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SHORT COMMUNICATION

A NEW APPROACH TO PREPARING BULK RAPIDLY SOLIDIFIED METAL/GLASS COMPOSITES

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Metal glass composite based on metal powder and SiO_2-B_2O_3 was prepared by combining sol-gel and rapid undercooling techniques.

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With the rapid development of modern science and technology, the requirement for specific materials properties becomes essential. Sometimes the demands are mutually contradictory so that no monolithic base alloys can meet them. Metal matrix composites, when compared to their monolithic base alloys, typically show improved performance, such as higher Young's modulus, higher working temperature, improved wear resistance, better fatigue resistance and reduced coefficient of thermal expansion. In the past decades, MMCs have engendered extensive interest from industrial and academic researchers, including US ARL and US Academia [1]. The main preparation methods include liquid-state method [2-5], liquid/solid-state method [6,7] and powder metallurgy [8-10]. Powder metallurgy is the preferred method, especially for materials with high volume fraction of reinforcement. However, it is often less competitive in terms of the performance versus costs and only suitable to fabricate products with simple shapes [10]. The liquid/solid-state method is used only in some special cases [11]. Compared with the above two method, liquid-state method can allow to fabricate products with complicated shapes, convenient operation and on cost. Unfortunately, the innate disadvantages, such as the segregation and aggregation of reinforcement [12,13], low volume fraction of reinforcement [14] and bad interfacial bonding ability, limit its use. In this article, by combining the investigations of the techniques of high undercooling [15-17] and sol-gel [18], a new approach to preparing metal/(SiO_2-B_2O_3) glass composites (MGCs) is advocated.

Usually, there are three keys in the research and development of composites, matrix material, reinforcement and the interfacial bonding ability.

It is well known that rapid solidification is an effective way to obtain homogenous materials with higher toughness and higher ductility. Both rapid quenching and high

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undercooling techniques belong to the category of rapid solidification. The former is applicable only to the production of thin ribbon, strip and powder, of which the practical use is generally limited to the electronics and powder industries. In order to get bulk matrix material, powder metallurgy is the only way. During powder metallurgy processing, materials lose some rapid-solidified characteristics. Recent investigations have shown that solidification behavior during high undercooling technique, essentially resembles that of rapid quenching, and high undercooling makes it possible to fabricate bulk three-dimensional materials. In addition, within a certain undercooling range, bulk unidirectional materials can be obtained. Compared with the alloy obtained by common solidification, the elongation and ultimate tensile strength and 0.2 % yield strength of unidirectional $Cu_{70}Ni_{30}$ materials improved by folders of 25, 3 and 1.3, respectively [16,17].

Reinforcement is another key. Al_2O_3 and SiC with particle or fiber shapes are the main reinforcements. Glass phase has never been highlighted as a kind of reinforcement. However, glass phase have many advantages, such as high stiffness, low thermal expansion coefficient, better structural stability in a wide temperature range, especially, it doesn't stimulate nucleation in undercooled alloy melts. So, high undercooling of alloy melts can be obtained, thus being possible to get a glass phase. The next problem is how to produce the net-shaped glass reinforcement.

Many new methods for producing glass and amorphous film materials have also been put forward. Sol-gel is one of the most promising methods [18]. Gel glass has many advantages, such as low density (3 mg/cm^3), high void ratio, low coefficient of thermal expansion, and it has been applied in many engineering fields [18]. In this new approach, we choose sol-gel technique to prepare nano-scale net-shaped SiO_2-B_2O_3 gel glass as reinforcement.

As reinforcement, the main problem of glass is the wettability. The mechanical properties are bad because of the weak bonding ability [19-22]. Current investigations classify the interfaces into three categories, reactive, non-reactive and diffusion-adhesive interface. The conventional wisdom is that non-reactive interface is associated with poor wettability and weak interfacial adhesion, whereas interfacial reactions are thought to ensure good wettability and high interface strength. One problem with interfacial reaction products, however, is that the resulting reaction layer is often brittle and tends to provide sources for crack initiation, especially when the thickness of the reaction layer exceeds about 1μm [19]. Research on diffusion-adhesive interface reveals that under the conditions of weak reaction, decreasing the thickness of reaction layer and making full use of the absorption and segregation of active metal atoms can lower the interfacial energy to improve the interfacial bonding ability. So we can take into account of the addition of trace alloy elements.

In short, the whole process consists of three steps. The first step is preparing SiO_2-B_2O_3 gel solution by sol-gel technique, the second is mixing metal power and gel by ball milling and then extruding a block, the third is preparing rapidly solidified directional composites by undercooling the obtained block in middle undercooling range.

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