ACID ASSISTED COLD WELDING AND INTERMETALLIC FORMATION AND DENTAL APPLICATIONS THEREOF

This is a Divisional of Ser. No. 08/317,729 filed Oct. 4, 1994; which in turn is a Continuation-in-Part of U.S. patent application Ser. No. 08/133,316, filed Oct. 8, 1993 now abandoned; which in turn is a Continuation-in-Part of U.S. patent application Ser. No. 07/802,420, filed Dec. 4, 1991, which issued on Jun. 7, 1994 as U.S. Pat. No. 5,318,746.

FIELD OF INVENTION

The invention relates to a process of consolidating metallic and intermetallic composite materials and a process of forming bulk intermetallics at ambient temperatures. In preferred embodiments, the invention relates to processes for forming the metallic composite materials as in situ dental restorations, high temperature materials, copper-tungsten and similar materials for thermal management, aluminides such as nickel aluminides, nickel titanium alloys for shape memory effects applications and titanium nickel tin alloys.

BACKGROUND

Powder metallurgy is a processing technique whereby very small diameter powder particles are compressed into parts or shapes by a number of methods that include vacuum hot pressing, hot isostatic pressing (HIP), sinter hipping, hot forging, etc. These processes require the sequential or simultaneous application of high temperature and pressure. Typically, the temperatures used in powder metallurgy are at an appreciable fraction of the melting point (T_m) of the compressed elements or alloys, usually above 0.8 T_m. The pressures applied are often near or beyond the yield point of the metals involved. In the case of metal foils or sheets, consolidation is often done by hot roll bonding. One of the reasons for these severe conditions results from the need to break up the naturally occurring oxide on the surface of the material, thereby enabling the surfaces of the powder particles (foils or sheets) to weld together at a sufficient number of contact points so as to provide adequate adhesion between the individual particles, sheets or foils.

Powder metallurgy is useful as an alternative to comelting appropriate amounts of metal constituent components in forming intermetallic compounds. Intermetallic compounds have a great potential for a variety of applications as a result of their specific properties such as hardness, high elastic moduli and oxidation resistance. On the other hand, the inherent brittleness of intermetallic compounds severely curtails their use in conventional thermomechanical processing operations to form net shapes. As an alternative, powder technology is often used for processing intermetallic compounds. The starting materials for this approach are prealloyed compounds that have been comminuted by various methods into powder particles. The limitation of this approach is that it relies on compaction of powders which are inherently brittle and do not deform with ease. Compound formation, however, may also take place by solid state interdiffusion of mostly ductile constituent elements which can be compacted with relative ease. Mixtures of elemental metal powders, maintained in close mutual contact for a sufficient length of time at the appropriate temperature, interdiffuse and form intermetallic compounds. In some situations, intermetallic compound formation is required, but exposure to elevated temperature has to be limited or avoided. An example of such a situation may be the requirement for compound formation (for protheses or as dental restorative material) in a human body environment.

Intermetallic compound formation by interdiffusion of the constituent elements or extremely finely divided multi-phase solid formation by non-compound forming and non-interdiffusing elements is favored when the starting materials are in the form of a very small size particle powder. Such powders possess a large specific surface area, and hence, when mixed, form a relatively large interface area between the different constituents. The generation of an interface area between the different constituents depends on the efficiency of the mixing technique and also on the nature and properties of the mixed powder particles.

Several mixing techniques are commonly used in order to maximize the contact points (interface area) between particles of different kinds. If the effect of particle properties on the outcome of the mixing process is neglected, prolonged mixing will tend to maximize the number of contact points between different particles by striving towards a random distribution of the particles of different kind. Many particle properties such as particle size and shape, surface roughness, in addition to electrostatic phenomena, promote segregation effects and thus reduce and curtail the homogeneous mixing of different powders. Thus, multimodal particle size distribution favors space filling and increased density but also favors particle segregation. The most commonly used mixing technique relies on the tumbling-type blending of the powders. Ball milling is another technique that is used for mixing and also for reducing particle size. An extension of ball-milling is the mechanical alloying technique that yields alloyed powder products from elemental powder mixtures. Alloy or compound formation by ball milling is dependent on the kinetic energy input due to the rapidly rotating hard balls impinging on the powder particles. Thus ball-milling leads to high local temperature increases.

Intermetallic compound formation at the interface of two metals in intimate contact is a documented phenomenon. In some instances, the formation of intermetallic compounds is beneficial, in others, its effects may be detrimental. The formation of a new compound at temperatures below the melting point of the metals in contact relies on interdiffusion effects in the solid state. In most binary combinations, ambient temperature is well below the melting temperature of the constituent metals and, consequently, little or no compound formation takes place at the interface, Notable exceptions to this are diffusion couples in which one of the constituent metals, e.g. mercury or gallium, has a low melting point, below or close to room temperature. Another important group of binary combinations which shows room temperature compound formation, consists of a group I-B of the periodic table (Cu, Ag or Au) metal juxtaposed to a group III-A or IV-A (In, Sn or Pb) element. K. N. Tu et al., *Jap. J. Appl. Phys. Suppl.,* Pt.1, 633 (1974). It is believed that room temperature compound formation in these systems is related to fast diffusion behavior of the noble or near noble component (the I-B elements) in the matrices of the group III-A or IV-A metals. A. D. LeClaire, *J. Nucl. Mat.* 69 & 70, 70 (1978). Fast diffusion occurs by virtue of the interstitial or partly interstitial diffusivity of the fast diffusing components, W. K. Warburton et al., "Diffusion in Solids, Recent Developments", Nowick and Burton (eds.), Academic Press, New York, 1975, p.172. It is noteworthy that interfaces between two components, each of which respectively belongs to one ot the two classes previously defined, are of common occurrence in electronic devices and it is not surprising, therefore, that such systems have been subject to relatively close scrutiny over the past years K. N. Tu, *Ann. Rev. Mater. Sci.,* 15, 147 (1985). The quasi-totality of the room temperature intermetallic compound formation studies