Evaluation / Assessment of Thermal Properties of NITI

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Abstract: ***Nickel titanium, also known as nitinol (part of shape memory alloy), is a metal alloy of nickel and titanium, where the two elements are present in roughly equal atomic percentages .Nickel containing alloys are present in a substantial amount and in wide range of appliances and auxiliaries and utilities used in orthodontics and are hence an integral part of every orthodontic intervention.Nickel titanium is a base metal alloy used in orthodontics. Niti arch wires have two remarkable properties, namely shape memory and super elasticity, which helps in achieving Nitinol alloys exhibit two closely related and unique properties: shape memory effect (SME) and super elasticity (SE; also called pseudo elasticity, PE).***

Keywords: Nickel titanium, alloy, elasticity

1. Introduction

Nickel titanium, also known as nitinol (part of shape memory alloy), is a metal alloy of nickel and titanium, where the two elements are present in roughly equal atomic percentages .Nickel containing alloys are present in a substantial amount and in wide range of appliances and auxiliaries and utilities used in orthodontics and are hence an integral part of every orthodontic intervention. Allergy to nickel is commonly seen in the population and is a concern for orthodontists, who might be required to treat patients with allergy. Nickel titanium (Ni-Ti) wires contain about 47-55% of nickel(1). It is also a component of orthodontic brackets, stainless steel, etc. Recent evidence has attributed carcinogenic2, mutagenic3, cytotoxic3 and allergenic action5-7 to nickel in various forms and compounds, posing a threat to patients undergoing orthodontic treatment who are potentially allergic to nickel. Nickel leaches from orthodontic appliances and forms a solution in saliva and causes the effects.(2) Orthodontic wires which generate biomechanical force communicated through brackets, for tooth movement are central to treatment mechanics in orthodontics and ideally, arch wires are designed to move tooth with light continuous force. Nickel titanium is a base metal alloy used in orthodontics. Niti arch wires have two remarkable properties, namely shape memory and super elasticity, which helps in achievingNitinol alloys exhibit two closely related and unique properties: shape memory effect (SME) and super elasticity (SE; also called pseudo elasticity, PE). Shape memory is the ability of nitinol to undergo deformation at one temperature, and then recover its original, undeformed shape upon heating above its "transformation temperature". Super elasticity occurs at a narrow temperature range just above its transformation temperature; in this case, no heating is necessary to cause the undeformed shape to recover, and the material exhibits enormous elasticity, some 10-30 times that of ordinary metal and levelling and aligning during the preliminary clinical phase of fixed appliance of approach.

2. History

The term nitinol is derived from its composition and its place of discovery: (Nickel Titanium-Naval Ordnance Laboratory). William J. Buehle along with Frederick Wang, discovered its properties during research at the Naval Ordnance Laboratory in 1959(3, 4, 5, 6). Buehler was attempting to make a better missile nose cone, which could resist fatigue, heat and the force of impact. Having found that a 1:1 alloy of nickel and titanium could do the job, in 1961 he presented a sample at a laboratory management meeting. The sample, folded up like an accordion, was passed around and flexed by the participants. One of them applied heat from his pipe lighter to the sample and, to everyone's surprise, the accordion-shaped strip stretched and took its previous shape (7). While the potential applications for nitinol were realized immediately, practical efforts to commercialize the alloy did not take place until a decade later. This delay was largely because of the extraordinary difficulty of melting, processing and machining the alloy. Even these efforts encountered financial challenges that were not readily overcome until the 1990s, when these practical difficulties finally began to be resolved.The discovery of the shape-memory effect in general dates back to 1932, when Swedish chemist Arne Olandefirst observed the property in gold-cadmium alloys. The same effect was observed in Cu-Zn (brass) in the early 1950 (8, 9).

3. Mechanism

Nitinol's unusual properties are derived from a reversible solid-state phase transformation known as a martensitic transformation, between two different martensite crystal phases, requiring 10,000–20,000 psi (69–138 MPa) of mechanical stress. At high temperatures, nitinol assumes an interpenetrating simple cubic structure referred to as austenite (also known as the parent phase). At low temperatures, nitinol spontaneously transforms to a more complicated monoclinic crystal structure known as martensite (daughter phase) (10). The temperature at which austenite transforms to martensite is generally referred to as the transformation temperature. More specifically, there are four transition temperatures. When the alloy is fully austenite, martensite begins to form as the alloy cools at the so-called martensite start, or Ms temperature, and the temperature at which the transformation is complete is called the martensite finish, or Mf temperature. When the alloy is fully martensite and is subjected to heating, austenite starts to form at the As temperature, and finishes at the Af temperature (11). The cooling/heating cycle shows thermal hysteresis. The hysteresis width depends on the precise nitinol composition and processing. Its typical value is a temperature range spanning about 20-50 K.Nitinol is typically composed of approximately 50 to 51% nickel by atomic percent (55 to 56% weight percent).Making small changes in the composition can change the transition temperature of the alloy significantly. One can control the Af temperature in nitinol to some extent, but convenient super elastic temperature ranges are from about −20 °C to +60 °C. One often-encountered complication regarding nitinol is the so-called R-phase. The R-phase is another martensitic phase that competes with the martensite phase mentioned above. Because it does not offer the large memory effects of the martensite phase, it is, more often than not, an annoyance.

Types of NITI Wires

Super elastic and

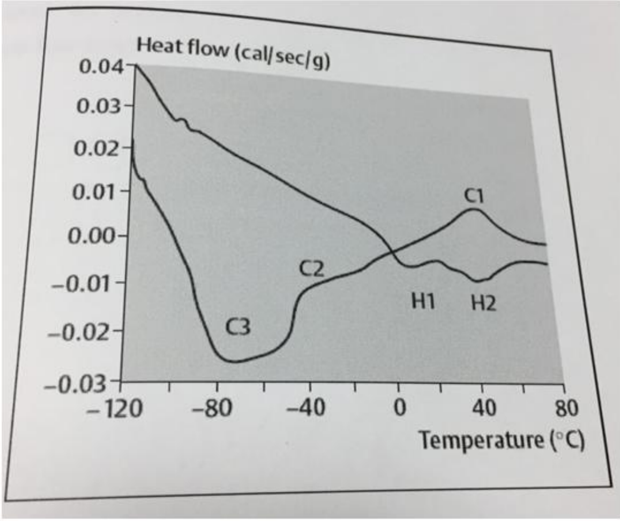
Non super elastic based on mechanical properties

Test to Evaluate Thermal Properties:

- Differential scanning calorimetry (DSC)
- Electrical resistivity tests
- Transmission electron microscopy.

a) Differential Scanning Calorimetry

DSC is a highly important member of general class of thermo analysis method that includes thermo mechanical analysis, thermo gravimetric analysis and differential thermal analysis. DSC has been extensively used for the study of NITI arch wire alloys. In the DSC procedure the differential heat flow required to heat or Cool the experimental and reference samples at the same scanning rate is recorded as a function of temperature to yield the spectrum or thermo gram. DSC is particularly useful for studying phase transformations. With the aid of computer software associated with the DSC apparatus, the areas of peaks on the DSC plots are readily available along with any structural transformation process. Advantage with DSC are that experiments can be performed rapidly with the useful scanning rates and temperature ranges, the specimen sizes are quiet small and the analysis provide information about the bulk material. DSC heating and Cooling curves for superplastic nitinol where peak H1 on DSC curve which corresponds to the transformation from martensitic to austenite and peak H2 corresponds to transformation from R phase to austenite. On cooling peak, C1 corresponds to the transformation from austenite to R phase and peak C2 corresponds to transformation from R phase to martensitic. While results from DSC analysis of NITI wires are qualitatively consistent.DSC provides information about phase present in bulk specimen.Another advantage with DSC is that enthalpy changes can be measured for comparison with published values in material science literature.



b) Transmission Electron Microscopy

Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through it. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a fluorescent screen, on a layer of photographic film, or to be detected by a sensor such as a charge-coupled device. TEMs are capable of imaging at a significantly higher resolution than light microscopes, owing to the small de Broglie wavelength of electrons. This enables the instrument's user to examine fine detail—even as small as a single column of atoms, which is thousands of times smaller than the smallest resolvable object in a light microscope. TEM forms a major analysis method in a range of scientific fields, in physical, chemical and biological sciences. TEMs find application in cancer research, virology, materials science as well as pollution, nanotechnology and semiconductor research. At smaller magnifications TEM image contrast is due to absorption of electrons in the material, due to the thickness and composition of the material. At higher magnifications complex wave interactions modulate the intensity of the image, requiring expert analysis of observed images. Alternate modes of use allow for the TEM to observe modulations in chemical identity, crystal orientation, electronic structure and sample induced electron phase shift as well as the regular absorption based imaging.At smaller magnifications TEM image contrast is due to absorption of electrons in the material, due to the thickness and composition of the material. At higher magnifications complex wave interactions modulate the intensity of the image, requiring expert analysis of observed images.In 1986, Ruska was awarded the Nobel Prize in physics for the development of transmission electron microscopy [12].

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