

Composite Ceramic Materials Based on Vitreous Carbon as Transplantation Materials in the Human Organism - Obtaining and Structure

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The scheme of obtaining and main results of the structural researches of the composite material is represented. This structure is with an exceptionally developed surface proved to be particularly favourable for producing of strongly connected with the basic matrix carbidized layers, respectively layers of vitreous carbon.

In the process of preparing of the composite material the ceramic elements undergo a high temperature pyrolysis together with a polymeric organic material of the type $(C_nH_m)_n$ and the released during the decomposition of the organic substance H_2 extracts the labile O^{2+} ions from the crystal lattice of the rutile. On the surface layers the liberated valency bonds are being saturated by the atomical carbon obtained during the pyrolysis of the organic substance while in depth remain the polycrystal material with oxygen vacancies without a decomposition of the compound. The developed in the system $TiO_2 - Nb_2O_5$ composite materials have very good layers of vitreous carbon with an exceptionally tight bond with the basic ceramic material.

Key words: composite materials, vitreous carbon, implants, vascular surgery.

Introduction

The construction ceramic materials based on titanium compounds and vitreous carbon represent a wide range of semiconductor materials with specific, exactly determined properties. They combine an exactly defined conductivity with a high wear-resistance which are the basic requirements for elements implanted directly in the blood stream since they are the precondition for a minimum accumulation of static charges on the blood corpuscles. This phenomenon is responsible for the improvement of the blood transport respectively for decreasing of the tendency toward formation of thrombi.

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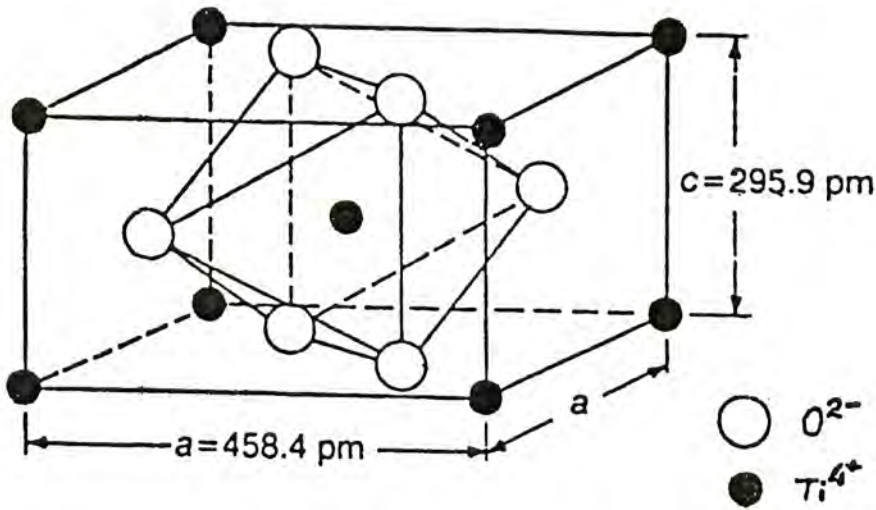


Fig. 1. Structure of the titanium dioxide-rutile modification



Fig. 2. X-ray analysis of the phases of rutile ceramics of the system $\text{TiO}_2 - \text{Nb}_2\text{O}_5$

The present work treats the preparing of a composite substance on the base of rutile ceramics of the system (titanium dioxide — niobium pentoxide) in which the quantity of the niobium pentoxide is of 0.3 to 10 mol % [1, 2].

The production of the composite material linked with carbon depends very much on the structure and the reactivity of rutile ceramics. Of the three modifications of



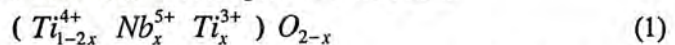
Fig. 3. Structure of rutile ceramics of the system $\text{TiO}_2 - \text{Nb}_2\text{O}_5$.

titanium dioxide rutile possesses the densest package of oxygen ions with that of titanium [3] and Ti^{4+} occupies half of the octahedral places (Fig. 1).

Ti^{4+} occupies the centre of a disrupted oxygen octahedral which determines its exclusively great capacity to include in its lattice donor elements.

Nb^{5+} is commensurate with Ti^{4+} ($R_{\text{Ti}^{4+}} = 0,69\text{\AA}$, $R_{\text{Nb}^{5+}} = 0,70\text{\AA}$) and in little quantities, without changing of the crystal lattice, is being incorporated into the places of the octahedral gaps which results in a slight change of the spacing. The structural investigation by X-ray (Fig. 2) in fact shows that by increasing the quantity of Nb^{5+} in the lattice the strongest peaks of the rutile undergo also a shift toward lesser angles of refraction, i.e. toward greater values of the spacing.

On the other hand, by low concentrations of Nb_2O_5 the result received is one reduced Ti^{3+} ion for every Nb^{5+} so as to preserve the mean charge 4^+ of the titanium places in the crystal lattice. In this case the compound is like this:



and the material obtained has got semiconductor properties on the basis of the oxygen deficit.

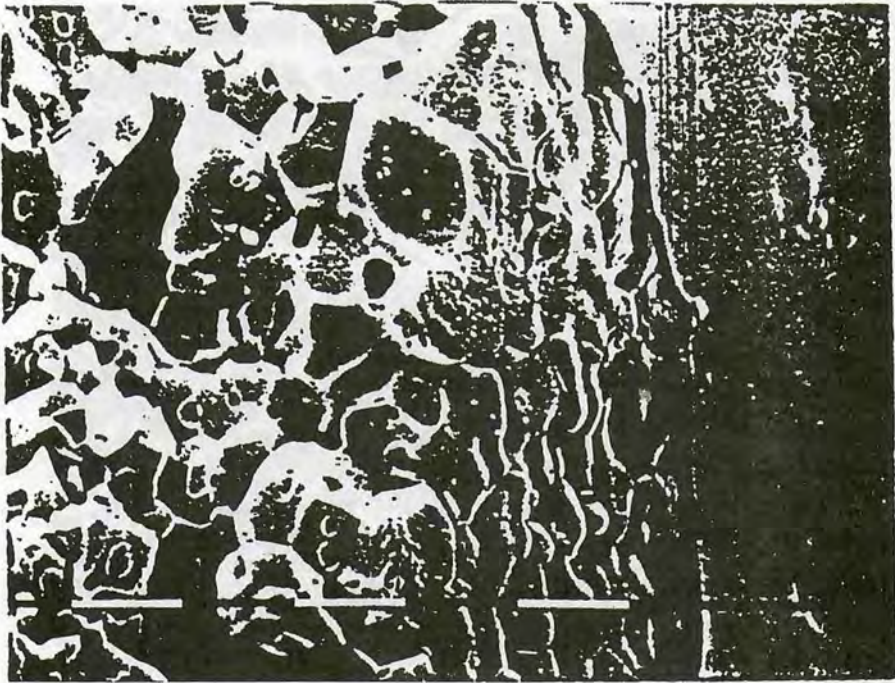


Fig. 4. Structure of composite material. Magnification $\times 1500$. Marker $10\ \mu\text{m}$

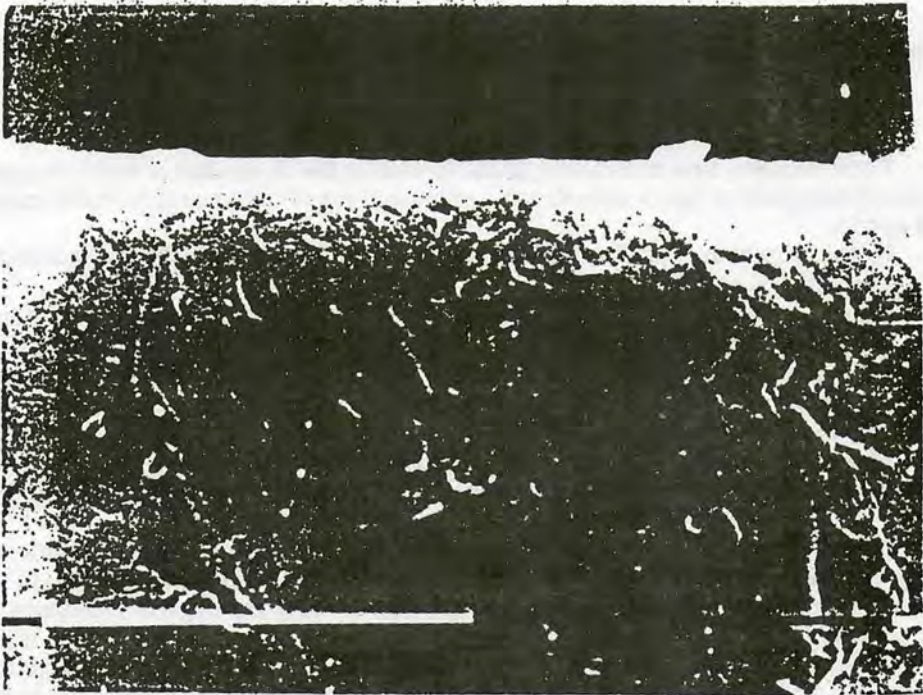


Fig. 5. Structure of the median carbided layer. Magnification $\times 5000$, marker $10\ \mu\text{m}$

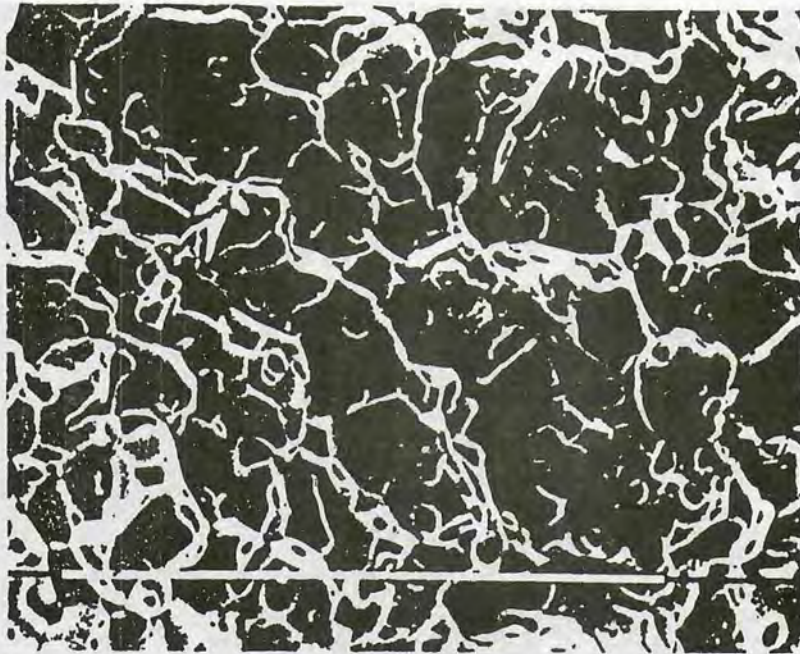
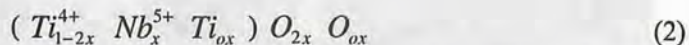


Fig. 6. Structure of the carbidized surface layer. Magnification $\times 845$, marker $100 \mu\text{m}$

In case of higher concentrations of the alloying five-valent ion the result is hard solutions with vacancies, in general of the kind:



These deficient structures owing to the stresses in the crystal lattice (some increase in the spacing) show also a considerably enhanced reactivity toward external reducing agents.

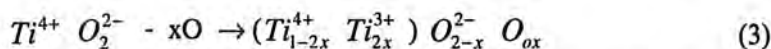
In this respect the data for the structure of ceramic materials offer an exceptionally good illustrative example (Fig. 3).

As you can see, it is composed of isometric grains with characteristic oval pores, the size of the grains being maximum $20 \mu\text{m}$ and that of the pores $3-4 \mu\text{m}$. The increased concentration of the pores is typical mostly of 4 mol.% Nb_2O_5 , these pores being on the average of the order 7-10 on a square of $10 \mu\text{m}$. In case of concentration of Nb_2O_5 over 5 mol % the quantity decreases abruptly.

This structure with an exceptionally developed surface proved to be particularly favourable for producing of strongly connected with the basic matrix carbidized layers, respectively layers of vitreous carbon.

In the process of preparing of the composite material the ceramic elements undergo a high temperature pyrolysis together with a polymeric organic material of the type $(C_n H_n)$ and the released during the decomposition of the organic substance H_2 extracts the labile O^{2+} ions from the crystal lattice of the rutile. On the surface layers the liberated valency bonds are being saturated by the atomical carbon obtained during the pyrolysis of the organic substance while in depth remain the polycrystal material with oxygen vacancies without a decomposition of the compound.

The produced semiconductor ceramics possesses an "n"-type conductivity of the kind:



An examination with an Auger electron microscope corroborates this distribution of the layers in the composite material. A segment of the lateral face of the ceramic specimen shows in fact a layerlike structure of the composite material (Fig.4).

We can observe a layer of vitreous carbon, later on the compact layer of non-stoichiometric oxytitanium carbides (4) and the basic matrix of rutile ceramics with oxygen deficit.



With a higher magnification (Fig.5) in the medial layer we can see crystal formations, probably originating from carbides, tightly connected with the basic matrix.

Of greatest importance for the good bond between the different layers of the composite material is the structure of the original ceramic material which secures, thanks to its numerous orifices, possibilities for the formation of a uniform skeletal net of carbides, tightly connected with the basic matrix (Fig.6).

Conclusion

The developed in the system $TiO_2 - Nb_2O_5$ composite materials have very good layers of vitreous carbon with an exceptionally tight bond with the basic ceramic material. They are particularly suitable for the production of transplantation elements for vascular surgery and other implants for the human organism.

References

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