
ETCHING OF NITINOL

What is Nitinol?

Nitinol is an alloy of nickel and titanium (NiTi) in which the two metals are present in roughly equal atomic percentages. This alloy is characterized by a unique combination of super-elasticity, shape memory, and corrosion resistance. Nitinol was originally brought into practice in 1965 by William Buehler and Raymond Wiley (US patent 3174851).

Shape memory

Shape memory is the effect of restoring the original shape of a deformed material by heating it. The shape-memory effect in NiTi was discovered in the early sixties at the US Naval Ordnance Laboratory (hence the name Nitinol).

Nitinol can exist in two different solid structures: austenitic or martensitic. The austenitic crystal structure is highly ordered while the martensitic structure is less ordered and can be deformed quite easily. The ability of Nitinol to change its structure from austenitic to martensitic and vice versa gives Nitinol its shape memory and super-elasticity.

Above a certain temperature, called the transformation temperature, Nitinol exists in the high-strength austenitic phase, whereas below this temperature, the alloy is martensitic and can be easily deformed. For example, if a straight piece of Nitinol wire is deformed into a coil at a temperature below its transformation temperature, the coiled wire will spring back to its original shape once it is heated above the transformation temperature. This is due to a transformation from the martensitic structure to the austenitic structure. Effectively, the alloy 'remembers' its original shape and reverts to it when heated above the transformation temperature.

This shape recovery occurs over a temperature range of just a few degrees. This temperature window can be adjusted by slight variations in alloy composition and through heat treatment.

Super-elasticity

While the martensitic form of Nitinol normally exists below the transformation temperature, deformation at a temperature slightly higher than the transformation temperature can lead to the formation of some martensite. As soon as the stress is removed, the martensite reverts immediately to the austenitic form that was present prior to the deformation. This gives Nitinol a characteristic 'rubber-like' elasticity.



Biocompatibility and corrosion resistance

Due to its composition and corrosion resistance, Nitinol is a biocompatible material that has found widespread use in a variety of medical applications.

Biocompatibility is the ability of a substance to be accepted by the body. Nickel is present in different human tissues at very low concentrations (~ 0.1 ppm), but higher concentrations of nickel can be harmful. In Nitinol, nickel and titanium form an intermetallic compound; in other words, the nickel is converted into a compound and is therefore chemically locked. As a result, there is no risk of nickel release from Nitinol implants into the body. Indeed, research has shown that the release of nickel from Nitinol implants into biological tissue is negligible and undetectable, thus confirming the biocompatibility of Nitinol.

Moreover, the corrosion resistance of Nitinol contributes to its biocompatibility. After an appropriate passivation treatment, the surface of Nitinol becomes covered by a titanium-rich oxide layer that is both stable and uniform. This surface oxide layer protects the bulk alloy from bio-corrosion and also creates a physical and chemical barrier against nickel oxidation. Research has also shown that this oxide film is able to sustain large deformations induced by the shape memory effect, and that it is more resistant to chemical breakdown compared to the oxide film on passivated 316L stainless steel.

Applications

Due to the above-mentioned properties, Nitinol is especially useful for medical applications where it is used for implants in orthopaedics and orthodontics. It is also becoming widely used in devices for minimally invasive interventional procedures, such as stents, graft support systems and filters. For example, super-elastic stents are guided into the body while they are tightly compressed, and when released, they spring back to their original larger shape, thus holding open the blood vessel to improve blood flow.

There are also non-medical applications of Nitinol, such as in temperature control where the shape memory of Nitinol can be utilized to activate a variable resistor or a switch. Nitinol is also used in mechanical watch springs and as an insert for golf clubs.

Photochemical etching of Nitinol

Traditionally, titanium and nickel-titanium alloys have been etched in hydrofluoric acid, HF, sometimes in combination with nitric acid. This process requires special safety precautions due to the hazardous nature of the two acids. Moreover, these acids tend to cause detachment of the photoresist during the etching process.

Through a vigorous R&D programme, ACE has been able to develop a safer, non-HF chemistry to etch Nitinol and other titanium alloys. Among its many advantages, the new TiME process is able to achieve tight tolerances, and the etched parts are stress- and burr-free. Importantly, the process

does not alter the mechanical and chemical properties of Nitinol, namely, its super-elasticity, shape memory and biocompatibility.

The TiME process can produce Nitinol parts incorporating complex features and geometries. Thicknesses ranging from 25 μm to 1.0 mm can be processed.

The new titanium and Nitinol etching capability is part of the company's recent expansion which includes new staff and state-of-the-art etching, cleaning, measuring and inspection equipment.

