

BIOGLASS COATED AL₂O₃ CERAMICS

BACKGROUND OF THE INVENTION

The strength, anti-friction and high wear resistance properties of Al₂O₃ ceramics make them ideal for use in the construction of artificial prostheses and orthopedic devices. The biological inactivity of Al₂O₃ ceramic surfaces, however, makes it extremely difficult, if not impossible, to achieve cement-free implantation of the prosthesis since bone tissue will not bond or grow thereon.

Various techniques have recently been suggested for activating the ceramic surfaces in order to enhance the bone-tissue bonding capabilities of the Al₂O₃ prosthesis. However, all of these techniques are either extremely expensive and time-consuming or result in ceramic structures of decreased mechanical strength, anti-friction properties and wear resistance.

It is an object of the present invention to provide a cement-free bone prosthesis implant comprising a bioactive Al₂O₃ ceramic and a method for the preparation thereof which is inexpensive and does not result in a decrease of the mechanical strength, anti-friction and wear resistance properties of the Al₂O₃ ceramic material.

SUMMARY OF THE INVENTION

The present invention comprises a method of coating a compacted Al₂O₃ ceramic surface with a biologically active glass having a thermal coefficient of expansion different from that of the ceramic comprising:

1. Contacting the glass with the ceramic surface at a temperature and for a time sufficient to bond the glass to the ceramic surface by ion diffusion,
2. Cooling the coated substrate to a temperature sufficient to produce interconnected micro-cracks in the glass coating as a result of the thermo-mechanical stresses induced by the differential in thermal coefficients of expansion of said ceramic and glass, and,
3. Overcoating the micro-cracked glass coating with at least one additional coating of the biologically active glass.

The invention also relates to the product of the above-described process.

The biologically active glass coated compacted Al₂O₃ ceramic of the present invention comprises a ceramic surface coated with at least two layers of biologically active glass having a thermal coefficient of expansion different from that of the Al₂O₃ ceramic wherein the first layer is bonded to the ceramic surface by ion diffusion and is characterized by having interconnected thermo-mechanical stress induced micro-cracks therein and wherein the subsequent layer or layers are coated thereover.

The invention also relates to a cement-free bone prosthesis implant comprising the above-described bioactive glass coated Al₂O₃ ceramic.

DETAILED DESCRIPTION OF THE INVENTION

It is well known that when applying a glaze of higher thermal expansion to a body of lower thermal expansion, thermal stresses will arise upon cooling. Since these thermal stresses result in an overall weakening of the coated structure, it is conventional according to prior art practices to attempt to match the thermal coefficients of expansion of the respective materials as

closely as possible in order to minimize these stresses. This necessarily results in a drastic reduction in the number and variety of coatings which can be applied to a particular substrate.

According to the present invention, extreme mismatches between the relative thermal coefficients of expansion are relied upon to induce thermo-mechanical stresses in the biologically active glass glaze coating. Upon cooling, the glaze cracks in order to relieve the stresses due to thermal mismatch, thereby resulting in isolated islands of biologically active glass coating separated by small interconnected flaws or micro-cracks. These cracks range from about 0.05 to 0.8 microns wide. The small islands of biologically active glass are bonded to the compacted Al₂O₃ ceramic surface by a large diffusional bond which is developed by processing at elevated temperatures (1100°-1350° C). The diffusional bond is a chemical bond between the Al₂O₃ substrate and the biologically active glass coating thereby eliminating a welldefined Al₂O₃-biologically active glass interface and results in an enhancement of the overall strength characteristics of the ceramic.

Multiple coatings of biologically active glass can then be applied over the micro-cracked glaze with no danger of inducing thermo-mechanical stresses in the structure. This is due to the fact that the second and subsequent glass layers are bonded to the first biologically active glass layer and not to the Al₂O₃ substrate. Thus, the second glass layer has physical properties identical to the first glass layer with no mismatch in the respective coefficients of thermal expansion.

The resulting structure has the capacity to bond living tissues to an implant material comprised of the coated ceramic substrate due to the properties of the biologically active glass. In addition, the coating process does not deleteriously affect the mechanical strength of the Al₂O₃ ceramic since all thermo-mechanical stresses are relieved during the first coating operation and no further stresses are induced by the second and subsequent glass coating steps.

Since no regard need be given to the thermal coefficient of expansion match, a wider variety of biologically active glass materials can be coated upon the ceramic surface than by the techniques presently prevalent in the prior art.

Indeed, by carefully controlling the coating procedure, the strength of the compacted Al₂O₃ ceramic can actually be enhanced. By maintaining the size of the flaws or micro-cracks at below 1 micron, the strength and fatigue resistance of the Al₂O₃ ceramic is increased.

Any biologically active glass may be employed for the purposes of the present invention. It will be understood by those skilled in the art that any suitable biologically active glass, depending upon the ultimate use for which the coated ceramic is intended, may be utilized. Generally, the biologically active glass is one capable of bonding to living tissue and contains, by weight:

SiO₂ — 40- 62%

Na₂O — 10- 32%

CaO — 10- 32%

P₂O₅ — 3- 9%

CaF₂ — 0- 18%

B₂O₃ — 0- 7.5%

Na₂O + CaO must be above 30% to achieve bonding to live tissue.

Suitable specific glasses include those of the following compositions: