

High Temperature Synthesis of Shape Memory Titanium-Nickel Superelastic Alloys: A Mini-Review

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ABSTRACT

Currently, the synthesis technology of porous Ti-Ni-based alloys with shape memory effect is being extensively studied and has attracted significant interest in various fields of application. Due to their unique functional properties, such materials are widely used in medicine, high-precision instrument manufacturing, as well as in aerospace and aviation technologies. However, many conventional production methods often require expensive raw materials and complex, energy-intensive equipment, which limits their industrial efficiency. To address these challenges, self-propagating high-temperature synthesis (SHS) is proposed as an alternative technology. The ability to achieve high temperatures through internally generated heat from exothermic reactions enhances the energy efficiency of this synthesis method while reducing the need for external heat sources. As a result, the obtained product exhibits structural uniformity, and the overall production costs are minimized. This scientific review comprehensively explores the potential of producing Nitinol via the SHS method, as well as the structural and functional properties of the resulting material, and the influence of synthesis parameters on material quality.

1. Introduction

Intermetallic titanium-nickel-based alloys, particularly Nitinol (NiTi), have attracted considerable attention in modern materials science due to their unique functional properties [1-3]. One of their key features is the shape memory effect and superelastic behavior, which enable the material to recover its original geometric shape through thermally triggered phase transformations [4]. This distinctive combination of properties allows Nitinol to be widely applied in various fields, including medical implants and orthopedic devices, temperature-sensitive actuators, as well as in aerospace engineering, microelectronics, and robotics [5-6]. The unique properties of Nitinol are closely associated with martensitic-austenitic phase transformations occurring within its crystalline structure. These phase changes impart high mechanical strength, excellent wear resistance, and corrosion resistance in aggressive environments, thereby ensuring the material's long-term performance in biological systems [7-8].

At present, the most commonly used methods for producing Nitinol alloys include vacuum induction melting [9], powder metallurgy techniques [10], and thermochemical transformation processes [11], among others. These methods enable the fabrication of high-quality alloys with the desired phase composition and mechanical properties. However, their production processes are complex and involve multiple stages. Moreover, they require high-purity raw materials and specialized equipment, which significantly increases production costs and reduces overall economic efficiency. To overcome these technological and financial limitations, self-propagating high-temperature synthesis technology has recently been proposed as an alternative approach [12-16]. The heat released as a result of exothermic reactions occurring within the system enables material synthesis without the need for external heating sources. The SHS method enables complete material synthesis throughout the bulk by utilizing self-sustained heat propagation following the initiation of the reaction, thereby characterizing

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it as a highly energy-efficient technology. This approach allows for the reduction of production costs by utilizing nickel and titanium in either metallic or oxide forms. Furthermore, the rapid nature of the synthesis process enables effective control over the microstructure of the resulting material, adjustment of its porosity, and achievement of phase homogeneity. These characteristics make Nitinol particularly suitable for biomedical applications, especially in implantable devices.

Studies have shown that Nitinol synthesized via the SHS method possesses high-quality structural and mechanical characteristics, while exhibiting lower production costs compared to conventional techniques [17-18]. In addition, this technology is environmentally advantageous, as the synthesis process generates minimal harmful byproducts and does not require additional purification steps. Thus, the SHS method is considered a promising, cost-effective, and environmentally safe alternative for Nitinol production. This scientific study systematically investigates the key technological

parameters of the SHS method and their influence on the structural, mechanical, and functional properties of the resulting alloy.

2. Physicochemical Properties of Nitinol

2.1. Physical Properties of Nitinol

Nitinol is an alloy of nickel and titanium, renowned for its unique physicochemical properties. It has a density of approximately 6.18 g/cm³ and a melting point around 1310 °C. While its thermal and electrical conductivities are relatively low, it exhibits high mechanical strength, with tensile strength ranging between 700 and 1400 MPa. Nitinol shows limited resistance to acids such as HCl, HF, and H₂SO₄, and may react with alkalis at elevated temperatures. One of its most significant advantages is the shape memory effect, which enables the material to return to its original form upon heating. Additionally, it exhibits high elasticity and bioinertness, making it suitable for a wide range of engineering and biomedical applications (Table 1).

Table 1. Physical Properties of Nitinol

Physical Properties of Nitinol	Property value	References
Molecular formula	NiTi	Wikipedia
Molecular weight	107	Wikipedia
Color	Silver-white	[19]
Density	6.18 g/cm ³	[20]
Melting point °C	1240-1310	[21]
Proper volume	0.155 cm ³ /g	[22]
Coefficient of thermal expansion at 20 °C	6.6 × 10 ⁻⁶ /°C	[23]
Solubility in water 200	Insoluble	[24]
Modulus of elasticity	75-83 GPa	Wikipedia
Tensile strength	800-1100 MPa	Wikipedia
Oxygen content	0.05%	[25]
Specific heat capacity from 0 °C to 31 °C	0.46 J/g K ³	[26]
Thermal expansion coefficient (austenite)	11×10 ⁻⁶ /°C	[27]
Thermal expansion coefficient (martensite)	6.6×10 ⁻⁶ /°C	[27]
Magnetic permeability	< 1.002	Wikipedia
Magnetic susceptibility (austenite)	3.7×10 ⁻⁶ emu/g	Wikipedia
Magnetic susceptibility (martensite)	2.4×10 ⁻⁶ emu/g	Wikipedia
Modulus of elasticity (austenite)	75-83 GPa	[27]
Modulus of elasticity (martensite)	28-40 GPa	[27]
Yield strength (austenite)	195-690 MPa	Wikipedia
Yield strength (martensite)	70-140 MPa	Wikipedia
Poisson's ratio	0.33	[27]

2.2. Chemical Properties of Nitinol

The chemical properties of Nitinol are determined by its intermetallic structure, which is composed of nickel and titanium, and it is characterized by high chemical stability in various aggressive environments. In air, a thin passive layer of titanium dioxide (TiO_2) forms on its surface, acting as a protective barrier against oxidation. Upon exposure to strong mineral acids—particularly hydrochloric, hydrofluoric, and sulfuric acids—dissolution of titanium ions can occur. Nitinol can react with alkaline solutions (such as NaOH and KOH) at elevated temperatures, although it remains chemically inert at room temperature. Its high corrosion resistance in seawater and biological fluids makes it highly suitable for use in medical implants. In electrolytic environments, anodic polarization contributes to the reinforcement of the titanium dioxide layer. At high temperatures, the titanium component of Nitinol may chemically interact with oxygen, nitrogen, and carbon, potentially altering its structural and mechanical properties. Therefore, in addition to its physical and mechanical characteristics, the investigation of Nitinol's surface physicochemical properties remains highly relevant. Nazarov et al. [28] conducted a comparative study on the effects of $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2$, $\text{HCl}/\text{H}_2\text{SO}_4$, and $\text{NH}_4\text{OH}/\text{H}_2\text{O}_2$ solutions on the surface morphology, wettability, surface free energy, and chemical composition of Nitinol samples (Fig. 1).

The research findings indicated that treatment with the $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2$ solution does not significantly alter the surface morphology, whereas exposure to $\text{HCl}/\text{H}_2\text{SO}_4$ results in the formation of a complex microrelief. These solutions lead to the formation of sulfur-containing residues, which reduce the surface's wettability stability. The $\text{NH}_4\text{OH}/\text{H}_2\text{O}_2$ solution affects the surface dissolution of titanium, causing the formation of plate-like structures ranging from 10 to 20 μm and the appearance of surface cracking; however, it enhances hydrophilicity (with a contact angle ranging from 32° to 58°). The treatment duration (30 and 120 min) influences changes in surface morphology, wettability, and surface energy under the action of $\text{HCl}/\text{H}_2\text{SO}_4$ and $\text{NH}_4\text{OH}/\text{H}_2\text{O}_2$ solutions. Still, it does not significantly affect the chemical composition of the samples.

2.3. Nitinol synthesis methods

Currently, several technological methods for synthesizing NiTi alloys are being extensively studied. These include vacuum induction melting, powder metallurgy, mechanochemical synthesis, selective laser melting, electrolytic deposition, and physical vapor deposition. Each method offers specific advantages and limitations, significantly influencing the structure, phase composition, mechanical properties, and potential applications of the resulting material.

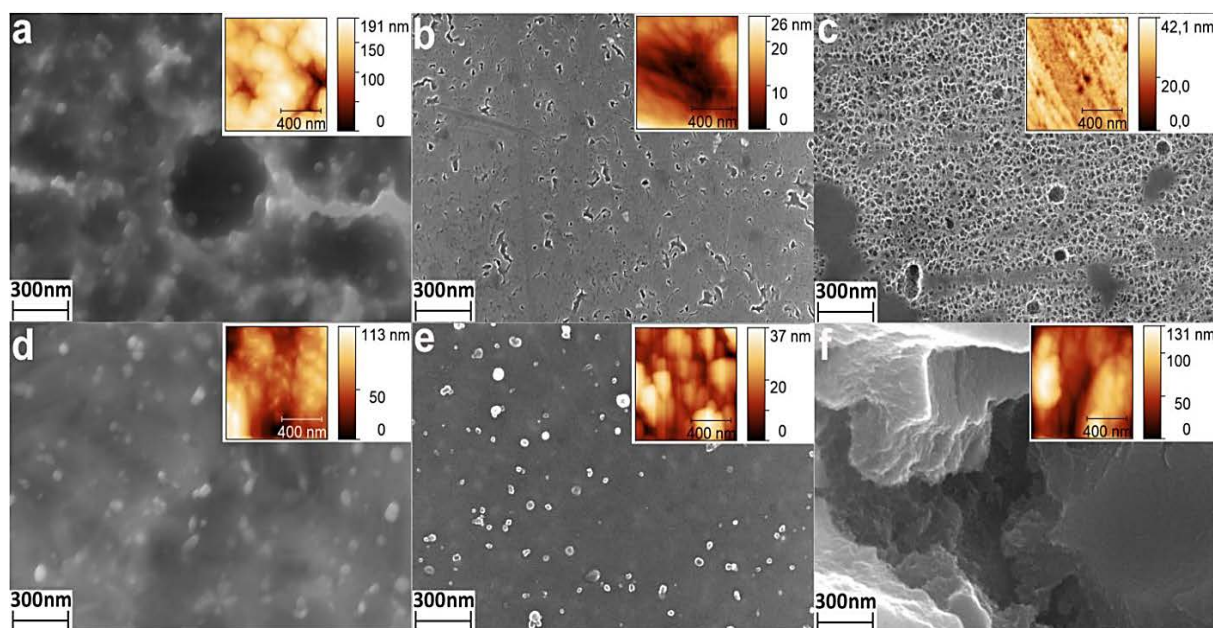


Fig. 1. SEM images (300 nm scale bars) of nitinol surface for samples: (a) $\text{HCl}/\text{H}_2\text{SO}_4$ – 30 min, (b) $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2$ – 30 min, (c) $\text{NH}_4\text{OH}/\text{H}_2\text{O}_2$ – 30 min, (d) $\text{HCl}/\text{H}_2\text{SO}_4$ – 120 min, (e) $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2$ – 120 min, (f) $\text{NH}_4\text{OH}/\text{H}_2\text{O}_2$ 120 min. The insets show the AFM surface topographies of the corresponding samples. Reproduced from [26], published under CC BY 4.0 license.

The vacuum induction melting method enables the production of high-quality and chemically homogeneous alloys, as nickel and titanium are melted and mixed in precise proportions under controlled conditions [27]. However, this method requires high temperatures, a vacuum environment, and specialized equipment, resulting in elevated production costs. The powder metallurgy approach is based on low-temperature synthesis using pure nickel and titanium powders as starting materials. It allows for precise control of the microstructure; however, the complexity of the compaction and subsequent heat treatment stages, along with the risk of powder contamination, are considered its main drawbacks [28]. Mechanochemical synthesis involves initiating chemical reactions through high-energy mechanical activation, enabling phase transformations to occur at relatively low temperatures. This method can produce homogeneous, fine-grained structures and highly reactive composite mixtures.

Laser-based technologies, including selective laser melting (SLM), have gained significant importance in recent years for the synthesis of Nitinol. Mehrpouya et al. demonstrated the potential of laser welding to join Nitinol wires with minimal thermal damage [29]. This method is particularly effective in biomedical device fabrication, as it helps preserve the material's original properties and characteristics. Butler et al. [30] employed spark plasma sintering and extrusion techniques to synthesize products with high homogeneity. During the SLM process, the laser beam power has a significant influence on martensitic phase transformations. Yang et al. [31] investigated the effects of laser energy on phase changes in NiTi alloys, emphasizing the need for precise control of laser parameters to optimize superelasticity and mechanical properties. However, improper parameter selection may result in phase instability and reduced functional performance. Electrolytic deposition and energy-directed deposition techniques are also being actively explored for Nitinol synthesis. Gao et al. [31] employed spatially focused high-energy laser beams to melt titanium-nickel alloys, producing materials with high strength and excellent shape memory properties. The homogeneity of the phase composition and microstructure makes this method particularly promising.

In addition, several researchers have employed coating technologies to enhance the properties of Nitinol alloys. For instance, McNamara et al. [32] utilized physical vapor deposition (PVD) to apply a tantalum layer, thereby limiting the migration of both

nickel and titanium. Although effective, this method requires a vacuum environment, complex equipment, and precise control of parameters, which presents limitations for large-scale industrial implementation. In the field of nanostructured coatings, Parmar et al. [33], and Paul et al. [34] explored novel approaches to modeling the microstructural evolution and deformation resistance of shape memory alloys. Their studies highlight the sensitivity of the martensitic phase in Nitinol to external loading and underscore the practical significance of its reverse transformation behavior.

In recent years, there has been growing interest in high-entropy shape memory alloys. For example, Dobrzański et al. [35] investigated the effect of non-stoichiometric compositions on the phase transformation temperatures and microstructure in the Ni-Cu-Pd-Ti-Zr-Hf system. Although vacuum melting in this context ensures compositional homogeneity and enables control over the phase constitution, it requires additional heat treatment to achieve the desired material properties.

Synthesis in a reactive gas atmosphere is also considered a crucial method. Porous Nitinol produced by this approach is widely used in medical implants [36]. The synthesis scheme is illustrated in Fig. 2.

Porous NiTi alloys can be synthesized via self-propagating high-temperature synthesis in a filtration combustion mode under an argon or nitrogen atmosphere. This method is characterized by a short synthesis time, high temperatures, structural homogeneity, and energy efficiency, making it a promising alternative to conventional techniques.

In conclusion, the various methods used for synthesizing Nitinol significantly influence the structure and properties of the resulting material. Among them, self-propagating high-temperature synthesis (SHS) has emerged as an effective technique for controlling structural and phase parameters. Materials produced by this method exhibit high resistance to temperature and pressure, possess fine-grained and porous structures, and thus broaden the scope of their functional applications.

2.4. Self-Propagating High-Temperature Synthesis Method

Self-propagating high-temperature synthesis is an energy-efficient and technologically versatile method for producing materials, based on solid-phase exothermic reactions. The key feature of this technique is the self-sustaining propagation

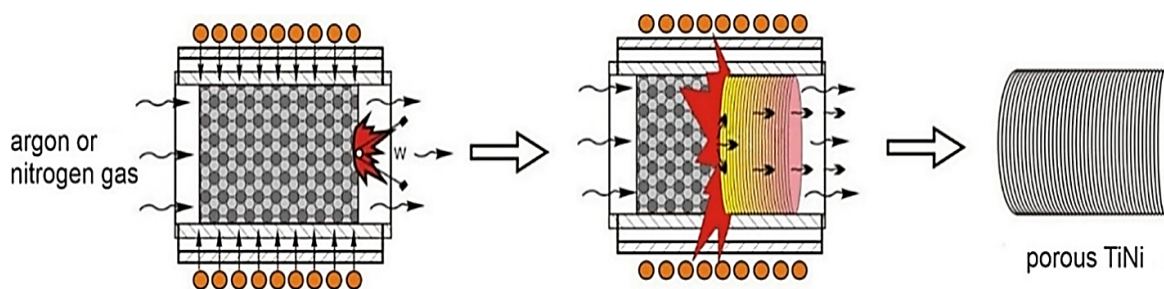


Fig. 2. SHS scheme in a flow reactor for obtaining porous NiTi alloy. Reproduced from [36], published under CC BY 4.0 license.

of a reaction front throughout the entire volume of the reactant mixture, initiated by heating the starting components to their ignition temperature. The heat released during the reaction maintains the synthesis process without the need for external energy sources. This synthesis method is considered an effective alternative for producing metallic and ceramic materials that require high temperatures. It ensures a rapid and high-yield synthesis process while also enabling optimization of the structural and physicochemical properties of the resulting materials [37–48].

The application of the self-propagating high-temperature synthesis method for synthesizing NiTi-based shape memory alloys has become increasingly relevant in recent years. In particular, Maashaa et al. [49] evaluated the efficiency of synthesizing porous Nitinol by employing preliminary ultrasonic activation of nickel and titanium powders. During the study, mechanical-acoustic treatment was applied to enhance the reactivity of the initial powders, followed by thermal processing at 300 °C. The reaction was carried out in an inert atmosphere using a nichrome wire as the ignition source, and the entire synthesis process was completed within just 5 s. This demonstrates the high reaction rate and the overall efficiency of the SHS process.

Morphological analysis (Fig. 3) revealed significant differences in the porous structure of the synthesized alloys. In samples without ultrasonic treatment, elongated, directionally aligned channels were observed, whereas in ultrasonically activated materials, the pores were more rounded, with sizes ranging from 500 to 1000 μm . Furthermore, high-magnification surface examination revealed the presence of secondary phase precipitates, distinguished by optical contrast, in addition to the primary NiTi matrix phase. These findings indicate a high degree of structural homogeneity and effective control over phase separation during the synthesis process.

Preliminary ultrasonic treatment not only

optimized the porosity of the alloy but also enhanced its phase composition by increasing the relative fraction of the NiTi phase. These changes contribute to improved mechanical stability as well as enhanced thermal and structural stability of the material. Additionally, the reduced amount of precipitates formed during synthesis indicates a higher degree of surface cleanliness and improved functional properties. The high structural homogeneity of the material enhances its application efficiency and ensures the long-term stability of its functional characteristics. Analytical results demonstrated not only the mechanical strength of the synthesized material but also its excellent compatibility with biological systems. The porous structure facilitates osseointegration and enhances the material's ability to interact with living tissues. These properties make the material particularly advantageous for use in orthopedic and dental implants.

Overall, NiTi alloys synthesized via the SHS method using ultrasonically activated powders exhibit structural integrity, phase stability, and enhanced mechanical and biomedical properties. Such materials are considered promising candidates for functional implant applications.

Resnina et al. [50] investigated the structural characteristics and martensitic phase transformations of nickel-titanium-based porous materials synthesized using the self-propagating high-temperature synthesis (SHS) method. Additionally, the study comprehensively examined the effects of ultrasonic treatment and the influence of various preheating temperatures on the synthesis process. Figure 4 presents longitudinal cross-sections of NiTi samples obtained via SHS, visually illustrating the impact of preheating temperature on the material's structure.

The research findings demonstrated that when the preheating temperature ranged between 350–400 °C, the samples—regardless of whether ultrasonic vibration treatment (UVT) was applied—tended to form a layered-porous structure (Fig. 4a, 4b, 4f, 4g).

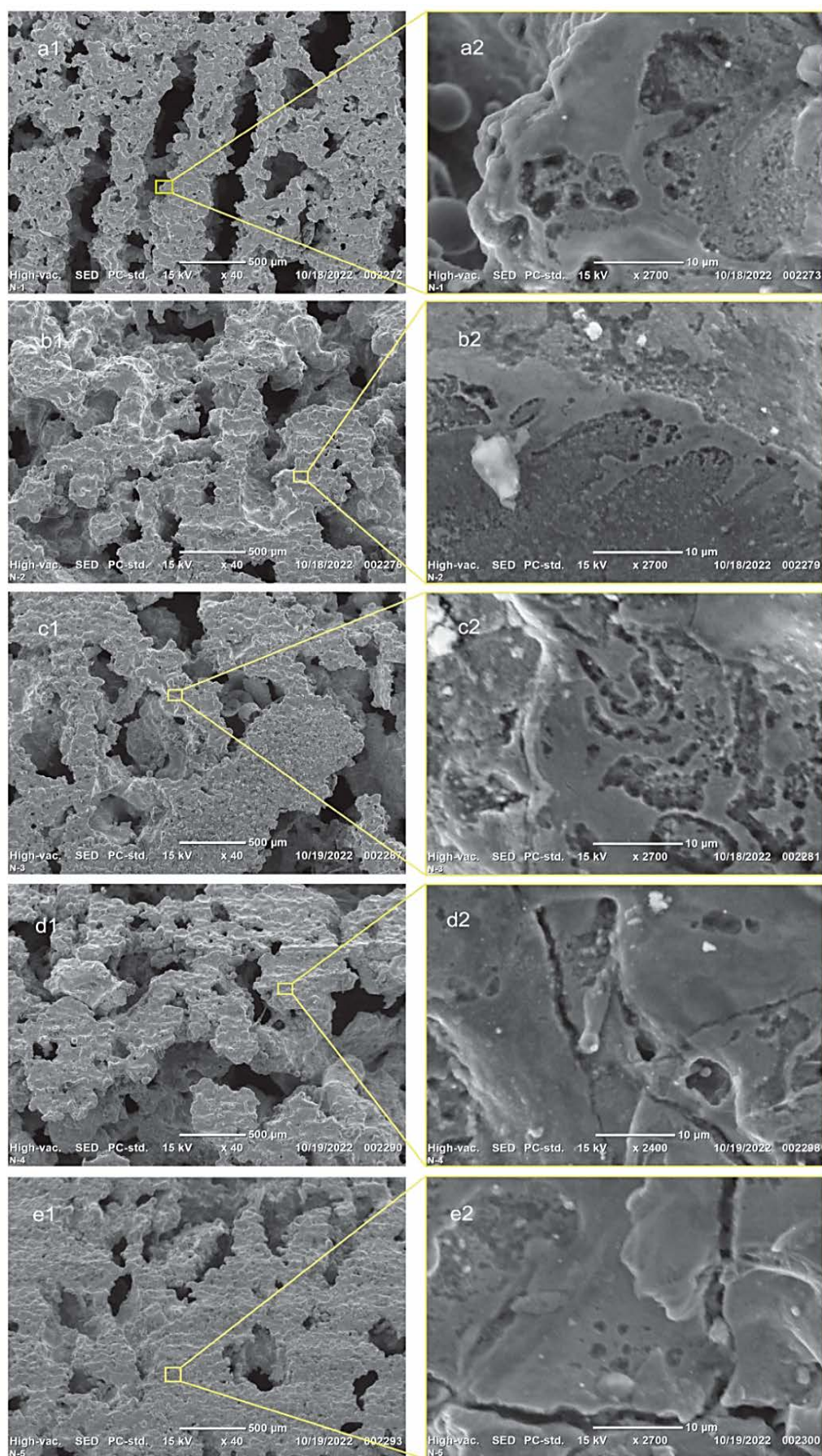


Fig. 3. Micrographs of the lateral surface of porous Ni-Ti SMAs: (a1, a2) not treated with ultrasound; (b1, b2) ultrasound treated for 15 min; (c1, c2) ultrasound treated for 30 min; (d1, d2) ultrasound treated for 60 min; (e1, e2) ultrasound treated for 120 min. Reproduced from [49], published under CC BY 4.0 license.

However, increasing the preheating temperature to 450 °C altered the nature of the porosity, as the morphology shifted from anisotropic to isotropic (Fig. 4c and 4h).

In the samples synthesized by SHS without UVT, large voids were observed in the inner region (Fig. 4c), whereas such voids were absent in the UVT-treated samples (Fig. 4h). When the preheating temperature exceeded 450 °C, individual large pores appeared in the samples synthesized via SHS combined with UVT (Fig. 4i and 4j), whereas in those obtained without UVT, both large and small pores were present in significant quantities simultaneously (Fig. 4d and 4e). These results confirm that ultrasonic treatment has a considerable impact on the synthesis process, positively influencing both the degree of porosity and the structural homogeneity of the resulting material.

The approaches employed in this study provided more profound insights into the structural properties and phase transformation mechanisms of NiTi alloys. They were considered key parameters in controlling their physicochemical characteristics. In particular, the combined effects of preheating temperature variation and ultrasonic treatment on the martensitic phase transformation and porosity level of the material were thoroughly investigated. These methods aim to enhance the structural stability of the material and optimize its mechanical and functional properties.

Marchenko et al. [36] conducted a comprehensive investigation of the structural characteristics, phase composition, biocompatibility (cytocompatibility), and functional properties of porous nickel-titanium (NiTi) alloys synthesized via the self-propagating high-temperature synthesis (SHS) method under

inert atmospheres such as argon and nitrogen. A comparative phase analysis of NiTi-(Ar) and NiTi-(N) samples was performed using X-ray diffraction (XRD) (Fig. 5). The study revealed that the porous NiTi-(Ar) alloy predominantly contained the austenitic TiNi phase as the main structural constituent. In addition, a mixture of martensitic TiNi, Ti₂Ni, and T₄Ni₂O phases was identified. The phase composition of the NiTi-(N) alloy included not only the phases observed in the argon-synthesized sample but also trace amounts of the TiNi₃ phase. The identified intermetallic phases were found to be highly crystalline.

This study aims to evaluate the influence of the gaseous environment used during alloy synthesis, assess the potential applicability of the obtained material in the biomedical field, and elucidate the correlation between its structural-phase state and functional properties.

Nitinol is distinguished by its unique properties, including high elasticity, shape memory effect, and wear resistance. Its ability to undergo martensitic-austenitic phase transformations enables the material to recover its original shape in response to external stimuli. Furthermore, Nitinol can withstand significant deformation and recover due to its shape memory behavior, making it widely used in medicine, aerospace, and structural engineering. These combined mechanical characteristics make the material highly suitable for functional structural applications. Consequently, many researchers have extensively investigated the mechanical properties of synthesized Nitinol alloys. In the study [40], the mechanical properties of NiTi-(Ar) and NiTi-(N) porous alloy samples were evaluated using uniaxial tensile testing (Fig. 6a). The test results showed that all samples exhibited brittle fracture

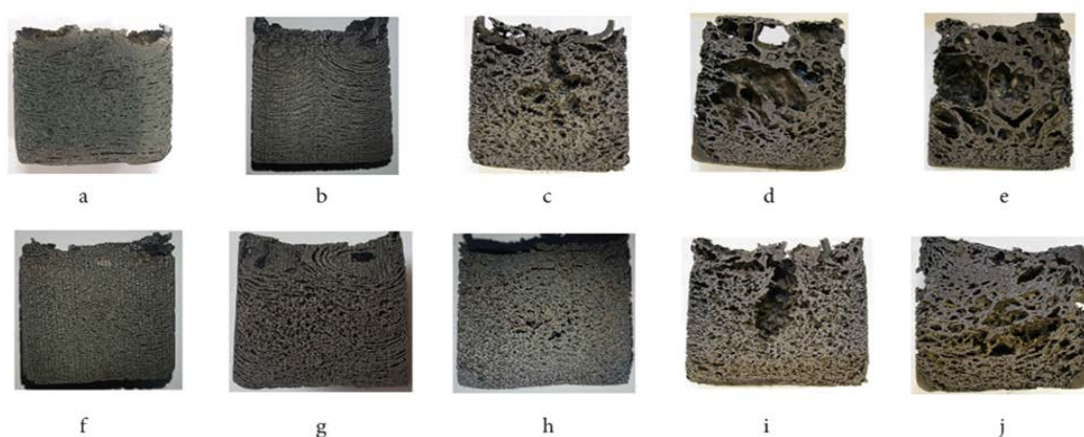


Fig. 4. Longitudinal section of the NiTi samples produced by SHS without USV (a-e) or with USV treatment (f-j). The preheating temperature of the mixture was 350 °C (a, f), 400 °C (b, g), 450 °C (c, h), 500 °C (d, i), 550 °C (e, j). The sample diameter was 30 mm. Reproduced from [50], published under CC BY 4.0 license.

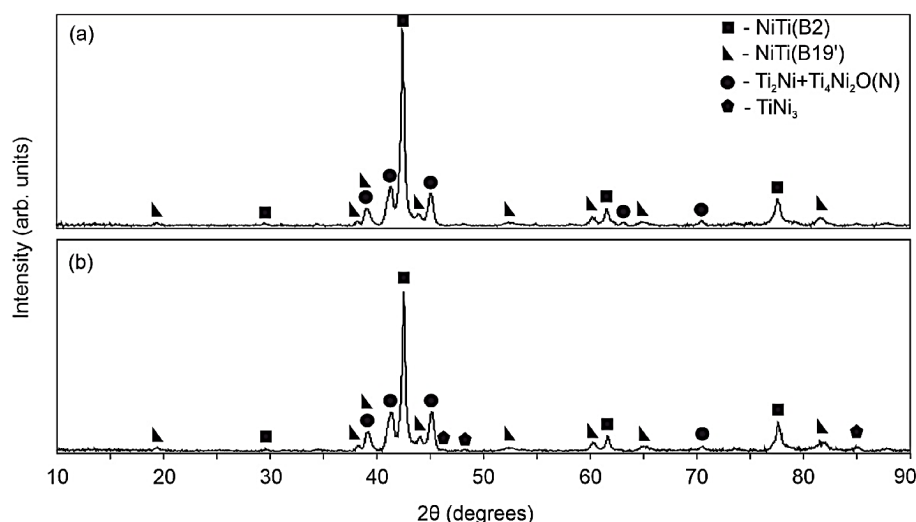


Fig. 5. X-ray diffraction patterns of porous NiTi-(Ar) (a) and NiTi-(N) (b) alloys synthesized via self-propagating high-temperature synthesis method. Reproduced from [36], published under CC BY 4.0 license.

behavior, regardless of the gas atmosphere used during the SHS process. However, before fracture, the deformation of the porous structures followed an elastoplastic mechanism. This phenomenon was observed during the analysis of the interconnecting bridges within the porous framework (Fig. 6b).

The obtained results can be attributed to the presence of a brittle intermetallic boundary layer surrounding the ductile matrix phase in NiTi, as well as the incorporation of the Ti_2Ni phase, which is known for its brittle characteristics. Fractographic analysis revealed dimpled fracture

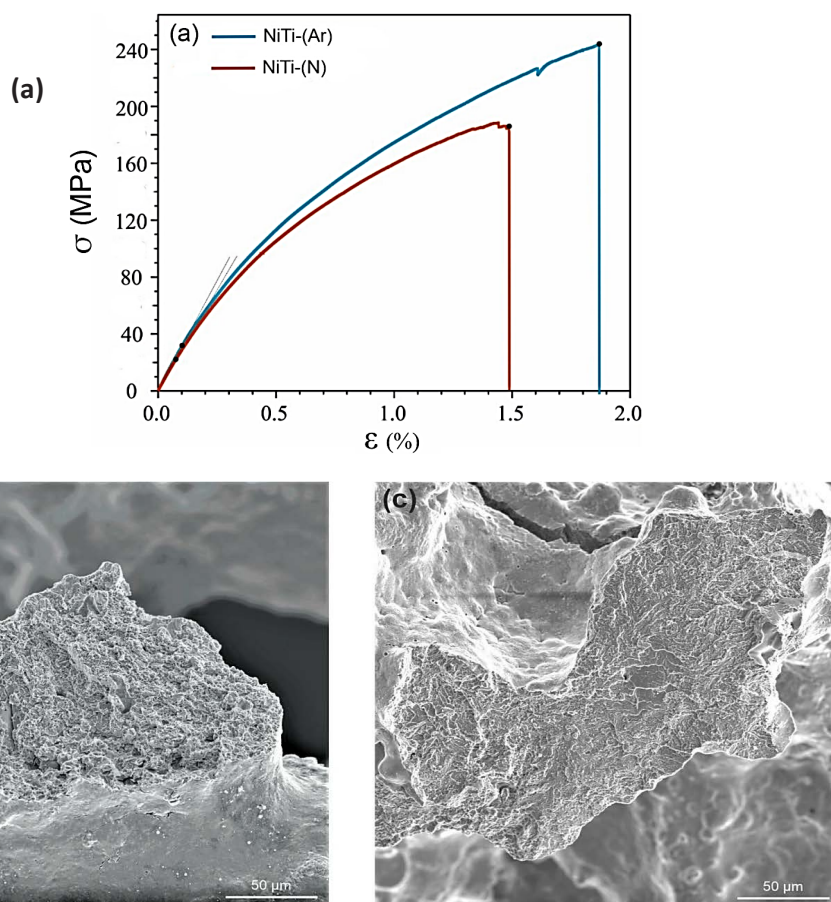


Fig. 6. Deformation diagrams obtained during uniaxial tension of porous NiTi plates in size (a), general view of the interconnective bridge fractogram of the porous NiTi-(Ar) (b) and NiTi-(N) (c) plates. Reproduced from [36], published under CC BY 4.0 license.

patterns associated with the ductile austenitic TiNi phase, quasi-brittle fracture regions corresponding to the martensitic TiNi phase, and brittle fracture features of the secondary Ti_2Ni and T_4Ni_2O phases. Comparatively, the proportion of brittle fracture surfaces was significantly higher in the NiTi-(N) alloys.

The structure of porous NiTi alloys synthesized via the SHS method exhibits a layered morphology. SHS represents a type of combustion process driven by exothermic reactions that generate high temperatures. This method ensures the self-sustained propagation of chemical reactions, where both initiation and propagation occur due to the heat released by the reaction itself, thereby significantly accelerating the synthesis process. The exothermic nature of the response enables rapid and efficient synthesis, making it a time- and energy-saving alternative compared to conventional methods.

The unique properties of materials synthesized via the SHS method allow for controlled tailoring of their structure. The structural features resulting from self-propagating synthesis—such as porosity and interconnected pore architectures—significantly influence the physical and mechanical properties of the material. The layered structure of porous alloys synthesized through this method enhances the specific surface area, thereby improving the material's strength and durability. Furthermore, the ability to control the porosity and structural characteristics of such materials represents a key factor in developing new functional properties tailored for specific applications.

The SHS method offers the advantage of efficiently utilizing high temperatures and pressures during material synthesis, thereby enhancing material properties. One of the key benefits of self-propagating high-temperature synthesis is its ability to produce materials with uniform and stable structures, thereby facilitating the optimization of their physical and mechanical characteristics. These structural control capabilities play a crucial role in enhancing the strength, hardness, and other key properties of the synthesized materials.

In addition, this method enables the rapid and efficient synthesis of nanostructured composite materials, which is highly important for industrial-scale applications. The high-efficiency production and controllability of materials, combined with reduced energy consumption, contribute to the widespread adoption of the SHS method in industrial settings. Compared to conventional techniques, SHS offers a significantly faster and more cost-effective approach.

3. Conclusion

The synthesis of Nitinol alloys using the self-propagating high-temperature synthesis method represents a highly relevant direction in contemporary materials science and biomedical engineering. The results of the present review demonstrate the technological flexibility of this method and its potential to improve product quality. Compared to conventional approaches, SHS technology enables the achievement of structural homogeneity, phase stability, and reduced energy consumption. However, several challenges remain in scaling this method to the industrial level, including technical limitations, the need for precise control of reaction parameters, and ensuring consistency in product quality. Future research should focus on developing thermodynamic and kinetic models of the SHS process, characterizing phase transformation mechanisms in detail, and comprehensively evaluating the biomedical safety of synthesized structures. Advancements in these areas will pave the way for the development of next-generation Nitinol-based materials suitable for applications in medicine, robotics, and intelligent systems. Furthermore, the functional capabilities of NiTi structures synthesized via SHS can be expanded through integration with additive manufacturing technologies, nanocoating techniques, and surface modification methods. Such interdisciplinary approaches offer targeted control over material properties and hold promise for enabling innovative solutions in both scientific research and industrial applications.

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Исследование параметров высокотемпературного синтеза титано-никелевых суперупругих сплавов с памятью формы мини-обзор

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АННОТАЦИЯ

В настоящее время технология синтеза пористых сплавов на основе Ti-Ni с эффектом памяти формы активно изучается и вызывает значительный интерес в различных областях применения. Благодаря своим уникальным функциональным свойствам такие материалы широко используются в медицине, прецизионном приборостроении, а также в аэрокосмических и авиационных технологиях. Однако многие традиционные методы производства требуют дорогостоящего сырья и сложного, энергоемкого оборудования, что ограничивает их промышленную эффективность. Для решения этих проблем в качестве альтернативной технологии предлагается метод самораспространяющегося высокотемпературного синтеза (СВС). Возможность достижения высоких температур за счет внутреннего тепла, выделяемого экзотермическими реакциями, повышает энергоэффективность данного метода синтеза и снижает потребность во внешних источниках тепла. В результате получаемый продукт обладает структурной однородностью, а общие производственные затраты минимизируются. Данный научный обзор всесторонне рассматривает потенциал получения нитинола методом СВС, а также структурные и функциональные свойства полученного материала и влияние параметров синтеза на его качество.

Keywords: титан-никелевый сплав, эффект памяти формы, сверхэластичные свойства, высокотемпературный синтез, фазовые превращения.

Пішінді есте-сақтайтын титан-никельді суперсерпімді қорытпалардың жоғары температуралық синтезі мини-обзор

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АҢДАТПА

Қазіргі уақытта пішінді есте сақтау эффектісі бар кеуекті Ti-Ni негізіндегі қорытпаларды синтездеу технологиясы кеңінен зерттеліп, әртүрлі қолдану салаларында үлкен қызығушылық тудыруда. Осындай материалдар өздерінің бірегей функционалдық қасиеттерінің арқасында медицинада, дәлме-дәл аспап жасау саласында, сондай-ақ аэроғарыш және авиация технологияларында кеңінен қолданылады. Алайда дәстүрлі өндіріс әдістерінің көпшілігі қымбат шикізатты және күрделі, энергияны көп қажет ететін жабдықтарды талап етеді, бұл олардың өндірістік тиімділігін шектейді. Осы мәселелерді шешу мақсатында баламалы технология ретінде жоғары температуралы өздігінен таралатын синтез (ТТС) әдісі ұсынылады. Экзотермиялық реакциялар нәтижесінде ішкі жылу түзілу есебінен жоғары температураға жету мүмкіндігі бұл әдістің энергия тиімділігін арттырады және сыртқы жылу көздеріне деген қажеттілікті азайтады. Нәтижесінде алынған өнім құрылымдық біртектілікке ие болады және жалпы өндіріс шығындары төмендейді. Бұл ғылыми шолу ТТС әдісі арқылы нитинол алу мүмкіндігін, алынған материалдың құрылымдық және функционалдық қасиеттерін, сондай-ақ синтез параметрлерінің материал сапасына әсерін жан-жақты қарастырады.

Түйін сөздер: титан-никель қорытпасы, пішінді есте сақтау әсері, суперсерпімді қасиеттер, жоғары температуралық синтез, фазалық түрлендіру.