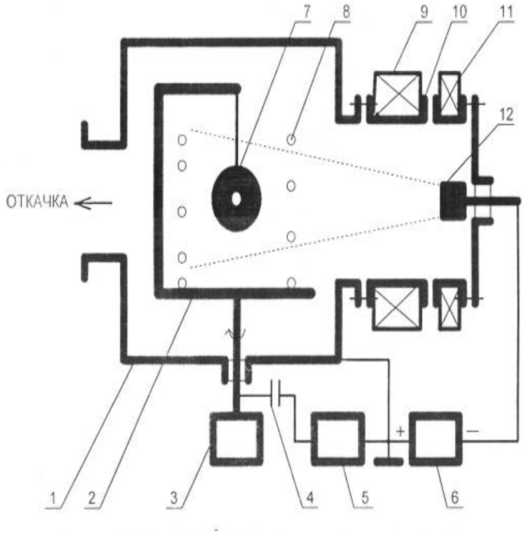

Fig. 1. Experimental device: 1 – vacuum chamber; 2 – rotator; 3 – redactor; 4 – capacitor; 5 – HF-generator; 6 – arc power source; 7 – substrate-container; 8 – HF antenna; 9 – focusing coil; 10 – anode; 11 – stabilizing coil

For HF cleaning (Fig. 2) and subsequent deposition, the samples were placed in a fluoroplastic holder, jointly with the masks of PTFE or aluminum foils in titanium polyacetal special container.

The sample container and the electrode with HF coils are mounted on a rotating device in the center of the vacuum chamber against the arc evaporator. Rotating table was connected to the HF generator via a capacitance. The advantages of plasma method of ion cleaning is in its uniformity allowed processing of details of a difficult form, and simplicity of technical realization

At the same time, during application of dielectrics with assisted HF potential, it is possible to eliminate the accumulation of over-discharge-surface and hence inhibition of ions that occurs at long constant-displacement potentials. An important fact is a decrease of droplet-fraction formations during application.

Fig .2. Finishing ion cleaning with HF-generator in Ar at P_{Ar}= (1…5)·10^{-1} Pa, Ucm HF = (-0.7…1) kV

During HF-plasma generation with closed HF-output, the resulting signal consists of three components: sinusoidal voltage, positive and negative shifts. The negative shift rate is almost equal to HF-amplitude.

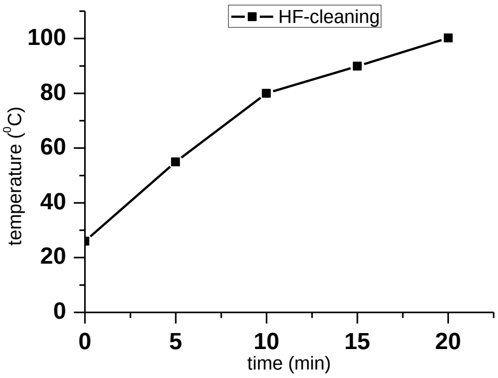

Fig. 3. Samples temperature during coatings application

The cleaning process starts with the start of the rotary apparatus, neutral Ar gas inlet and supplying HF voltage to the target (sample container, HF-coil). Aproximate cleaning mode: the shifting voltage U_s = -(700….900) V; pressure. The cleaning took 3…5 minutes, and temperature was not higher than 60°C (Fig. 3).

The application of coatings starts immediately after cleaning. A characteristic feature is pulsed operation of the evaporator on a particular program. The plasma ion method lead to heating the substrate (container with the sample) up to a temperature above permissible, therefore, there was designed a pulse mode of operation of the evaporator with switched HF voltage (assisted sputtering). In such a mode the temperature do not exceed 120°C (Fig. 4). The coatings thickness was 0.2….0.3 µm.

Parameters for coatings applying: arc current – 100 A; pulsed evaporator mode - 2 min, pause duration – 3 min, the number of cycles - 10; the shift voltage – 100 V; focusing coil current - 1.4 A; frequency of HF generator – 5 MHz. The total time of the coating is determined on the basis of the required thickness of the contact area (200…450 nm).

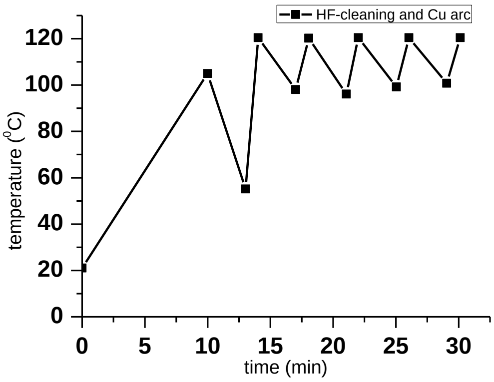

Fig. 4. The temperature of the samples during applying coatings

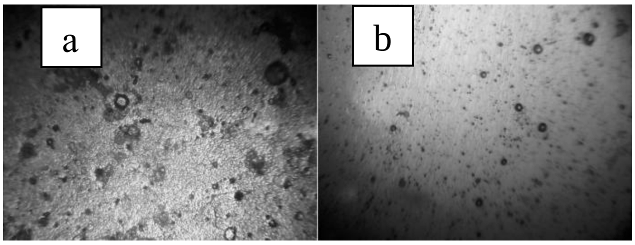

Fig. 5. Images of droplet fractions with (a) – arc plasma source; (b) – arc plasma source and assisted HF field

To determine the thickness of the coatings we use several “screens” (glass or glass-ceramics), the thickness of the coatings were determined with the help of "MII-2" device and profilometer “HOMMEL TESTER T500”.

It should be noted that the application of the HF coil for cleaning, increased sputtering rate of the target due to additional ionization.

Combination of plasma arc discharge with HF discharge significantly increases the adhesion of the film, helps to seal texture coating and significantly reduces droplets formation (Fig. 5).

2. RESULTS AND DISCUSSION

The study of detector’s electro-physical properties was carried out by measuring the current-voltage characteristics and registering the pulse-height distributions of the detector signal under α irradiation from uncollimated ^{239}Pu source on the open air. For measuring the current-voltage characteristics we employed Keithley 6487 picoammeter as a displacement voltage source and a measuring device. The spectrometric measuring system consisted of a preamplifier, a shaping amplifier Canberra 2026, high-voltage source Canberra 3106D, multichannel analyzer Canberra Multiport II and computer with Genie2000 software. Conventional incoming control for pCVD diamond samples consists of magnetron sputtering of Au contact with the following study of electro-physical properties. The pulse-height distributions of the detector signal under α irradiation from ^{239}Pu source for detectors with different contact materials (Cr, Au) are shown in Fig. 6.

These distributions could be considered to be equal; the existing differences are within the reproducibility of the experiment. Based on these results, in further experiments Cr was used as a main contact material for developing CVD diamond detectors, because of its significantly greater adhesion to the rough surface of unpolished pCVD diamond.

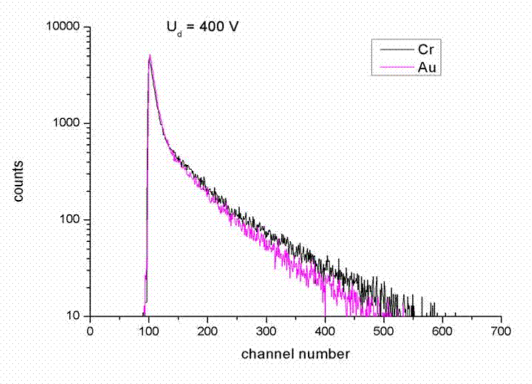

Fig. 6. The pulse-height distributions of the detector signal under α irradiation from ^{239}Pu source for different contact materials (Au, Cr)

The main purpose of depositing bilayer contacts is solving the problem of connecting detector to the readout electronics in the operating conditions, when heating above T=120°C is possible, because at this temperature the degradation of conductive adhesive contact occurs.

One of solutions of this problem is the connection to readout electronics by soldering. Bilayer contacts were deposited on pCVD diamond films, where the first layer was chromium, and the second layer – copper or stainless steel respectively.

The current-voltage characteristics for detectors with different bilayer contacts in the voltage range -2…+2 V are shown in Fig. 7.

Linear character of current-voltage curve in low voltages area is the evidence of obtainment the ohmic contact with selected method. Stainless steel is more resistant to environmental influences material in comparison with copper, so copper as the material for the second layer of metal contact for further manufacturing of pCVD diamond detectors wasn’t used. The typical pulse-height distributions of the detector signal under α irradiation from ^{239}Pu source for detectors with bilayer metal contacts (Cr-stainless steel) are shown in Fig. 8.

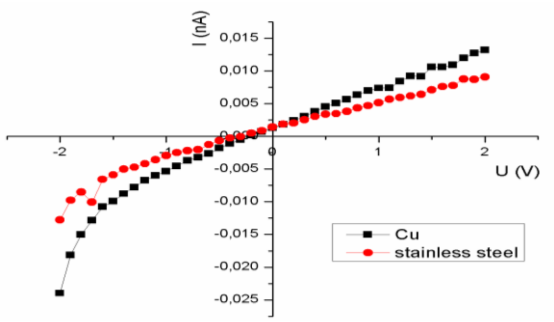

Fig. 7. The current-voltage characteristics for bilayer contacts (Cr-Cu, Cr-stainless steel)

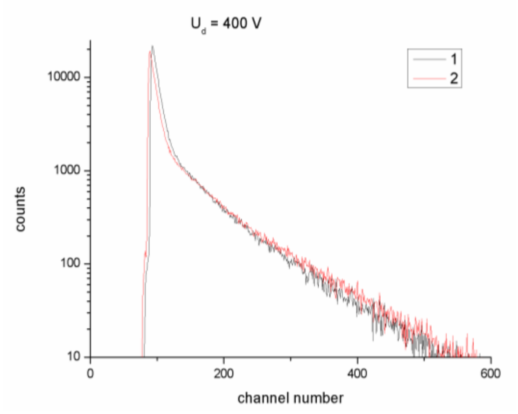

Fig. 8. The pulse-height distributions of the detector signal under α irradiation from ^{239}Pu source (Cr-stainless steel metal cotacts)

CONCLUSIONS

The technology for application of metal contacts on pCVD diamond samples was developed with combination of high frequency and arc plasma sources. Detectors of ionizing radiation have been constructed. For electrical contacts - Cr, Cu and stainless steel were proposed. Coating in vacuum-arc setting with high-frequency field to assisted allowed to apply coatings on dielectric samples at low temperatures - up to 150°C. The method allows adjusting the thickness of different metals deposited to 1.5 microns. In addition, it gives the opportunity to increase the adhesion and to achieve a high density and pore-free coatings.

Electro-physical characteristics of pCVD diamond detectors were studied by measuring the current - voltage characteristics and registering the pulse-height distributions of the detector signal under α irradiation from uncollimated ^{239}Pu source on the open air. At present time pCVD diamond detectors with bilayer metal contacts are tested in “Accelerator” Science and Research Establishment of NSC KIPT.

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РАЗРАБОТКА И НАНЕСЕНИЕ МЕТАЛЛИЧЕСКИХ КОНТАКТОВ НА ПОЛИКРИСТАЛЛИЧЕСКИЕ АЛМАЗНЫЕ ПЛЕНКИ С ИСПОЛЬЗОВАНИЕМ КОМБИНАЦИИ ВЧ- И ДУГОВОГО ПЛАЗМЕННЫХ ИСТОЧНИКОВ

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Представлена технология нанесения омических контактов с помощью дугового разряда с ассистированным ВЧ-полем для полупроводниковых датчиков ионизирующего излучения. Поликристаллический алмазный материал для производства детекторов был синтезирован методом химического осаждения из газовой фазы (CVD) в ННЦ ХФТИ. Двухслойные контакты наносились на pCVD-алмазные пленки, первый слой состоял из хрома, а второй – из меди или нержавеющей стали соответственно. Исследованы электрофизические характеристики детекторов на основе поликристаллического алмаза с разным материалом контактов.

РОЗРОБКА Й НАНЕСЕННЯ МЕТАЛЕВИХ КОНТАКТІВ НА ПОЛІКРИСТАЛІЧНІ АЛМАЗНІ ПЛІВКИ З ВИКОРИСТАННЯМ КОМБИНАЦІЇ ВЧ- І ДУГОВОГО ПЛАЗМОВИХ ДЖЕРЕЛ

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Представлена технологія нанесення омічних контактів за допомогою дугового розряду з асистированим ВЧ-полем для напівпровідникових датчиків іонізуючого випромінювання. Полікристалічний алмазний матеріал для виробництва детекторів був синтезований методом хімічного осадження з парової фази (CVD) в ННЦ ХФТІ. Двошарові контакти наносилися на pCVD-алмазні плівки, перший шар був з хрому, а другий – з міді або нержавіючої сталі відповідно. Досліджено електрофізичні характеристики детекторів на основі полікристалічного алмазу з різним матеріалом контакту.