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PROSPECTS OF BIOMORPHIC CERAMICS BASED ON SILICON CARBIDE AS A NEW MATERIAL FOR IMPLANTATION FOR MAXILLO-FACIAL SURGERY

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Research and introduction into clinical practice of a new class of implant materials created in accordance with the principles of biomimetics is a very promising area of medical materials science at the moment. These materials are synthesized from biological tissues or have properties similar to living structures or biologically active products of their life [4, 9]. Within this area of biometric branch of medicine natural structures which are pseudomorphic biological objects present a great interest. As an example, plant raw material, including wood and its derivatives, has a complex structure and is characterized by great mechanical resistance, low density, high toughness, elasticity and endurance against damage. These advantages are caused by genetically-formed structure that developed and perfected in the process of evolution [3, 8].

In this aspect, functional similarity of wood and bone is noteworthy, in particular their ability to remodeling of the internal structure in response to external, often mechanical irritation, the presence of cambial cell layer for peripheral volume increase and continuous self-renewal. That is the wood as a matrix for the manufacture of carbon materials with natural architectonics increasingly attract the attention of researchers from different countries [2, 5, 7]. Therefore, on the basis of natural raw materials more and more types of ceramic materials have been produced recently.

Production of ceramics with biomorphic properties in most cases involves two main stages: creation of carbon matrix from biological preform and its direct conversion into ceramics. The presence of carbon matrix of a biological object allows to obtain material which is pseudomorphic to this object and it will have similar structure to the biological sample at the micro, meso and macro levels. Such natural hierarchical porous structures have a high level of complexity that are not available in other modern technologies of production [7].

Potentially promising material of this class has been developed at V.E. Lashkaryov institute of semiconductor physics NAS of Ukraine. It has been made by silica impregnation of "channel" carbon matrices that have been obtained due to pyrolysis (carbonization) of different species of wood [1, 6].

At the same time one of the pressing issues of modern maxilla-facial surgery is the search and development of new implant materials to expand the range of treatment methods while eliminating defects, deformities of tissues or impart them a new shape and function. Conducting a series of maxilla-facial operations requires the use of synthetic materials as fixators of bone fragments, barriers between different types of tissue, supports to hold the shape or the implementation of a specific function.

Taking into account the prospects of ceramics based on silicon carbide as a material for implantation for solving various problems of reconstructive surgery of maxilla-facial area, we set the goal to research experimentally the reaction of bone tissue and peculiarities of reparative osteogenesis in the implantation area of samples of ceramics based on silicon carbide by scanning electron microscopy (SEM).

Materials and methods. To achieve this goal we performed an experiment on 20 white laboratory male rats weighing 250-280 g. Foraminous bone defects of the mandible were applied with bur with a diameter of 1,5 mm to a depth of 3 mm under intramuscular ketamine narcosis according to the principles of medical ethics. After hemostasis silicon carbide samples of the same size with a diameter of 1,5 mm and a length of 2 mm were placed into the defects. The tissue layers were cut down. Five intact rats served as a control group. The animals were kept under normal conditions of vivarium and they were taken out of the experiment in terms of 7, 30, 90 days after implantation by lethal dose of the drug for narcosis.

SEM research of the contact zone of samples of biomorphic ceramics based on silicon carbide with bone tissue after removing them from the body of experimental animals were carried out on the device JEOL-100 (Japan) Institute of Physics of NAS of Ukraine, Kyiv. After intake of the specimens defatting and washing of bone fragments in 96% alcohol were performed. Then they were dried out in a vacuum. In order to prevent the accumulation of surface charge on the surface of the sample, which could potentially affect the secondary electron emission, it was covered with a thin film of gold with thickness of 100 A° by cathode sputtering. The thickness of the film deposition was tested by piezoelectric crystal sensors directly inside the vacuum evaporator. Scanning electron microscopy was carried out in the various fields of view, with an increase from 1:40 to 1:10,000, researching the entire surface of the sample of biomorphic ceramics and adjacent areas of the surface layers of the bone in the area of contact with the bio SiC.

Results. The study of biomorphic silicon carbide surface by SEM revealed the presence of cellular structure of given material, it was found that the diameter of the pores ranged from 10 to 100 microns, and a microscopic picture of the bio SiC surface was very similar to the SEM image of the sample surface of bone tissue, confirming biomorphic researched ceramics based on silicon carbide (Fig. 1).

In conducting scanning electron microscopy 5 samples of biomorphic silicon carbide removed from the body of experimental animals a week after implantation revealed settlement of pores of given material by living cells (Fig. 2). In all cases there was predominant colonization of the pores of given material by the cells in the form of clusters that resemble the formation of colonies. Their predominant location is observed in the region of pores in the structure of biomorphic ceramics.

This fact can be interpreted as the potential possibility of the material to promote the process of reparative osteogenesis due to the presence of conditions for adhesion of cells. The main reason for this phenomenon we see in the peculiarities of architectonics of the researched material revealing in some of its structural similarity to bone tissue.

In the analysis of SEM images of silicon carbide surface in bone tissue obtained one month after implantation of the implants in the body of experimental tissues revealed that in all observations material surface is completely covered with a continuous layer of living cells without a clear organization. With greater magnification power it was found

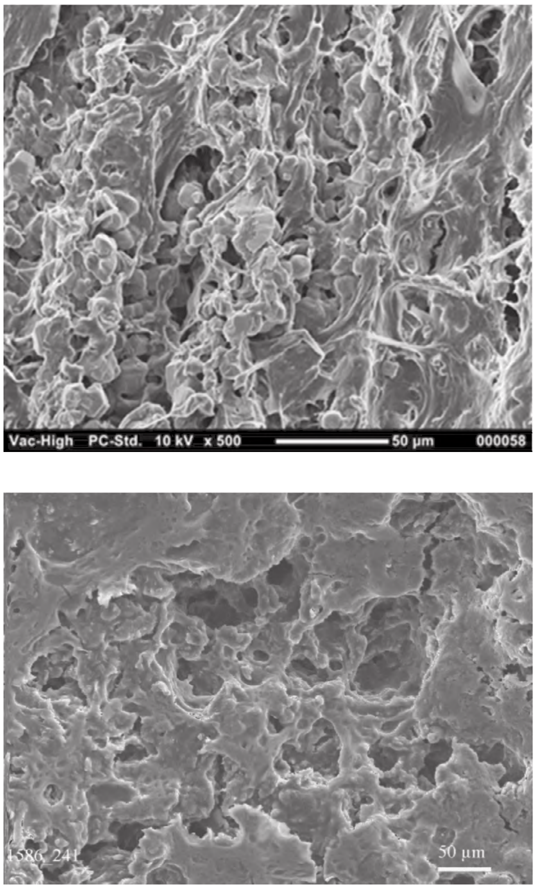

Fig. 1. SEM images of the sample surface morphology of biomorphic silicon carbide and bone tissue

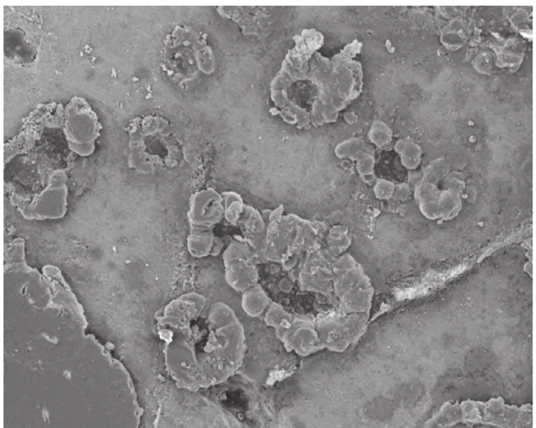

Fig. 2. SEM images of surface of silicon carbide samples within 7 days after implantation

that this coating consists of many layers of cells intimately soldered together by intercellular matrix (Fig. 3).

The presence of direct contact of living cells with the structure of researched material, their proliferation with deposition of intercellular matrix on its surface indicates favorable conditions for integration of the material in the structure of bone tissue. In presented SEM images the transition from the colonial character of proliferation of living cells in the initial phase of regeneration to formation of a continuous coating layer on the surface of the material is marked indicating the conditions for cell regeneration.

In the analysis of SEM images of contact area of biomorphic silicon carbide with bone tissue at low magnification a crateriform surface reconstruction of the adjacent bone tissue toward the surface of the implanted material is clearly visible. This fact can be explained by the fact that during the experiment the bone defect was formed with bur and introduced material was not adapted to its shape. However, in the SEM images in 90 days after surgery there was elimination of the consequences of the destruction of bone tissue, ending of its reconstruction and adaptation to the surface of implanted fragment of biomorphic silicon carbide (Fig. 4). This indicates the possibility of normal flow of the processes of reparative regeneration of bone tissue in the presence of biomorphic silicon carbide and the possibility of bone tissue to adapt to the peculiarities of relief of the implanted material surface. This position confirms the high biocompatibility of the researched biomorphic ceramics and the absence of negative impact on the course of reparative regeneration of bone tissue.

In the microsection "material-bone tissue" in the plane perpendicular to the surface of the mandible of experimental animals a tight attachement of bone tissue to the material material is observed. Thus in many places narrow fissure of the contact is interrupted or is unclear due to bone ingrowth into the pores of biomorphic ceramics. Especially narrow fissure or its visual absence is observed in the area of the contact of the material with cortical bone. In many places there is invagination of bone tissue with its ingrowth into the pores of researched material (Fig. 5). This picture gives reason to claim about the possibility of reconstruction of bone tissue bordering with silicon carbide and its adaptation to the surface of the material with the ingrowth of bone trabecula into the pores of the material.

Thus, the above mentioned results of the research confirm the prospects of biomorphic ceramics based on silicon carbide as a material for the manufacture of implants for various purposes for use in maxilla-facial surgery.

Obtained results deny the possibility of negative impact of implants of silicon carbide on the course of reparative regeneration of bone tissue. Judging from the results the existing microarchitectonics of given ecoceramiics that resembles the structure of bone tissue, promotes the flow of reparative osteogenesis processes by providing conditions for colonization of the surface of the material by living cells.

The possibility of contact coexistence of bone tissue and implants with biomorphic silicon carbide without signs of its \ rejection or its delimitation is the main background for conducting clinical researches of use of the implants from this material with the purpose of elimination of defects and deformities of the maxilla-facial area. As the basis for this we consider the results of SEM of the contact area of biomorphic silicon carbide with bone tissue including revealed facts of adaptation and structure reconstruction of bone tissue in the

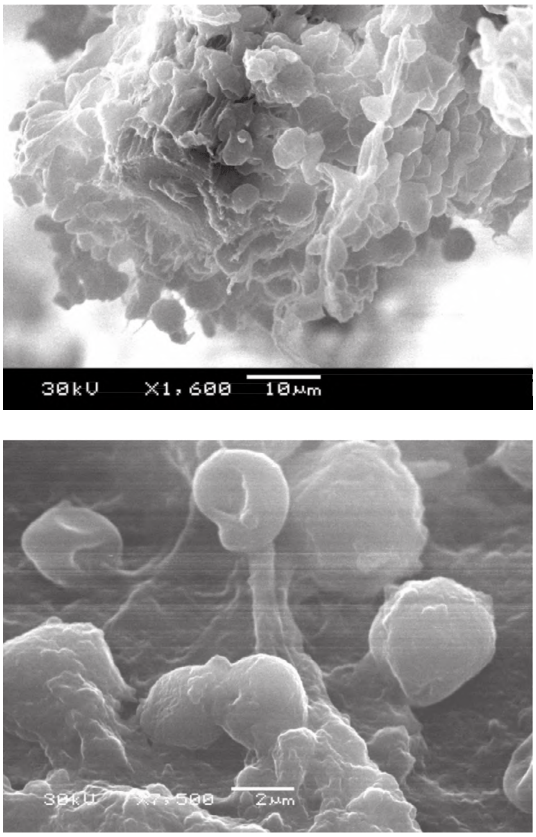

Fig. 3. SEM images of the surface of the implant from biomorphic silicon carbide after a month from the start of the experiment.

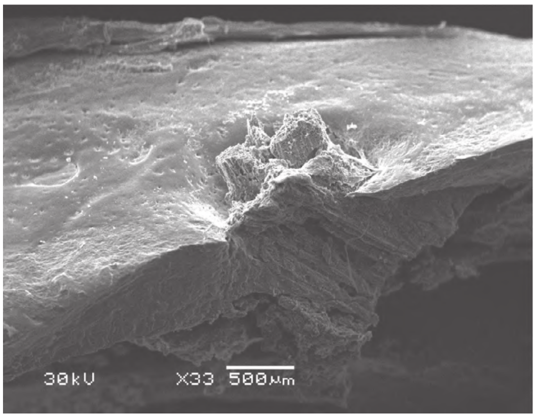

Fig. 4. SEM of the surface experimental bio-SiC sample in the area of its contact with bone tissue.

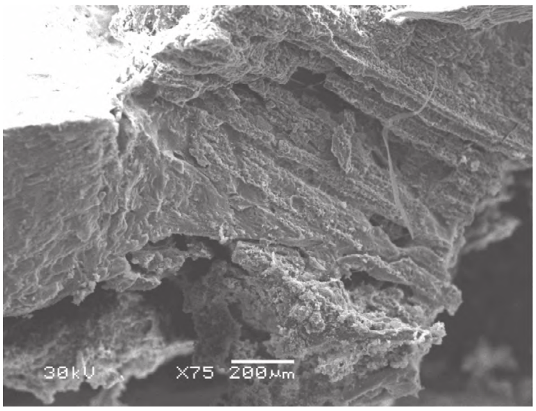

Fig.5. SEM of the surface of experimental bio-SiC sample in the area of its contact with bone tissue.

presence of silicon carbide and its ingrowth into the pores of the material and a tight attachement to its surface. Taking into account mechanical properties of silicon carbide and its potential possibility of implants manufacture of any shape and size of the readily available sources of raw materials this branch of scientific research in dentistry seems to us promising.

Reviewer: professor V.P. Nespriadko

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ПЕРСПЕКТИВИ БІОМОРФНОЇ КЕРАМІКИ НА ОСНОВІ КАРБІДУ КРЕМНІЮ ЯК НОВОГО МАТЕРІАЛУ ДЛЯ ІМПЛАНТАЦІЇ У ЩЕЛЕПНО-ЛИЦЕВІЙ ХІРУРГІЇ

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Резюме. В даній статті представлені результати дослідження взаємодії біоморфної кераміки на основі карбіду кремнію з кістковою тканиною в експерименті методом скануючої електронної мікроскопії. Даний матеріал розроблено в Інституті фізики напівпровідників імені В.Є. Лашкарьова НАН України, шляхом просочування кремнієм "канальних" вуглецевих матриць, що отримують внаслідок піролізу (обвуглення) різних сортів деревини. Для досягнення поставленої мети в експерименті на 20 лабораторних щурах проведено імплантацію зразків досліджуваного матеріалу в кісткову тканину нижньої щелепи. Тварини виводились з експерименту в строки 7, 30 та 90 діб після початку експерименту з наступним дослідженням поверхні та зони контакту матеріалу з кістковою тканиною. На основі отриманих результатів, встановлено, що мікроархітектоніка досліджуваної кераміки сприяє протіканню процесів репаративного остеогенезу за рахунок забезпечення умов для колонізації поверхні матеріалу живими клітинами. Доведена можливість контактного співіснування кісткової тканини та імплантатів з біоморфного карбіду кремнію без ознак його відторгнення чи відмежування При аналізі результатів СЕМ ділянки контакту біоморфного карбіду кремнію з кістковою тканиною виявлено адаптацію та структурну перебудову кісткової тканини в присутності карбіду кремнію та її проростання в пори матеріалу зі щільним приляганням до його поверхні.

Ключові слова: екокераміка, скануюча електронна мікроскопія, біоміметика.

ПЕРСПЕКТИВЫ БИОМОРФНОЙ КЕРАМИКИ НА ОСНОВЕ КАРБИДА КРЕМНИЯ КАК НОВОГО МАТЕРИАЛА ДЛЯ ИМПЛАНТАЦИИ В ЧЕЛЮСТНО-ЛИЦЕВОЙ ХИРУРГИИ

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Резюме. В данной статье представлены результаты исследования взаимодействия биоморфной керамики на основе карбида кремния с костной тканью в эксперименте методом сканирующей электронной микроскопии. Данный материал разработан в Институте физики полупроводников имени В.Е. Лашкарева НАН Украины, путем пропитки кремнием "канальных" углеродных матриц, которые получают в результате пиролиза (обугливания) различных сортов древесины. Для достижения поставленной цели в эксперименте на 20 лабораторных крысах проведено имплантацию образцов исследуемого материала в костную ткань нижней челюсти. Животные выводились из эксперимента в сроки 7, 30 и 90 суток после начала эксперимента с последующим исследованием поверхности и зоны контакта материала с костной тканью. На основе полученных результатов, установлено, что микроархитектоника исследуемой керамики способствует протеканию процессов репаративного остеогенеза за счет обеспечения условий для колонизации живых клеткок на поверхности материала. Доказана возможность контактного сосуществования костной ткани и имплантатов из биоморфного карбида кремния без признаков его отторжения или отграничения. При анализе результатов СЭМ участка контакта биоморфного карбида кремния с костной тканью выявлено адаптацию и структурную перестройку костной ткани в присутствии карбида кремния и ее прорастание в поры материала с плотным прилеганием к его поверхности.

Ключевые слова: экокерамика, сканирующая электронная микроскопия, биомиметика.