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Improved adhesion of NiTi wire to silicone matrix for smart composite medical applications

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ABSTRACT

Recent uses of intelligent composites in biomedical appliances aggrandize the necessity of bonding-strength improvement in NiTi/silicone matrix interface. SEM micrographs and pull-out tests are employed to determine the strength of the NiTi/silicone bonds in a flexible composite piece. Greater adhesion strengths are obtained due to the presence of thin oxide layer, surface roughness and frictional forces between the embedded-wires and the contacting phase. Effect of curing treatment on phase transformation temperatures of the wires is determined by electrical resistivity (ER) measurements. Results show that the curing treatment shifts the transition points of the wires towards higher temperatures at the heating and lower temperatures at the cooling try-outs, respectively. These changes affect the shape memory behavior of the NiTi wires embedded within the biocompatible flexible composite segments.

1. Introduction

Recent acceleration of R&D activities on SMA (Shape Memory Alloy) embedded composites is due to the SMA sensing/actuating properties which inspire the technology developers to different innovative biomedical potential applications [1]. Combining the magnificent properties of SMAs with the well known biocompatibility of silicone can lead to invention of a nifty functional composite for artificial muscle manufacturing.

The performance of the SMA-silicone composites depends on the quality of the metal–matrix interface. The interface must have sufficient strength to transfer the applied stresses and strains from the SMA constituents to the surrounding matrix [2]. For improved toughness, the interfacial adhesion should be both strong and flexible enough to allow some energy dissipation through debonding processes [3].

Many treatments can influence the quality of the NiTi-polymer matrix interface. Paine et al. [4] showed that surface preparation can improve the adhesion of the NiTi wires to the graphite/epoxy. Jonalagadda et al. [5] suggested that sandblasting increased rebinding stress to increase the mechanical interlocking during the pull-out. This technique does not seem, however, to be suitable for NiTi wires with micro- and/or nano-sized features because it cannot operate when the reinforcement phase is on the same size-scale or smaller than grains of the sand. Smith et al. [2] used silane coupling agents to improve the adhesion between NiTi wires and the PMMA. Hamming et al. [6] improved the interfacial adhesion between NiTi-oxide and the PMMA by performing the surface-initiated polymerization by way of a biomimetic initiator. Lau et al. [7] showed that changing the surface roughness and the geometry of the embedded NiTi wires could improve the bonding strength between NiTi wires and the epoxy. Neuking et al. [8] showed that appropriate combinations of the sequential mechanical treatment (grinding and polishing) and physical (plasma) surface treatments could result in good adhesive strength.

The flexibility and ease to apply plus nobility of the silicone elastomers have led them being the most widely used polymers in biomedical applications [9]. Some of their uses include heart valves [10], urological catheters [11], breast prostheses [12,13] and maxillofacial prostheses [14]. Combining the biocompatibility/viscoelastic properties of the silicone matrix with the NiTi shape memory effect provides a composite material appropriate for candidacy of the biomedical/intelligence applications like artificial anal sphincter [15] and nerve cuff electrode system [16].

Composites of NiTi and polymer are usually formed in a hot press or autoclave by a few hours of curing such that the matrix material becomes fully polymerized [17]. This process can change the transformation temperatures of the NiTi wires. Variation in the shape memory properties of the composites generally occurs due to the transformational characteristic changes of the embedded SMA wires. Studying the effects of the curing treatment on the transformation temperatures of the NiTi wires seems therefore needed to design SMA/elastomer composite objects.

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