METHOD OF BONDING A BIOGLASS TO METAL

BACKGROUND OF THE INVENTION

It has been proposed to utilize metals for the construction of artificial prostheses and orthopedic and dental devices. The biological inactivity of metal surfaces, however, renders it impossible to achieve cement-free implantation of metal prostheses since bone tissue will not bond or grow thereon.

Various biologically active glasses have recently been introduced for the preparation of artificial prostheses. It is known that bone and other biological tissue will bond to or grow on these biologically active glasses. However, the strength characteristics of the glasses are such that it is impossible to construct sufficiently strong orthopedic or dental devices therefrom.

It has been suggested to overcoat metal substrates with biologically active glasses to provide sufficiently strong orthopedic or dental devices capable of bonding to bone tissue. However, there are numerous difficulties associated with bonding such glasses to metal surfaces. For example, the thermal coefficients of expansion of the metal and glasses are so dissimilar at both the melting and softening points of the glasses that cooling the coated metal substrate results in extreme thermomechanical stresses in the glass and metal layers which, when relieved, cause cracks, etc., in the glass coating.

Prior art methods of coating metals with glasses necessarily require the utilization of glasses and metals which have substantially identical thermal coefficients of expansion and which can withstand those temperatures at which the glass flows. The prior art methods are particularly disadvantageous where it is desired to coat a particular metal with a particular high melting glass in order to obtain a product with specific properties. The problems which normally arise in this connection are:

(1) Excessive scaling of the metal substrate at the elevated temperatures:

(2) Loss of compositional control of the glass through long firing times;

(3) Excessively high diffusion of metal ions into the glass bulk;

(4) The virtual impossibility of matching the thermal coefficients of expansion due to the fact that the choice of glass and metal substrate are fixed because of the desired application of the product.

It is possible to coat metal substrates with mismatched (thermal coefficients of expansion) glass by flame spraying; however, this method gives rise to other disadvantages, namely, high volatilization and loss of glass components, limited choice of glass compositions, extremely high working temperatures and adverse surface reactions on the metal substrate.

It has been proposed to utilize biologically active glasses and metals having similar thermal expansion coefficients; however, this approach drastically limits the number and variety of permissible combinations.

It has also been proposed to coat metal surfaces by applying powder mixtures of the glass thereto and utilizing long firing times and multiple coatings to produce transition layers between the metal and glass having gradient coefficients of expansion to thereby relieve the thermo-mechanical stresses. Obviously, however, this is an expensive and time consuming procedure which, by its very practicality, severely limits the practicality of the ultimate product. German Pat. DT 2,326,100 B2 describes a glass coated material useful as a prosthetic device. However, the German patent requires an intermediate layer of low reactivity glass between the metal substrate and the biologically active glass.

It is an object of the invention to provide an inexpensive method for bonding biologically active glass to metal for the formation of artificial prostheses and orthopedic and dental devices.

SUMMARY OF THE INVENTION

The invention relates to a method of bonding a bioglass layer to a metal substrate comprising:

(1) heating a metal substrate having a roughened, oxidized surface to about a maximum temperature (T_1) where said T_1 is selected such that the total volume expansion of said metal is substantially equal to that of said bioglass at the temperature (T_s) at which the temperature dependence of the volume of said bioglass becomes non-linear,

(2) providing a body of molten bioglass at temperature T_w where T_w is sufficiently high that the said bioglass is sufficiently fluid to allow immersion of said metal heated to temperature T_1,

(3) immersing said metal surface in said molten bioglass for the minimum time required to permit a layer of desired thickness of said bioglass to adhere to said surface upon termination of said immersion, the time of said immersion being of such duration that the temperature of said metal surface does not rise substantially above T_1,

(4) terminating said immersion,

(5) allowing said coating to cool rapidly from T_w to about T_3, whereby the thermomechanical stresses in said bioglass layer are rapidly relieved, and

(6) allowing said coated substrate to further cool to a temperature below about T_s whereby the thermomechanical stresses in said bioglass coating and said metal surface are relieved at a substantially equal rate due to the substantially linear thermal expansions thereof,

said bioglass coating being bonded to said metal surface by ion diffusion through said oxidized surface.

The invention also relates to the product produced by said process.

IN THE DRAWINGS

FIG. 1 represents a graph showing how two metals of differing composition can be coated with the same glass. See Examples 1 and 3. Immersion takes place at the working temperature T_w (temperature of molten bioglass). The glass cools rapidly to near the softening point T_s. The T_1's for the metals are chosen so that volume expansion for both glass and metal are substantially equal.

FIG. 2 represents a graph showing how one metal can be coated with bioglass of differing compositions. See Examples 1 and 2. The metal is heated to T_1 or T_1' so that volume expansion matches either glass **1** and **2**, at T_{s1} and T_{s2}, respectively. As in FIG. **1**, the T_1's are chosen by matching the volume expansion of the glass when it reaches T_s.

FIG. 3 represents a graph showing the degree of diffusion of the elements of the metal and glass across the interface by reason of the coating and diffusion bonding process following the procedure described in Example 1.