Nitinol: the superelastic metal that remembers its shape

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The development of the novel nickel-titanium alloy nitinol and the discovery of its unique properties didn't happen by chance, but equally not entirely by design.

In 1959, a team of scientists stationed at the US Naval Ordnance Laboratory (the initials for which gave nitinol the last three letters of its name) were seeking to formulate new hard-wearing metals to be used in naval missiles.

During one of the experiments, a scientist composed a metal of a similar composition to the nitinol used today (55.8% nickel and 44.2% titanium) and found that its strength and durability remained intact no matter how often it was bent and reshaped.

The true potential of this material was only realised at a later point when, in the spirit of rigorous experimentation, a colleague placed a lighter beneath the reshaped nitinol wire and discovered that when heated, it returned to its original untouched form.

This initial discovery did not prove to be the major find its military and defence research funding had no doubt been intended to uncover, but, in the years since, starting mainly in the 1990s, nitinol has proved to be a critical material within a wide range of medical devices.

The first scientist bending and reshaping it had uncovered its superelasticity, and the lighter-fuelled transformation carried out by his colleague revealed its shape memory, both of which have proved highly valuable features when it comes to putting wires or small medical instruments into hard-to-reach places.

Soon after it started to be tested and experimented within the medical setting, a third key benefit was found, with its metallic composition offering high levels of both biocompatibility and corrosion resistance when treated, making it an ideal material for use in the body.

The material of choice for stents and guidewires

The advantages of these features are particularly evident in nitinol's widespread adoption as the material of choice for the guidewires that are used to deliver a range of stents that are inserted into weak or narrowed arteries to aid blood flow.

In the case of stents, the shape memory of nitinol enables it to be packed into its catheter vessel in one shape and left in the vessel in another more suitable form when released; its superelasticity offers it the flexibility to travel through the body more smoothly; and its biocompatibility renders it safe to be exposed to the body.

This has led it to become a key component within the most well-known of stents, such as a coronary stent that ensures the supply of oxygen-rich blood to the heart, and even more dominant in those stents used in areas where added strain resistance is required, such as those impacted by the bending of joints. According to a study by GlobalData, this has seen nitinol used in 63% of peripheral stents.

“The properties of nitinol allow for manufacturing of components such as stents to a specified geometry, the ability to constrain the material for delivery and recovery to shape when deployed,” explains John Corsten, technical sales representative at Custom Wire Technologies (CWT).

“When you're delivering a stent and you go under that transformational temperature, that shape will collapse and will be easier to insert into a catheter and then deliver it,” explains Corsten. “Then, once it reaches the body, the body temperature means it will go back into whatever shape it was set in.”

Having first entered the nitinol market more than a decade ago at the request of a client who wanted a suture threader with shape-memory functionality, CWT has grown to offer solutions to a broad range of medical device developers looking to make the most of the material.

In addition to suture threaders and stents, nitinol has supported the development of urological retrieval baskets, which take the form of tiny, long-handled wire baskets that are used in the surgical removal of kidney stones, and guidewires used to navigate devices such as catheters around the body.

Explaining how its superelasticity has proven so key to its growing usage and demand, he points to the fact that while nitinol can take up to 8% strain without losing any structural integrity, an alternative such as stainless steel can only take 0.5% strain.

“That's an improvement by a factor of 16 and that's huge for medical devices,” says Corsten. “A lot of times we're dealing with a tortuous path throughout the body in a guidewire application, so the material needs to be able to take that strain and not bend. It needs to come back to its original form.”

The transformative benefits of shape memory

While the potential of such capabilities opens up valuable opportunities to medical device manufacturers, ensuring that they operate in the right way in the right place is a precise act of materials science, engineering and production.

To provide the widest possible range of activation temperatures for shape-memory nitinol devices – which can occur between -20°C and 22°C – CWT draws upon four separate grades of superplastic nickel titanium, each of which is composed of specific chemical compositions, unique quality, and transformation temperatures.

Through close consultation with the manufacturer, the company can then understand the requirements and recommend the right grade from which to manufacture the product. With the correct grade identified and the final design of the shape supplied, the material is put through a shape-setting process that will fix it in place. This involves first securing the nitinol wire around a fixture to enable it to keep its shape before the whole fixture is heat-treated in an air furnace or fluidised bath.

Both the temperature and the duration of the heat treatment are carefully calibrated to the specific shape and size of the device, but once the correct temperature is achieved, the shape is set in place.

Once complete, the final structure will be in its fixed state until it falls below the specific temperature, at which point it will become malleable and easily manipulated. In practical terms, the nitinol could be cooled artificially to make it one shape for delivery through the body only to revert to its original shape once body heat takes it back up to its fixed temperature.

In addition to shape-setting nitinol, CWT excels at grinding and coiling. The grinding and coiling process is where CWT's expertise really comes into play, with experienced engineers. Grinding nitinol requires specialised tools and processes, such as centerless or profile grinding, to ensure the end product meets its precise shape and dimensions.

"Additionally, the surface treatment of nitinol components can undergo a process of electropolishing and/or passivation," says Corsten. "This leaves the material with a passive surface layer, which provides protection against corrosion and any risk of toxic elements being released."

The use of nitinol in medical devices continues to expand and the demand is ever-increasing. There is no indication of demand slowing down in the future.

"For us, it comes down to years of experience working with the ins and outs of nitinol," Corsten says. "CWT's engineers have many years of experience grinding nitinol and possess a variety of tools to address concerns."

Procurement and supply of the specialist metal

While its unique features of flexibility and transformation offer functionality and potential that alternative materials are unable to match, these and the specialised treatments do not come without added complexities to the procurement process.

For a start, due to the specialised nature of the design, manufacture and supply of the finished components, these extra steps require extra time, so the lead times in receiving them are typically longer than more standardised alternatives.

CWT is able to alleviate this by carrying out all processes in-house, and, as with the development of any product or device, careful pre-planning can further ease the process.

Since nitinol has a limited number of suppliers compared with stainless steel, and given the additional processing that is carried out to activate its special properties, nitinol is comparatively more costly. However, this will reduce as demand and innovation increase.

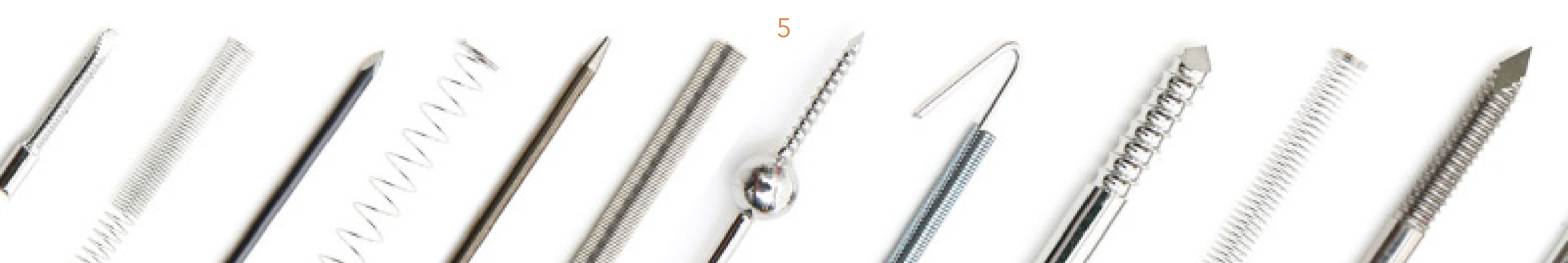
“CWT sees the demand for nitinol increasing and innovative devices being developed around nitinol,” says Corsten.

With its longstanding relationship with one of the premier suppliers of nitinol in the world, CWT is strategically placed to capitalise on the new advancements being made with the material. An example of this is linear elastic nitinol. Rather than being weakened when bent, the material becomes stronger, which offers particular value to applications such as guidewires.

While significant growth is expected, both the company and nitinol sector are certain that its application and appeal will remain focused on specialist applications where its unique features will offer the greatest value and enhancements.

“There’s a lot of applications where you don’t need nitinol,” says Corsten. “People aren’t going to switch to nitinol if they don’t need high strain or memory. It’s really an application-by-application situation. When you need those qualities, you’ll go to nitinol. If you don’t, you’ll stick with stainless steel.”

To find out more about nitinol and how CWT can help with your next development project, visit www.customwiretech.com



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