U. Smart Materials

Organizers: Chengbao Jiang, Xiaobing Ren, Yunzhi Wang, Weimin Huang, Yingqing Fu

U-01

Strain Glass as A New Class of Smart Materials
Xiaobing Ren;
Xi’an Jiaotong University

For more than one century, martensite, a micro-sized microstructure, has played a central role in both structural materials (e.g., steels and Ti-alloys) and functional materials (e.g., shape memory alloys). The mechanical and functional properties of these materials come from the micron-sized martensite and martensitic transformation, and the manipulation of which by temperature and stress can lead to effects of technologically importance, such as shape memory effect and superelasticity. Contrasting with the martensite materials, it has been found in recent years that there exists a new class of martensite-derived materials called “strain glass”, which is characterized by nano-sized martensite domains and a sluggish strain glass transition. The manipulation of these nano-domains by temperature and external field can lead to novel effects not found in conventional martensitic materials, such as nearly hysteresis-free superelasticity and Invar effect. In this talk I shall talk about the state-of-the-art of strain glass studies and its potential applications as novel smart structural materials.

U-02

New-type confined martensitic transformation explored by synchrotron-based X-ray and neutron diffraction techniques
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Recently a kind of new-type martensitic transformation called as confined martensitic transformation (CMT) in shape memory alloys with the transformation kinetics obviously different from that found in traditional martensitic transformation (TMT) has been experimentally evidenced. For the TMT, the collective motion of martensitic variants controls the transformation kinetics, while the growth of martensite is confined for the CMT due to three intrinsic physical factors: (1) the irregular distribution of point defects, (2) the disordered stacking of multiple martensitic structures, (3) the nano-scale distribution of disorder structure or inhomogeneous chemical composition. This talk will summarize our new experimental findings on magnetic field-driven new functional behaviors in shape memory alloys, such as NiFeGaCo, NiMnGa and NiMnInCo systems, which exhibit CMT. The in-situ experimental investigations on evolution of the complex crystallographic structures and transformation kinetics under magnetic field by the high-energy X-ray and neutron diffraction techniques will be given. The in-depth understanding of the new physical mechanism on CMT-related partial phonon softening in the above-mentioned interesting alloy systems will be also presented.

U-03

Martensite structure of Ti-Ni-Cu shape memory alloy thin films containing different precipitates
Xianglong Meng, Jing Wang, Xiaoyang Yi, Wei Cai;
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Aim: Ti-Ni-Cu thin films are attractive candidates for microactuators in the field of micro-electro-mechanical system (MEMS) applications because they show a large recoverable strain and a high recovery force. The different second phases, such as GP zones, Ti2Cu, Ti2Ni, Ti(Ni, Cu)2, TiCu, precipitate when the amorphous Ti-Ni-Cu thin films were annealed at different temperatures. These precipitates strengthen the Ti-Ni-Cu thin films significantly and increase the output work per volume. This makes it possible to fabricate smaller and more reliable microactuator by using Ti-Ni-Cu thin films. In the present paper, the martensite structure of Ti-Ni-Cu shape memory alloy thin films are investigated and the effect of precipitates on the martensite structure are discussed.

Methods: Ti-Ni-Cu thin films with different chemical compositions were deposited on glass substrates using a carrousel-type magnetron sputtering apparatus. The substrate temperature was kept at 473K and the Ar gas pressure was 0.13Pa. The substrate holder was rotated at 60rpm to obtain a homogeneous composition during the sputtering. After sputtering, the deposited films were peeled off the glass substrates and then annealed at 773, 873 or 973K for 1h to produce crystallization. These heat treatments were carried out in a vacuum furnace equipped with infrared lamps. Tensile tests were carried out using a small tensile tester equipped with a heating and cooling system. The microstructure of the annealed thin films was observed using a JEOL-2000 FX II transmission electron microscope (TEM) at an accelerating voltage of 200kV.

Results: For Ti-rich Ti-Ni-Cu thin films with precipitates, the amount of martensite with single-pair morphology decreases compared to that for thin films and ribbon materials without precipitates. In the thin films with the GP zones or Ti2Ni precipitates, the martensite variants in some grains show a single-pair morphology. In the thin film with both Ti2Cu and Ti2Ni precipitates, the martensite variants with a single-pair morphology almost vanish. The martensite variants can pass through the GP zones during martensitic transformation. The movement of the twin boundaries is slightly obstructed by the GP zones parallel to the martensite plate and produce a wavy interface. The martensite plates can cut through Ti2Cu precipitates by elastic deformation of the precipitates. In addition, Ti2Cu precipitates sometimes change the width or direction of the martensite plates. The Ti2Ni precipitates disturb or impede the growth of the martensite variants, leading to a decrease in the output of transformation strains during the thermomechanical cycling.

For the (Ni, Cu)-rich Ti-Ni-Cu thin films, the Ti(Ni, Cu)2 particles precipitate during annealing. The fine Ti(Ni, Cu)2 precipitates can be cut through by the twinning shear, but they usually obstruct the movement of twin boundaries to some extent. This suggests that the fine Ti(Ni, Cu)2 precipitates only slightly affect the growth of martensite plates. However, the coarse Ti(Ni, Cu)2 precipitates strongly disturb or stop the growth of martensite plates. This is one of the reasons for the decrease in maximum recoverable strain when the annealing temperature increases. B19’ martensite is frequently observed near the coarse Ti(Ni,Cu)2 precipitates or the grain boundaries in the (Ni,Cu)-rich thin films. The formation of B19’ martensite is most likely caused by the local stress concentration near the precipitates or grain boundaries.

Conclusions: The different precipitates can be obtained by proper annealing in the amorphous Ti-Ni-Cu shape memory alloy thin films. The type, size and distribution of the precipitates affect the martensite structure seriously. Therefore, the Ti-Ni-Cu shape memory alloy thin films containing precipitates can show a ultrahigh strengthen and excellent recovery properties. Controlling the precipitation of amorphous thin films is an effective methods to improve the mechanical properties of the Ti-Ni-Cu shape memory alloy thin film as actuator materials.

U-04
Achieving superior two-way actuation by the stress-coupling of nanoribbons and nanocrystalline shape memory alloy
Inspired by the driving principle of traditional bias-type two-way actuators, we developed a novel two-way actuation nanocomposite wire in which a massive number of Nb nanoribbons with ultra-large elastic strains are loaded inside a shape memory alloy (SMA) matrix to form a continuous array of nano bias actuation pairs for two-way actuation. The composite exhibits a two-way actuation strain of 3.2% during a thermal cycle and an actuation stress of 934 MPa upon heating, which is about twice higher than that (~500 MPa) found in reported two-way SMAs. Upon cooling, the composite shows an actuation stress of 134 MPa and a mechanical work output of 1.08*10^6 J/m^3, which are about three and five times higher than that of reported two-way SMAs, respectively. It is revealed that the massive number of Nb nanoribbons in compressive state provides the high actuation stress and high work output upon cooling and the SMA matrix with high yield strength offers the high actuation stress upon heating. Compared to traditional bias-type two-way actuators, the two-way actuation composite with small volume and simple construct is in favour of the miniaturization and simplification of actuators.

U-05
Sandwich-like Strain Glass Phase Diagram of Ti49Ni51-xPdx
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Two kinds of phase diagrams can be observed in doped ferroic materials. A glass phase diagram is formed by doping a non-transforming end into a ferroic matrix, while doping a transforming end forms phase diagrams with a phase boundary separating two different ferroic phases. Here we report an exceptional phase diagram, in which a strain glass state is sandwiched between two distinct ferroelastic phases. This new type of phase diagram in doped ferroelastic materials bridges the above mentioned glass-state phase diagram and the phase diagram with a phase boundary. We thus established a 3D phase diagram of Ti50xPdx ternary alloys, in which the evolution of these different kinds of phase diagrams can be observed. An understanding from Landau free energy landscape suggests the transforming doping end plays three roles in influencing the ferroic matrix: (1) to destabilize the ferroic matrix phase, (2) to stabilize another ferroic phase different from the matrix one, and (3) to create random local field. Thus our work may provide experimental foundation for a unified mechanism to all the three types of phase diagrams.

U-06
Effects of sputtering parameters on composition and mechanical properties of TiNiCu thin films
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Analyzed the influences of different preparation technologies on morphology and composition and mechanical properties, to explore the best sputtering parameters. The Ti-Ni-Cu thin films were prepared by single target DC magnetron sputtering are amorphous and then annealed at 500 1min. The compositions were evaluated by energy dispersive spectroscopy. Tensile tests were carried out to determine high-quality thin film.
Compared with Si slide, SiO₂ slide and piezoid, using glass slide as substrate, the freestanding films were more easily to achieved. The Ar pressure significantly affect the quality of TiNiCu thin film, a Ar pressure low to 0.10Pa made the thin film have a better mechanical properties. With the increase of sputtering power, the content of Ni increases, while the content of Ti and Cu decreases. Then, the optimum preparation technology were confirmed.

U-07
Accelerated search for materials with targeted properties by adaptive design
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Finding new materials with targeted properties has traditionally been guided by intuition, and trial and error. With increasing chemical complexity, the combinatorial possibilities are too large for an Edisonian approach to be practical. Here we show how an adaptive design strategy, tightly coupled with experiments, can accelerate the discovery process by sequentially identifying the next experiments or calculations, to effectively navigate the complex search space. Our strategy uses inference and global optimization to balance the trade-off between exploitation and exploration of the search space. We demonstrate this by finding very low thermal hysteresis NiTi-based shape memory alloys, with Ti₅₀₀Ni₄₆.₇Cu₀.₈Fe₂.₃Pd₀.₂ possessing the thermal hysteresis of 1.84 K. We synthesize and characterize 36 predicted compositions (9 feedback loops) from a potential space of about 800,000 compositions. Of these, 14 had smaller thermal hysteresis than any of the 22 in the original data set.

U-08
Microstructure, Shape Memory Effect and Superelasticity Property of Ti-Nb Binary Thin Film
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Abstract: In the last decade, Ti-Nb and Ti-Nb-based shape memory alloys (SMA) have attracted great attention as Ni-free biomedical materials because of many advantages for biomedicine, such as excellent biocompatibility, high corrosion resistance, low elastic modulus and especially the novel shape memory effect (SME) and superelasticity effect (SE). The SME and SE of these alloys ascribe to the thermoelastic martensitic transformation from the beta phase to alpha” phase and the reverse martensitic transformation. According to previous reports, it suggests the possible existence of alpha phase, the martensitic alpha”, and beta phase with the possible precipitation of omega phase particles at room temperature, which are important to mechanical properties, SME and SE, by controlling the Nb content and the heat treatment process in bulk materials. However, in the case of thin film geometries, an extreme non-equilibrium thermodynamic process, the remarkable surface effect and strong internal stress condition may make it different with the bulk materials. In the present study, influence of post annealing temperature on martensitic transformation behavior, microstructure, SME and SE of Ti-Nb alloy in film geometries have been investigated.

Methods: The Ti-Nb binary thin films were deposited on silicon substrate by magnetron sputtering from a Ti-16Nb target. The base pressure was kept below 8.6 ×10⁻₅ Pa and the argon pressure was 0.3 Pa during sputtering. The DC power was 200W. The deposition was proceeded for 4 h and the thickness of the films were about 8 μm. The as-deposited films are annealed at 550, 650, 700, 750, 800 and 900°C for 3 min, respectively. The microstructure of the films was studied by XRD and TEM. The SME and SE were studied by tensile test.
Results: It is known from the XRD results that the as-deposited Ti-Nb thin film crystallizes completely because distinct diffraction peak, instead of the amorphous bread peak is observed in the XRD pattern. At room temperature the film consists mainly of beta phase and a (110) beta texture develops. However, in the solution treated bulk Ti-Nb alloy, which has the same composition with the film (~18 at.% Nb), it is only alpha″ martensite at room temperature. When annealing in a temperature range between 550 to 700°C, the films consist of beta phase as well. For the films annealed above 750°C, weak diffraction peaks corresponding to the alpha phase and alpha″ martensite appear in the XRD patterns. The TEM studies show that the grain size of the as-deposited Ti-Nb thin film is about 100 nm. The grains grow to several hundred nanometers when annealing and the grain size increases while the annealing temperature rises. Extra diffraction spots at trisection positions of [112] *beta in the SAD pattern and the corresponding dark field images show the precipitation of omega phase. It is seen that fine spherical omega phases about dozens of nanometers in size disperse in the beta phase matrix. In the Ti-Nb films annealed above 750, equiaxial alpha phases precipitate at the grain boundaries of the beta phase based on the TEM study. The alpha precipitations are about 100 to 200 nm in size. In some beta grains, except for spherical omega phases, thin martensite plates about dozens of nanometers wide is also observed to cross through the whole grain. The relevant SAD patterns confirm the existence alpha″ martensite. According to previous reports, the precipitation of omega phase restricts the martensitic transformation. Therefore, in the present Ti-Nb thin films with high density fine omega precipitations, the martensitic transformation is impeded and the beta phase remains at room temperature. Form the tensile test it is known that the tensile strength can reach ~1 GPa in Ti-Nb film with proper annealing temperature. There is an elastic recovered strain and a superelastically recovered strain during unloading in the stress-strain curves. There is also a transformation recovered strain when heating above the finish temperature of the reverse martensitic transformation. A maximal 3.4% recovery strain, including 2.4% superelastically recovered strain and 1% elastic strain, is obtained when tensile deforming to 4% in the Ti-Nb thin film. Grain refinement strengthening and dispersion strengthening are possible reasons for the enhanced tensile strength and superior SE of the Ti-Nb thin film.

Conclusion: (1) At room temperature, the Ti-Nb thin film consists of beta phase mainly. Fine spherical omega phase about dozens of nanometers in size embeds in the beta phase matrix. The martensitic transformation is restricted by the omega phase and only thin martensite plates about dozens of nanometers wide is observed. (2) A 3.4% recovery strain, which includes 2.4% superelastically recovered strain and 1% elastic strain, is obtained when tensile deforming to 4% in the Ti-Nb thin film.

U-09
Isothermal martensite formation originating from the crystallization of strain glass
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Time-dependence is the basic characteristic of diffusional transformations and the underlying physics of achieving diverse microstructure and physical properties (carbon-steel is the best-known example). On the other hand, time independence is a primary characteristic of martensitic or diffusionless transformations, which limits the diversity of martensitic materials and applications. Therefore, finding a mechanism of the martensite formation with time becomes a big challenge and opportunity to develop diverse martensitic materials. Recently, a new mechanism of the isothermal martensite formation have been discovered in thermalelastic Ti-Ni alloys, the so-called “crystallization” of strain glass, where R-martensite originates from the growth of a short-range ordered R phase (strain glass) with time [Ji, et al., PRL, 114, 055701 (2015)]. In order to overcome the infeasibility of R-martensite
and validate the universality, our results have shown that in non-thermalelastic Fe-Ni alloys the strain glass exists and transforms into a martensite with time. Our finding further suggests a unified model for isothermal martensitic transformation. It may also open a new way to develop diverse martensitic materials following the microstructure-property relationship.

**U-10**

**Phase Transition Graph – a New Tool for the Design of High Performance Ferroic Smart Materials**  
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1. The Ohio State University  
2. Xian Jiao Tong University

The symmetry of a crystal has profound effects on its physical properties and so does symmetry-breaking on the characteristics and properties of a structural phase transition. For an important class of smart materials, the ferroics, their functionality and performance are associated with cycling transitions from multiple structural states of one phase to those of the other. Using group and graph theories we construct phase transition graph (PTG) and show that both the functionality and performance of ferroics are dictated by the topology of their PTGs. In particular, we demonstrate how giant piezoelectricity in ferroelectrics and functional fatigue in shape memory alloys (SMAs) are related to their unique PTG topological features. Using PTG topology as a generic guide, we evaluate systematically new systems potentially having giant piezoelectricity and giant electro- and magneto-strictions and discuss design strategies for high performance SMAs with much improved functional fatigue resistance.

**U-11**

**Interface driven pseudo-elasticity in α-Fe nanowires**  
Xiangdong Ding;  
Xi’an Jiaotong University

Molecular dynamics simulations of bent [100] α-Fe nanowires show the nucleation of twins and nano-scale interfaces that lead to pseudo-elasticity during loading/unloading cycles. The new type of interfaces along {110} stems from the accumulation of individual <111>/\{112\} twin boundaries and stores high interfacial energies. These nonconventional interfaces provide a large part of the driving force for shape recovery upon unloading, while the minimization of surface energy is no longer the dominant driving force. This new pseudo-elastic effect is not much affected by surface roughness, and can be extend over a wide range of wire diameters, if the sample is seeded with conventional twin boundaries, which will transform to the desired \{110\} interfaces under bending.

**U-12**

**Superelasticity, corrosion resistance and biocompatibility of Ti–Zr–Nb–Fe shape memory alloy**  
Yan Li;  
Beihang University

Microstructure, mechanical properties, superelasticity and biocompatibility of a Ti–19Zr–10Nb–1Fe alloy are investigated. The results show that the as-cast Ti–19Zr–10Nb–1Fe alloy is composed of α’ and β phases, but only the β phase exists in the as-rolled and as-quenched alloys. The tensile stress–strain tests indicate that the as-quenched alloy exhibits a good combination of mechanical properties with a large elongation of 25%, a low
Youngs modulus of 59 GPa and a high ultimate tensile stress of 723 MPa. Superelastic recovery behavior is found in the as-quenched alloy during tensile tests, and the corresponding maximum of superelastic strain is 4.7% at the pre-strain of 6%. A superelastic recovery of 4% with high stability is achieved after 10 cyclic loading-unloading training processes. Potentiodynamic polarization and ion release measurements indicate that the as-quenched alloy shows a lower corrosion rate in Hanks solution and a much less ion release rate in 0.9% NaCl solution than those of the NiTi alloys. Cell culture results indicate that the osteoblasts adhesion and proliferation are similar on both the Ti–19Zr–10Nb–1Fe and NiTi alloys. A better hemocompatibility is confirmed for the as-quenched Ti–19Zr–10Nb–1Fe alloy, attributed to more stable platelet adhesion and small activation degree, and a much lower hemolysis rate compared with the NiTi alloy.

U-13
Formation and novel properties of the third class of ferroic materials: glass-ferroic composite
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The ferroic (ferromagnetic/ferroelectric/ferroelastic/multiferroic), being the well-known smart material, has been widely studied and used. So far, only the two classes of ferroic materials——ferroic crystal and ferroic glass——have been found. Here, we report the finding of the third one: a glass-ferroic composite (in short "glass-ferroic"), an analog of the composite of glassy and crystalline phases (glass-crystal composite, e.g., semicrystalline polymer). The formation of glass-ferroic stems from a time-dependent crystallization of the ferroic glass through the isothermal dwelling or the continuous cooling as demonstrated in the ferroelastic Ti48.7Ni51.3 and ferroelectric Pb0.87La0.13Zr0.4Ti0.6O3. Based on experimental results, a generic phase diagram is established to include all ferroic states, i.e., ferroic crystal, ferroic glass, and glass-ferroic. Being the third class of ferroic materials, glass-ferroics may open a new avenue for achieving novel properties and designing ferroic phase-change memory devices. Such one example has been given in the BaTiO3-based material, which has simultaneously achieved large electrostrain and low hysteresis over a broad temperature range.

U-14
Temperature memory effect of Ti-Ni-Hf-Y high temperature shape memory alloy
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The thermomechanical properties, such as: shape memory effect and superelasticity, are associated with reversible thermoelastic martensitic transformation. However, the incomplete martensitic transformation appears frequently in the practical application, which may have an influence on the thermomechanical properties. The so-called temperature memory effect (TME) appears when the martensite-austenitic transformation is incomplete. In the present study, the TME induced by partial transformation in the Ti-Ni-Hf-Y alloy is investigated.

Methods: The temperature memory effect induced by incomplete thermal cycling in Ti-Ni-Hf-Y high temperature shape memory alloy and undergoing 10 thermal cycles Ti-Ni-Hf-Y high temperature shape memory alloy was studied by means of the differential scanning calorimetry (DSC).
Results: The temperature memory effect induced by the partial transformation can be detected in the subsequent complete transformation for Ti-Ni-Hf-Y high temperature shape memory alloy (HTSMA). The temperature memory effect can be eliminated when the heating temperature is beyond the temperature of reverse martensitic transformation in the next thermal cycling; however, the temperature memory effect induced by partial thermal cycling can last at least 20 times complete thermal cycles with regard to the sample employed 10 times complete thermal cycles. Multiple-steps temperaure memory effect in the next heating process can be found when the sample undergoes the lower temperature partial thermal cycle in sequence.

Conclusion: In the present study, the TME induced by partial thermal cycling in Ti-Ni-Hf-Y high temperature shape memory alloy and Ti-Ni-Hf-Y high temperature shape memory alloy with undergoing 10 times thermal cycles is investigated. The results obtained show that the TME only can be detected in the heating process. In addition, The TME can last for about 20 times when the samples undergo 10 thermal cycles, which may be caused by the dislocations introduced by thermal cycling. The multiple-steps TME occurs when the samples perform several incomplete cycles on heating with different arrested temperatures with decreasing order.

U-15
Slim hysteretic superelasticity of Ti-Ni-Nb strain glass alloys
Andong Xiao, Xiaobing Ren;
Multi-Disciplinary Research Center, Frontier Institute of Science and Technology, Xi’an Jiaotong University

Superelasticity in shape-memory alloys exhibits a reversible up to several percent strain under the applied stress, compared with ~0.2% elastic strain of transitional metals. It has been widely used as pipe couplings, antennae for cellular phones and various actuators in electric appliances, etc. However, the large hysteresis of superelasticity, which originates from a first-order stress-induced structural (martensitic) transition, limits the applications. Therefore, how to overcome large hysteresis becomes the key issue to develop the next generation of shape memory materials. Recently, a strain glass transition has been discovered in shape memory alloys (ref. 2005 PRL), which involves a gradual formation and growth of nano-domains and is not thermodynamic phase transition. Here we report the superelastic behavior in Ti-39at%Ni-20at%Nb strain glass alloy with very slim hysteresis, presenting almost linear elasticity. The discovery of strain glass in traditional shape memory alloys may shed the light for designing new superelastic materials with low hysteresis.

U-16
A study of ultrafine-grained TiNiNb shape memory alloy
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In past years, TiNiNb shape memory alloys have received considerable attention because of their wide hysteresis which benefits the storage and transportation of coupling component. Lowering of martensitic transformation start temperature (Ms) is important for the reliability of coupling component. In this aspect, addition of quaternary element and refinement of microstructure are effective. Very recently, our group employed equal channel angular pressing (ECAP) to achieve a grain refinement in Ti₄₄Ni₄₇Nb₉ alloy. In the present work, microstructure, martensitic transformation and mechanical properties of ultrafine-grained Ti₄₄Ni₄₇Nb₉ alloy were investigated as a
function of processing parameters, including processing route and pass number. The results show that the grain size of Ti$_{44}$Ni$_{47}$Nb$_{9}$ alloy was reduced to about 200-300 nm after pressing for eight passes, irrespective of processing route. Ms temperature decreases with increasing pass number. After the samples in martensitic state were deformed, their reverse transformation proceeded into a multiple-stage manner upon first heating. The as-ECAP processed sample showed a much wider transformation hysteresis than that of initial alloy. This is ascribed to the enlarged strength mismatch between matrix and $\beta$-Nb phase. The yield strength of ultrafine-grained Ti$_{44}$Ni$_{47}$Nb$_{9}$ alloy were obviously improved as compared to initial alloy. The results may provide guideline on the further optimization of TiNiNb alloys.

**U-17**

**Effect of sintering temperature on the transformation behaviors, microstructure and mechanical properties in Ti-Ni-Hf high temperature shape memory alloys with a network structure**

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The shape memory effect is poor (~3%) owing to the lower matrix strength for the Ti-Ni-Hf high temperature shape memory alloy. In order to improve the strength of the matrix for Ti-Ni-Hf alloy, the Ti-Ni-Hf alloy with a novel network structure is fabricated. In the present study, we determine the optimal sintering parameters.

**Methods:** Ti-Ni-Hf alloys with a novel network structure were fabricated by hot-pressed sintering (HPS) at the sintering temperature ranging from 1000$^\circ$C to 1150$^\circ$C using the Ti-Ni-Hf alloy powders with $\phi$45$\mu$m~75$\mu$m in particle size. The transformation behaviors, microstructure and mechanical performance were investigated by differential scanning calorimetry (DSC), X-ray diffraction (XRD), scanning electron microscopy (SEM) and the compressive tests.

**Results:** Only one-step martensitic transformation occurs for all sintered samples and the martensitic transformation temperatures increase firstly and then decrease with the sintering temperature ranging from 1000$^\circ$C to 1150$^\circ$C. When the sintering temperature is 1000$^\circ$C, the sintered sample exists several pores; the sintered samples become compact when the sintering temperature exceeds 1100$^\circ$C. All samples consist of the martensitic phase and the second phase forming the network structure. The dimension of the network structure is determined by the particle size. Besides, the interior of the network structure is full of masses of dispersive second phases. The difference is that the second phase is (Ti,Hf)$_2$Ni phase when the sintering temperature is not more than 1100$^\circ$C, while as for the sample with 1150$^\circ$C sintering temperature, the second phase is Hf-rich phase. The compressive stress and strain continuously increase with the increasing of the sintering temperature. In addition, the compressive stress of all sintered samples is higher 1000MPa than that in the Ti-Ni-Hf alloy fabricated by arc induced melting (AIM), while the compressive strain is lower.

**Conclusion:** The strength of the Ti-Ni-Hf alloy with a novel network structure is higher 1000MPa than that in the Ti-Ni-Hf alloy fabricated by AIM. The strength of the sintered samples increases with the increasing of sintering temperature.

**U-18**

**Giant heterogeneous magnetostriiction in Fe-Ga alloys**

Chengbao Jiang, Yangkun He, Huibin Xu; 
Beihang University

Magnetostriective materials that undergo a deformation in the direction of an applied magnetic field are widely used in actuators, sensors and transducers. The origin of the magnetostriiction is the intrinsic distortion associated
with the spontaneous magnetization. However, the tenfold increase in magnetostriction that results from substituting some nonmagnetic Ga into the bcc Fe lattice is related to heterogeneous structure. The structural origin of the heterogeneous magnetostriction is unclear.

Methods: We studied the microstructure of nanoheterogeneities by TEM, Mossbauer spectroscopy and synchrotron XRD. Magnetic properties were studied by PPMS and strain gauge method. Domain structure is studied by Kerr microscopy.

Results: We indicate the microstructure of nanoheterogeneities to be modified D03 structure, where Ga-Ga pairs tetragonally distorted the surrounding matrix, leading to giant magnetostriction. A new model is proposed to explain heterogeneous magnetostriction. Based on this heterogeneous structure, we doped trace amount of large-sized dopants, and find that the lattice constant, tetragonal distortion, magnetoanisotropy and magnetostriction are linear with the size of the unmagnetic dopant. We also studied the effect of the crystal field of the dopant on the enhanced magnetostriction. The best trace dopants are the light rare earths Ce and Pr that give a transverse magnetostriction of up to -800 ppm, which is more than five times larger than the undoped materials. Increasing in-plane parallel magnetostriction in thinner single crystals indicates that the magnetic domains are likely to be perpendicular to the plane.

Conclusions: With the help of traces of light rare earths elements, longitudinal magnetostriction of up to 2000 ppm is achieved. This approach to enhance magnetostriction may be extended to other two-phase systems and signal a new approach to creating highly-magnetostrictive materials.

U-19

In situ low-temperature Lorentz TEM platform for smart magnetic materials via atomic structure design
Renchao Che;
Fudan University

Atomic structure design is a key issue for the application of smart materials. In this talk, we summarized the recent development of our group about the in situ TEM study of several important magnetic smart materials. Within recent years, a novel set of multi-functional in situ TEM instrument was established in our laboratory: applying electric/magnetic field, heating, cooling, flowing liquid reactant and so on. Therefore, many important scientific issues can be directly studied depending on this special system. Magnetic nanoparticle is important both scientifically and technologically. However, to deeply understand the physical association between microstructure and magnetic property is still in lack. Herein, via a series of advanced transmission electron microscopy (TEM), such as 3-D electron tomography, off-axis electron holography, and electron energy loss spectroscopy (EELS), the microstructure and magnetic property of manganese selenide (MnSe), L10-FePt, a-Fe/CNTs are comprehensively investigated. The 3-D morphology of the bullet-shaped MnSe nanorods has been demonstrated by the advanced TEM 3D-tomography technology. Examinations with HRTEM and EELS show that planar-defect structures such as stacking fault and twin along [001] direction are formed during the bullet-shapes growth. The differences of structure and composition between the Fe/CNx nanotubes and Fe/C nanotubes were investigated by EELS. At the boundary between Fe and the wall of a CNx nanotube, the additional electrons contributed from the doped ‘pyridinic-like’ nitrogen might transfer to the empty 3d orbital of the encapsulated iron, therefore leading to an intensity suppression of the iron L2, 3 edge and an intensity enhancement of the carbon Kedge.

U-20
Enhancing multifunctional properties of Heusler-type magnetic shape memory alloys via tailoring magnetostructural transformation
Daoyong Cong, Lian Huang, Xiaoming Sun, Yuhai Qu, Yandong Wang;
University of Science and Technology Beijing

Heusler-type magnetic shape memory alloys combine the ferroelastic and ferromagnetic order, and show a magnetostructural transformation from the high-magnetization phase to the low-magnetization phase upon the application of external magnetic fields. Owing to the magnetoelastic coupling, these alloys exhibit fascinating multifunctional properties, such as magnetic shape memory effect, magnetocaloric effect, magnetoresistance, and magnetic superelasticity. All these functional properties are intimately related to the coupling of the structural and magnetic transitions. Therefore, synergic tuning of the magnetostructural transformation parameters (such as transformation temperature, transformation width, thermal hysteresis, transformation entropy change, magnetization difference between the two phases across transformation, crystal structure change across transformation) are essential for obtaining optimal multifunctional properties.

In this talk, we will introduce our recent work on tailoring the magnetostructural transformation with new strategies. By tuning the magnetostructural transformation parameters we are able to manipulate the output and reversibility of the multifunctional properties as well as their working temperature range and actuation magnetic field. Examples from different alloy systems will be demonstrated. The results included in this talk may provide instructive information for designing high-performance magnetically actuated multifunctional martensitic alloys.

U-21
Development of Ni (CuCo)MnGa alloys with modified magnetostructural transition and magnetocaloric effect
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Magnetic materials undergoing the first-order magnetostructural transitions (FOMST) exhibit large magnetocaloric effect (MCE) and have potential applications in magnetic refrigeration. One such system is NiMnGa ferromagnetic shape memory alloys that undergo a FOMST from ferromagnetic martensite to paramagnetic austenite. However, for a long time the MCE working temperature span of NiMnGa alloys has been rather narrow, for example less than 5 K under the field of 5 T. This is limited by the intrinsically small magnetization change $\Delta \sigma$ ($< 30$ Am$^2$kg$^{-1}$) across the FOMST. Here Ni(CuCo)MnGa alloys are designed which undergo a FOMST from weak magnetic martensite to ferromagnetic austenite over wide temperature range of 150~400 K. The FOMST is accompanied by much larger $\Delta \sigma$ value around 100 Am$^2$kg$^{-1}$. Consequently the MCE working temperature span of NiMnGa alloys is effectively expanded to 18 K under the field of 5 T. The developed Ni(CuCo)MnGa alloys are expected to attract more attentions to Heusler alloys for magnetic refrigeration and also for thermoelectric conversion.

U-22
Improved elastocaloric effect in boron-doped Ni-Mn-In magnetic shape memory alloys
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Exploration of high-performance elastocaloric materials is of great significance to the development of environmentally friendly mechanocaloric cooling technology that could potentially substitute the conventional cooling technology based on vapor compression. In the present work, we systematically investigated the effect of microalloying with boron on the mechanical properties and elastocaloric effect as well as phase transformation and microstructure in Ni-Mn-In magnetic shape memory alloys. We found that the martensitic transformation temperature and transformation entropy change decreases as the B content increases. Also, the apparent yield strength of the alloys increases with increasing B content. More importantly, the boron addition is helpful for improving the cyclic stability of elastocaloric effect. Furthermore, a large stress-induced entropy change and a large adiabatic temperature change were observed in the boron-doped alloys. The possible mechanisms for the effect of boron addition were discussed. This study is instructive for the design of high-performance elastocaloric materials.

U-23
Microstructure and deformation behavior of Fe nanoparticle reinforced CuZnAl composite
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A Fe particle reinforced CuZnAl composite was prepared by means of friction stir processing, wire drawing and heat treatment. The microstructure of composite was studied by using of SEM, TEM and XRD. The mechanical property was researched by tensile test. Reinforcing effect of the Fe particle and deformation behavior in the composite were investigated by means of in-situ synchrotron X-ray diffraction. Fe particles with grain size 100 nm dispersed in the CuZnAl matrix. The maximum elastic strain of the Fe particle achieved was 0.7%, implying a component stress of 140 MPa on the particles. The Fe particles, with a volume fraction of 10%, carried 30% of stress fraction during tensile deformation.

U-24
Phase structure and magnetostrictive properties of Fe-Co alloys
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Magnetostriuctive materials exhibit reversible strains or change in dimensions in an applied magnetic field. They are widely used in actuator and sensor devices across a variety of technical disciplines. Magnetostriective effect was first discovered in iron by Joule in 1842. In the 1980s, Terfenol-D was invented with the giant magnetostriction of 2000 ppm, however, the application is limited because of its brittleness and high cost. In 2000, room temperature magnetostriction of as large as 400 ppm was found in binary rare earth free Fe-Ga alloy single crystal (known as Gafenol), with good mechanical properties. Recently, large magnetostriction was reported in Fe-Co alloy, which makes it a good candidate for magnetostriective materials. However, the relationship between phase structure and magnetostriiction is still unclear for its complex phase diagram. One point of view is the enhanced magnetostriction originates from the elastic field redistribution induced by fcc phase in nanometer scale under external magnetic field. On the contrary, someone suggested that the magnetostriection deteriorates with the appearance of fcc phase for its intrinsic negative magnetostriective effect. Here, the phase structure and magnetostriiction in Fe-Co alloy is systematically investigated by transmission electron microscopy. Results show that fcc phase can induce distortions into the matrix if the two phases remain coherent in [001] direction. In this case, the magnetostriiction of Fe-Co can be enhanced in the Co-rich region as reported. Further grow up of fcc
phase grains lead to a decrease of the magnetostriction. It is proposed that larger magnetostriction can be achieved in Fe-Co alloy by accurate controlling of phase structure.

**U-25**

**Magnetostrictive behaviors in ferromagnetic strain glass alloys**

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For more than half of a century, the magnetostrictive property in ferromagnetic materials has drawn constant interest because of the non-contacting advantage. The well-known magnetostrictive material is Terfenol-D (TbₓDy₁₋ₓFe₂, x ~ 0.3), which contains the expensive rare earth elements, thereby limiting wide applications. On the other hands, magnetic shape memory alloys (e.g., Ni-Mn-Ga) show the huge magnetostriction but large hysteresis, because it originates from a first-ordered structural transformation. Therefore, how to overcome large hysteresis becomes the key issue to develop the next generation of rare-earth-free magnetostrictive materials. Recently, a strain glass transition has been discovered in shape memory alloys (ref. 2005 PRL), which involves a gradual formation and growth of nano-domains and is not thermodynamic phase transition. Here we show that a ferromagnetic strain glass has been found in iron-based alloys. Moreover, it exhibits a nearly-zero hysteretic magnetostriction, although the value becomes smaller. This remarkable behavior originates from the growth of already existed nano-domains with applying the magnetic field. Our work may provide a new approach to design high performance magnetostrictive materials in magnetic shape memory alloys.

**U-26**

**Magnetically controlled damping in a polymer-bonded Ni-Mn-Ga composite**

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Ferromagnetic shape memory alloys such as Ni-Mn-Ga have emerged as an important class of high damping materials in recent years, not only due to their characteristic thermoelastic martensitic-austenitic transformation similar to the shape memory alloys, but also owing to their additional magnetically controlled reorientation of martensitic twin variants. However, the intrinsic brittleness of Ni-Mn-Ga alloys limited theirs applications. Recently, more attentions are put on Ni-Mn-Ga particles/polymer composite materials. The damping capacity of 30vol% Ni-Mn-Ga/epoxy resin composite is improved by the orientation magnetic field applied along the long direction of sample during sample fabricating. The IF value of magnetic field orientated composite increases, when the magnetic field is applied during the damping test along the orientation magnetic field.

**U-27**

**Advanced shape memory technology: fundamentals and applications**

Weimin Huang;
Nanyang Technological University
A few new shape memory phenomena have been reported recently, and right now, we have seen a range of shape memory materials (SMMs), from alloys and ceramics to polymers and gels, developed and well documented in the literature.

The unique feature of shape memory effect, which is different from the shape change effect in traditional materials and is behind all shape memory phenomena, provides us with many new approaches for advanced applications, in which conventional materials may have difficulties to cope with.

In this talk, a brief review of the various shape memory phenomena in SMMs is presented. The fundamentals behind them are discussed. The important features of the advanced shape memory technology are explained. Typical applications, from design, fabrication to recycling, are revealed to demonstrate the potential advantages of this technology.

U-28

Smart thin films and nanostructures for MEMS and lab-on-chip applications
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This talk will discuss about recent work on thin film shape memory alloy for microactuator applications, as well as piezoelectric ZnO films for acoustic wave-based microfluidics and bio-sensors. TiNi thin film based micro-actuators become the actuator of choice in many aspects in the rapidly growing field of MEMS, microsurgery, and biomedical applications. Different types of TiNi thin film based microdevices, such as microgrippers, microswitches, microvalves and pumps, microsensors are described and discussed. Piezoelectric ZnO film based acoustic wave devices can be successfully used as bio-sensors, based on the biomolecule recognition using highly sensitive surface acoustic waves and film bulk acoustic resonator devices. The acoustic wave generated on the ZnO acoustic devices can also induce significant acoustic streaming, small scale fluid mixing, pumping, ejection and atomization or nebulisation, particle concentration, cell manipulation, etc. The potential to fabricate an integrated lab-on-a-chip diagnostic system based on these ZnO acoustic wave technologies is introduced.

U-29

Strong and Automatic Self-healing Oxidized-CNT/Polymer Composite Hydrogel
Yujie Chen, Hafeez Rehman, Hezhou Liu;
Xi’an Jiaotong University

Objective: As self-healing ability is antagonist to mechanical strength of hydrogel, self-healing hydrogels so far suffer from mechanical weakness, which limits their application for any load-bearing devices such as actuators, tissue engineering scaffold and artificial cartilages. For most designs, external energy is required to achieve healing, especially for polymer materials with high mechanical strength.

Methods: We fabricated a novel composite hydrogel having well defined network structure amongst poly(acryloyl-6-amino caproic acid) (PAACA) and oxidized CNTs. Since carbon nanotubes generate a great potential in the synthesis of polymer composite due to its axial strength and has attracted great interest in electro-active and thermos responsive polymer composite. Whilst AACA hydrogel precursor have efficient, accurate and robust polymer bonding network decorated with dangling groups (carboxyl and amino groups) that mediate hydrogen bonding. We observed the self-healing and mechanical properties. Meanwhile, oscillatory rheological experiments proved the special strength and reversible behavior of composite. Structure features and internal cross linking
density of the composite were observed by allowing swelling and deswelling of composite in different pH solutions.

Results: The composite prepared by reversible hydrogen-bonding network generated amongst PAACA chains and oxides CNTs have high mechanical strength and best self-healing performance. This strengthens the composite up to 512.4 KPa at a break elongation of 1146.15% than that of pure PAACA hydrogel with a fracture stress of 64.54 KPa and elongation of 812.29%. Simultaneously, two contacted halves autonomous self-healed within 3 min which is less than PAACA whose minimum self-healing timing is 5 min. With the pH 6 3 aqueous solution, the self-healing time of composite hydrogel can be shortened to 1 min, which not only enhance self-healing but also increase tensile stress value from 400 KPa to 600 KPa for different contents of CNTs. However for pure PAACA the self-healing timing decreases from 5 min to 3 min.

Conclusion: This study has introduced a new bulky hydrogel composite material to biological scaffolding, artificial cartilages and engineering. Further the high storage stability of composite categorizes it for advance soft materials holding applications in biomedical science and engineering.

U-30
Fabrication of P(NIPAM-AM)@Au NRs hollow spheres for Near-Infrared Controlled Photothermal Drug Release
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Poly(N-isopropylacrylamide) (PNIPAM) is a typical thermoresponsive polymer, and it exhibits a lower critical solution temperature (LCST) at 32°C in water. The phase transition changes a PNIPAM linker brush from hydrophilic to hydrophobic, intervening in the interaction between the chains and water molecules. The PNIPAM chains interact with water molecules by hydrogen bonding below LCST, and hence remain in the swollen state. If the temperature is increased above the LCST, the chains are shrunken by the formation of intramolecular hydrogen bonding. Au NRs has unique optical and photothermal effect. If PNIPAM or its copolymer are coupled with Au NRs, P(NIPAM-AM)@Au NRs would exhibit the excellent Near-Infrared controlled photothermal drug release property.

P(NIPAM-AM)@Au NRs hollow spheres were prepared with SiO2 spheres as templates and the in-situ growth of Au NRs. The microstructure and micromorphology of P(NIPAM-AM)@Au NRs hollow spheres has been determined by FTIR, TGA, TEM and SEM. Meanwhile, P(NIPAM-AM)@Au NRs hollow spheres exhibit the high DOX loading capacity. At pH 7.4 and 37°C, the release ratio of Dox from the hollow spheres was 48.71% after 20h. When exposed to NIR laser irradiation, the accumulative releasing ratio of P(NIPAM-co-AM)/AuNRs hollow spheres was 76.79%.

U-31
Thermomechanical, Mechanical and Shape Memory Properties of Graphene Oxide /Styrene Based SMP Nanocomposite
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Northeast Forestry University

Graphene oxide/styrene based shape memory nanocomposites were prepared by in situ polymerization, styrene based shape memory polymer (SMP) was as the matrix and graphene oxide was as the active reinforcement. The monomers of the shape memory polymer consist of styrene, butyl acrylate and divinyl benzene. In order to
uniformly disperse the graphene oxide in the styrene solution, the surface of the graphene oxide were functionalizing treatment. The dispersion of the graphene oxide, thermal, mechanical and shape memory properties of the nanocomposites were analysis by TEM, SEM, TGA, mechanical experiments and shape-memory performance. The research results show that surface treatment of graphene oxide flake scattered in the styrene solution and it does not flocculate or reunited and in the composite material, the graphene oxide also exists in the form of the layer stack. The elongation at break of the composite material decreased with the increase of graphene oxide content and yang-style modulus increased. The thermal stability of the composite materials increased with the increase of the graphene oxide content.

U-32
2D Photonic Crystal Nanocomposite Hydrogel Membrane
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Taking advantage of optical performance of photonic crystal and rapid temperature-/swelling responsibility of nanocomposite hydrogel, a novel 2D colloidal crystal nanocomposite hydrogel membrane based on copolymerized microgel between styrene (St) and allylamine(AA) and poly(N-isopropylacrylamide) (PNIPAm)/nanoclay lithium magnesium silicate (LMSH) nanocomposite hydrogel was successfully synthesized. The poly(St-co-AA) microgel with diameter of 657 nm was firstly prepared by soap-free polymerization and then used to fabricate two-dimensional (2-D) monolayer nanoparticle arrays by the needle tip flow technique. Finally, the close-packed poly(St-co-AA) 2-D array monolayer was embedded into PNIPAm/LMSH nanocomposite hydrogel film. The chemical composition of poly(St-co-AA) microgel was confirmed by FTIR, NMR and XPS. The obtained 2D poly(St-co-AA) microgel observed by DLS, SEM, TEM and AFM presents highly monodisperse and well-ordered particle array, leading to vivid iridescent color. Under the stimulus of temperature from 25 to 35oC, poly(St-co-AA) particles present aggregation on account of constriction of nanocomposite hydrogel. During the process of swelling from 0 to 3.5 h, nanocomposite hydrogel present obvious red shift of the diffraction wavelength, indicating the neighboring spacing of the 2D opal hydrogel increased. The obtained samples can be used as sensing material for the visual detection of the water temperature or swelling process.

U-33
Machine-learning-assisted search for high electro-strain in BaTiO3-based ferroelectrics
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There is growing interest in accelerating the materials discovery process of finding materials with targeted properties by reducing the number of costly and time-consuming trial and error experiments. Machine-learning algorithms, which extract patterns between properties and material descriptors from known data, have been the recent choice to narrow the high-dimensional search space to find specific, desired materials. Three strategies can be employed to guide the next experiment: exploration that aims to accumulate data to improve the inference model, exploitation that selects the best-predicted property, and the balance trade-off between them such as efficient global optimization (EGO). As new experiments are always limited, identifying the best strategy to optimize targeted properties of materials is of great interests. In the present study, we chose the electro-strain in BaTiO3-based ferroelectrics as our modeled system to evaluate the above strategies. We employed algorithms of trial and error, exploration, exploitation and EGO to search for high electro-strain from 650000 probabilities based
on 60 known data. Our results shown that the algorithm of balance trade-off between exploration and exploitation outperformed the rest strategies and the electro-strain was improved by 53.3% with just three iterations.

U-34
CO2-switchable Polymers and Nanohybrids
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Polymer Research Institute, State Key Laboratory of Polymer Materials Engineering, Sichuan University

A major scientific challenge pertaining to polymers has been to craft smart switchable materials which can reversibly alter their structure and functionality on demand, in response to triggers produced by environmental changes. Among the triggers, CO2 has gained considerable attention owing to its wide availability, biocompatibility and free of contamination. Recently, we have been focusing on developing CO2-induced smart polymer and nanohybrid materials:

Switchable well-defined triblock copolymers and their assemblies.[1,2] These polymers contain hydrophilic PEO and a CO2-sensitive end blocks, in-between there is a strongly hydrophobic fluorine-bearing unit. Such polymers can form multicompartment micelles (MCMs) with a segregated corona, and can be switched “on” and “off” between MCMs and spherical micelles when sequentially treated with CO2 and N2. In the mixed solvent of water and ethanol, the aggregates self-assembled from the same copolymer evolve from spherical micelles to short rods, then long cylinders and finally WLMs when the volume ratio of water increases from 10% to 50%.

Switchable block-random segmented copolymers.[3,4] Both two structurally-similar and MW-equal terpolymers (full triblock copolymer, PEO45-b-PS66-b-PDEAEMA90; block-random segmented terpolymer, PEO45-b-P(St66-r-DEAEMA30)) can form polymersomes before CO2 treatment, but the vesicles resulted from the former do not change after uptaking CO2; instead, the vesicles from the latter would transfer into spherical micelles after reaction with CO2, but the spherical micelles cannot reversibly return back to vesicles. The segmented copolymer PEO113–b–P(4VP90–r–DEAEMA30) in aqueous media could self-assembly into vesicles firstly, which then fuse hierarchically into giant wormlike micelles; after bubbling CO2 into the copolymer solution up to saturation, the giant worms transform into polymersomes. The vesicles obtained could restore back to wormlike aggregates after depleting CO2 by N2.

Switchable amidian-containing copolymer and polymer/SWNTs hybrids.[5,6] An amidine-based polymer prepared by RAFT polymerization and “click” reaction undergoes a hydrophobic-hydrophilic transition upon the stimulus of CO2, and the hybrids of such a polymer and SWNTs shows reversible response in aqueous media upon alternate treatment of CO2 and N2.

Switchable polymer/graphene hybrids.[7-9] Graphene shows great potential for use in various applications, owing to its unique properties. However, the low dispersibility of graphene in water, given its hydrophobic nature, is considered an insurmountable problem that limits its use. Stably dispersed graphene using polymer dispersant containing a tertiary amine and a pyrene or melamine-based triamine group. The dispersant modifies the graphene surface, allowing it to be dispersed in water via π–π stacking. The dispersant undergoes a hydrophobic-hydrophilic transition upon being stimulated by CO2 and N2, exhibiting a faster response and lower recovery temperature (40 °C) than those of compounds with amidine-like structures.

Switchable honeycomb film.[10] We have developed honeycomb-patterned porous films with CO2-induced tunable and reversible surface wettability based on a series of diblock copolymers PS-b-PDMAEMA. Molecular hydrophilicity is found to play a crucial role in determining film structure, including pore size, porous layers, and regularity, and hydrophilic block PDMAEMA was observed to concentrate on inner surface of the pores providing CO2-responsive surface wettability. Furthermore, when original honeycomb film used as cell scaffolds, the
hydrophobicity of film surface can be changed into hydrophilicity in CO₂ atmosphere to enhance the interaction between film surface and cells during cell culture process, thus resulting in better cell attachment and proliferation.

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U-35
Research on abnormal physical properties of antiperovskite Mn₃XN compounds with strong spin-lattice coupling
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Antiperovskite structured Mn₃XN (X=Ga, Zn, Cu, Sn, etc.) have attracted great attentions due to their rich physical properties and important applications, such as giant magnetoresistance, negative thermal expansion(NTE), near zero temperature coefficient of resistance, and so on. Associated crystallographic and magnetic properties of the materials are highly intriguing in connection with mutual interactions among those freedom of lattice, spin, and charge. The band structure of Mn₃XN is significantly mediated by chemical bonding of MnN₆ octahedra, which forms a relatively narrow band. This probably results in rich varieties of electronic structure and physical properties of the materials because the conduction band of X highly overlaps with the narrow band.

In Mn₃ZnN, the Γ₅g AFM magnetic structure plays an important role in the near zero thermal expansion properties of Mn₃ZnN, Mn₃GaN, and Mn₃NiN. The mechanism will be discussed in detail about how to precisely control the zero thermal expansion of a single compound by achieving the special Γ₅g magnetic phase of Mn atoms. In addition, the pressure effect of Γ₅g AFM magnetic structure induced the baromagnetic effect in antiperovskite Mn₃Ga₀.₉₅N₀.₉₄. The macroscopic baromagnetic effect is 0.63 at 130 K around M-1 to Γ₅g magnetic transition by the hydrostatic pressure of 750 MPa. We will also show the large exchange bias effect observed in Mn₃CoN. In this work, neutron diffraction technique combined with Rietveld refinement to clarify the origin of the particular properties referred above, i.e. near zero thermal expansion, baromagnetic effect, large exchange bias, and so on.

U-36
Shape memory effect and superelasticity in two dimensional Li doped phosphorene
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The mechanical response under the external stimuli in atomically thin two-dimensional (2D) materials is highly desirable for nanoelectromechanical systems (NEMS) applications. Borrowing the idea from bulk materials, the larger strain outputs could be obtained from shape memory effects (SME) and superelasticity (SE) based on structural phase transition. However, these unique properties are still lacking in 2D materials up to date. 

METHOD: Here, by using density functional theory (DFT) based first-principles calculations, we report unexpected electric-field-induced reversible structural phase transitions as well as SME and SE effects in 2D Li doped phosphorene.

RESULTS: Two distinguishable structures had been found in two-dimensional Li doped phosphorene. Interestingly, applying electric fields can induce the recoverable phase transitions between these two structures. Such phase transitions can be explained from the energy competition between two phases under electric fields. Along with the structural phase transition, it is demonstrated the existence of (two-way) SME and SE in Li doped phosphorene. Consequently, these properties lead to a recoverable residual strain up to a 2.06% caused by SE, and a non-linear elastic strain up to a 6.2% caused by SE.

CONCLUSIONS: These novel SME and SE behaviors in Li doped phosphorene suggest a valid approach to obtain the larger strain outputs for 2D materials, which have potential applications in nano devices using mechanical response to high-frequency electric fields.

Poster

U-P01
Sensing an inhomogeneous strain due to the surface relief in FeNiCoTi shape memory alloy by using graphene
LiQiang Zhang, Lishan Cui;
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In this study, we present a novel method of using graphene for sensing the inhomogeneous strain due to the surface relief in FeNiCoTi shape memory alloy. In the experiment, a large sheet of graphene fabricated by chemical vapor deposition was transferred onto the FeNiCoTi substrate. The flat surface of the substrate would become winkle due to the surface relief formed during the FeNiCoTi substrate phase transformation, meanwhile loading a tensile strain on the surface graphene. It is found that the 2D Raman peak of graphene demonstrates a significant red shift due to the tensile strain. The different colors exhibited in the Raman mapping image of the graphene directly displayed the strain distribution information across the surface. In the future, we may alter to quantitatively analyze the surface relief by using Raman spectroscopy instead of the atomic force microscopy.


U-P02
Fabrication and magnetostrictive properties of large-size TbDyFe alloy
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Rods of TbDyFe giant magnetostrictive alloys D10 (the sample diameter is 10mm) have been prepared by magnetic levitation induction melting and zone melting directional solidification methods with the different solidification rates of 2.5mm/min, 3.5mm/min, 4.5mm/min, 5.5mm/min, respectively. It was found that the largest
The value of magnetostriction coefficient for D10 was achieved at the rate of 3.5 mm/min. Therefore, D30 (the sample diameter is 30mm) was produced by the same way with solidification rate of 3.5mm/min, followed with 2h annealing at the temperature of 1050℃. Results showed that the magnetostriction coefficient of D30 was slightly lower than that of D10 while the diameter tripled. The saturation magnetification coefficient of D30 reached 1046ppm at the magnetic field of 1500Oe at the pressure of 5MPa.

**U-P03**
The influence of Nb content on the corrosion behavior of NiTiNb shape memory thin films
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NiTiNb shape memory thin films with various Nb contents were sputter-deposited onto Si(100) substrates. To evaluate the influence of different Nb contents on the corrosion behavior of the NiTiNb films in 3.5wt.% NaCl solution, energy dispersive spectroscopy(EDS), X-ray diffraction(XRD), atomic force microscopy(AFM) and electrochemical measurements including open-circuit potential(OCP), potentiodynamic polarization and electrochemical impedance microscopy(EIS) were carried out after complete crystallization at 600℃. The films were composed of both NiTi(Nb) and Nb-rich grains. AFM results indicated that the film with an intermediate Nb content of 16%(at.%) shows the smallest surface roughness. Electrochemical tests proved that the above film shows the best corrosion behavior as well. The above phenomenon may be attributed to the distribution of the grain sizes of NiTi(Nb) and Nb-rich grains.

**U-P04**
Synthesis of Cs₅WO₃ and its near-infrared absorbing properties
Xiaopeng Cui, Zhang Chen, Yanfeng Gao;
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Development of Cs₅WO₃ is important for smart-window applications. In this work, nanoparticles of Cs₅WO₃ were successfully synthesized and characterized by UV-VIS-NIR transmittance spectroscopy, X-ray diffraction, scanning electron microscopy and energy dispersive spectroscopy. In order to achieve good dispersion of Cs₅WO₃, the influences of solvents and dispersant on the dispersion stability of Cs₅WO₃ particles were investigated. The results indicate that adding appropriate dispersant is conducive to dispersion of Cs₅WO₃. The Cs₅WO₃ coatings have a strong near-infrared shielding ability as well as high transparency in the visible light region, the film exhibits 5% transmittance at 950 nm and over 70% transmittance at 550 nm, and the haze is less than 1%.

**U-P05**
Perspective Smart Matters for Application in Cementing Slurry
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Technology transfer becomes one of the most important means of innovation in multidisciplinary fields. We mainly discuss the properties and prospect of several smart matters for cementing slurry.
Based on the material requirements in drilling engineering and mechanism analysis, we select several smart matters as alternative candidates.

Result
Cementing slurry is used to fill the annulus between the casing and wellbore during drilling process. A successful drilling well is dependent on the quality of the cementing job. The primary components of the cementing slurry are Portland cement and various additives. Here we mainly discussed several smart matters that serve as additives in the cementing slurry. Introduction of smart matters has become the important means of technology innovation in drilling engineering. Bacteria could potentially act as a self-healing agent in concrete. The bacterial mineral precipitation effectively repair the defects and cracks, i.e. significantly reduces the permeability of cracked concrete in order to protect the embedded reinforcement from corrosion and thus increases the durability of the concrete. Micro-electro-mechanical systems (MEMS) have been used in set-delayed cementing compositions. The cementing slurry comprising MEMS includes several sensors which could provide information about the cement setting as well as wellbore or subsurface conditions (including temperature, pH, moisture, ion concentration, etc.). At high-pressure, high-temperature (HPHT) conditions, the choice of cementing slurry becomes more difficult, because achieving desired mechanical and rheological properties of cement becomes harder and more complex. The multi-walled carbon nanotubes (MWCNT) could improve the rheological properties of cementing slurry and therefore their displacement efficiency at HPHT conditions.

Conclusion
Above mentioned features of smart matters can potentially be exploited to optimize certain behaviors to provide better performance in the wellbore environment.

U-P06
Synthesis, characterization and phase transition property of VO₂(M) nanostructures
Yasi Fang;

Cucumber-shaped and aggregate- like VO₂(M) nanostructures were synthesized successfully by a hydrothermal-calcination method only using NH₄VO₃ and H₂C₂O₄·2H₂O as the raw materials. First, cucumber-shaped VO₂(D) nanoparticles or nanoaggregates were synthesized by surfactant- free hydrothermal reduction of ammonium metavanadate by oxalic acid at 160~220 ℃. Then, the produced VO₂(D) was further calcined at 250~500 ℃ to obtain the cucumber- shaped VO₂(M) nanoparticles or nanoaggregates. To understand the hydrothermal reduction processes, both in situ powder X-ray diffraction (in situ PXRD) and ex- situ characterization were carried out. The results indicate a sequential process starting from reduction of ammonium metavanadate and nucleation of the vanadium precursor, followed by the formation of intermediate VO₂(B) nanosheets, and finally the phase transformation from VO₂(B) to VO₂(D) with a variety of morphologies. A crystal growth mechanism based on self - assembly and Ostwald ripening was proposed to explain the formation process of these unique nanostructures. The as-prepared VO₂(M) exhibited lower thermochromic phase transition temperature (47.0 ℃) and narrower thermal hysteresis width (6.6 ℃) than those nanopowders prepared by other methods. These results provide a low- cost way to prepare the VO₂(M) in a large scale, and show potential applications in the smart windows.

U-P07
To obtain as-casting La-Fe-Si magnetocaloric alloys with a dual-phase microstructure
Liang Yang, Zhenni Zhou, Jun Li, Qiaodan Hu, Jianguo Li;
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NaZn$_{13}$-type La(Fe,Si)$_{13}$ alloy is a promising material in magnetic refrigeration, because it will exhibit a itinerant electron meta-magnetic phase transition, resulting in a giant magnetocaloric effect. But this alloy is blocked in the industrial use due to its poor mechanic property, low thermal conductivity and difficult formation. Current research has shown off-stoichiometric La-Fe-Si alloys can exhibit enhanced properties due to the existence of extra alpha-Fe phase. However, there is still no La(Fe,Si)$_{13}$ phase generated in as-cast alloys. It also demands days of high-temperature annealing to obtain large volume fraction of La(Fe,Si)$_{13}$ phase. In this work, as-casting stoichiometric La-Fe-Si magnetocaloric alloys with the similar dual-phase microstructure have been produced directly by zone melting liquid metal cooling directional solidification. The dual-phase microstructure is composed of ~60% La(Fe,Si)$_{13}$ phase, and the remnant is alpha-Fe phase. Besides, alpha-Fe dendrites are observed mostly parallel to the solidification direction. The mechanic ability appears much better than single-phase La-Fe-Si alloys. The thermal conductivity for La-Fe-Si alloys with such dual-phase microstructure is ~7.5 W/mK at 220K, which has been enhanced a lot compared with the existing results.

**U-P08**

**Synthesis of V-ZrSiO$_4$ Ceramic Pigments from Gels**

Xue Di, Yanfeng Gao;
Shanghai University

A procedure is reported for the preparation of vanadium-doped zircon blue pigments by an extraordinary two-step route. Vanadium-zircon solid solution were prepared by gelling a mixture composed of ZrOCl$_2$·8H$_2$O, Na$_2$SiO$_3$·9H$_2$O and NH$_4$VO$_3$ and heat treatment of gels. Pigments were characterized by X-ray powder diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), selected area electron diffraction (SAED) and colourimetry (CIE Lab). The tetragonal V-ZrSiO$_4$ solid solution was obtained after hydrothermal treatment at 220°C, dark blue colour was observed after further heat treatment at 1000 °C. This procedure can be used for the preparation of V-ZrSiO$_4$ pigments of high-purity and controlled particle size (0.5 μm).

**U-P09**

**Synthesis and conductivity properties of Gd$_{0.8}$Ca$_{0.2}$BaCo$_2$O$_{5+\delta}$ double perovskite by sol-gel combustion**

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Double perovskite oxides Gd$_{0.8}$Ca$_{0.2}$BaCo$_2$O$_{5+\delta}$ have been successfully prepared by EDTA-citrate complexation process. The prepared samples were characterized by means of thermogravimetry-differential analysis, X-ray diffraction, Fourier transform infrared spectroscopy techniques. These analyses suggested that pure Gd$_{0.8}$Ca$_{0.2}$BaCo$_2$O$_{5+\delta}$ phase could be formed when the pH value was maintained above three and calcination temperature was higher than 850°C. The conductivity properties analyzed by means of four probes method, scanning electron microscopy and X-ray photoelectron spectroscopy indicated an improvement in conductivity with a high value of nearly 1200 S/cm, which was due to an increase in the number of small polaron hopping
conduction units, Co\(^{3+}\)-O-Co\(^{4+}\). Interestingly, the Gd\(_{0.8}Ca_{0.2}BaCo_2O_{5+x}\) samples exhibited a semiconducting behavior through a wide range of temperature below 100\(^\circ\)C and a metallic behavior at 100-500\(^\circ\)C, thereby demonstrating that Gd\(_{0.8}Ca_{0.2}BaCo_2O_{5+x}\) could fulfill the requirements in regard to intelligent and electrical properties for desired applications.

U-P10

Strain induced martensite stabilization and shape memory effect of Ti-20Zr-10Nb-4Ta alloy
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The phase transformation, the microstructure and the shape memory effect of the Ti-20Zr-10Nb-4Ta alloy are investigated. The X-ray diffraction measurements indicated that the alloy is composed of single orthorhombic \(\alpha''\)-martensite. The alloy showed a two-stage yielding behavior upon tension at 0.5 % and 6% strain with a yield stress of 215 MPa and 565 MPa, respectively. The strain induced martensite stabilization was identified because the reverse martensite transformation start temperature of the alloy increases from 348 to 405 K, with the pre-strain increasing from 0 to 8 %. This can be ascribed to the martensite reorientation that occurred at a low strain level and the dislocations formed at a large strain level. The maximum shape memory strain is 3.3 % in the Ti-20Zr-10Nb-4Ta alloy.

U-P11

Micro-abrasion-corrosion behaviour of a biomedical Ti-25Nb-3Mo-3Zr-2Sn alloy in simulated physiological fluid
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The micro-abrasion-corrosion behaviour of the biomedical Ti-25Nb-3Mo-3Zr-2Sn alloy in Hank’s solution with protein has been investigated using electrochemical measurements, tribological tests and scanning electron microscope (SEM) observations. The potentiodynamic polarization tests showed that the corrosion potential \((E_{corr})\) exhibits the maximum value at the abrasive concentration of 0.05 g·cm\(^{-3}\) despite of the load level. The tribological results indicated that the total material loss of the Ti-25Nb-3Mo-3Zr-2Sn alloy during micro-abrasion increased with the increasing abrasive concentration at a certain applied load. When the abrasive concentration is no more than 0.15 g·cm\(^{-3}\), the total material loss increases with increasing load, while the total material loss exhibits the maximum value at a moderate load in case of higher abrasive concentration levels. This was ascribed to the three-body or two-body micro-abrasion-corrosion at different abrasive concentration levels. The wastage map, abrasion mode map and synergy map associated with the applied load and the abrasive concentration were constructed to evaluate the micro-abrasion-corrosion behaviour of the Ti-25Nb-3Mo-3Zr-2Sn alloy in potential biomedical applications.

U-P12

Microstructure and magnetostriction of Tb-doped Fe-Ga alloys
Weina Zhao, Jianrong Gao;
Fe-Ga alloys have attracted much attention because of their large magnetostriction under a low magnetic field\textsuperscript{[1-3]}. It was found that doping of rare earth element Tb can enlarge the magnetostriction of Fe-Ga alloys\textsuperscript{[2]}. However, the underlying mechanism has not been fully clarified yet. In this work, we investigated microstructure and magnetostriction of a series of Tb-doped Fe-Ga alloys to produce insight into the role of Tb alloying. Alloys of Fe\textsubscript{83}Ga\textsubscript{17}Tbx (x = 0, 0.1, 0.3, 0.5, and 1) compositions were prepared by arc-melting of high-purity elemental materials under protection of an argon atmosphere. Then the alloys were sealed in a quartz tube and annealed at 1173 K for 2 h. The annealed alloys were quenched into water. The magnetostriction of the annealed alloys were measured as a function of the applied magnetic field using strain gauges and an electromagnet. The phase constituents of the annealed alloys were determined by means of the power X-ray diffraction (XRD) analysis using Cu-Ka radiation. The microstructure of the annealed alloys were investigated using a scanning electron microscope (SEM). Chemical compositions of bulk alloys and local regions were analyzed by means of X-ray energy-dispersive spectrometry (EDS) attached to the SEM. The strain measurements showed that the magnetostriction of the alloys depends strongly on the bulk Tb content. The alloy with bulk Tb content of x =0.3 exhibits a maximum magnetostriction of about 80 ppm in a magnetic field of 1 T. The XRD analysis revealed that Tb-doped alloys consist of a bcc phase and a rhombohedral phase of Tb\textsubscript{2}(Fe,Ga)\textsubscript{17}\textsuperscript{[3]}, which is especially evident for alloys with high Tb content. The lattice parameters of the bcc phase was found to decrease continuously with increasing Tb content. SEM investigations revealed that the Tb\textsubscript{2}(Fe,Ga)\textsubscript{17} phase appears to be isolated dots in the alloys with low Tb content, but exhibit a network-like morphology in the alloys with high Tb content. It was suggested that the enlargement of magnetostriction of Fe-Ga alloys by Tb doping might not be due to a change of the intrinsic properties of the bcc matrix phase, but due to a change of microstructure.

U-P13
Design of High Temperature Ti-Pd-Cr Shape Memory Alloys with Small Thermal Hysteresis
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The large thermal hysteresis ($\Delta T$) during the temperature induced martensitic transformation is a major obstacle to the functional stability of shape memory alloys (SMAs), especially for high temperature applications. We propose a design strategy for finding SMAs with small thermal hysteresis. That is, a small $\Delta T$ can be achieved in the compositional crossover region between two different martensitic transformations with opposite positive and negative changes in electrical resistance at the transformation temperature. We demonstrate this for a high temperature ternary Ti-Pd-Cr SMA by achieving both a small $\Delta T$ and high transformation temperature. We propose two possible underlying physics governing the reduction in $\Delta T$. One is that the interfacial strain is accommodated at the austenite/martensite interface via coexistence of B19 and 9R martensites. The other is that one of transformation eigenvalues equal to 1, i.e., $\lambda^2 = 1$, indicating a perfect coherent interface between austenite and martensite. Our results are not limited to Ti-Pd-Cr SMAs but potentially provide a strategy for searching for SMAs with small thermal hysteresis.

U-P14
Facile Preparation of Hierarchical Sn-doped WO\textsubscript{3} Nanomaterials with Enhanced Gas-sensing Properties
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Doping is a kind of an efficient strategy to improve semiconductor characteristics through introducing impurity levels in the bandgap, which has been widely used in the field of gas-sensor, electronic devices, solar cell, photocatalysis, etc. Here, Sn-doping micro-/nano- structures have been prepared by a facile solvothermal method in order to enhance carrier migration, sensitivity and selectivity of WO$_3$ sensors. The influence of tin incorporation on morphology, band structure and gas-sensing property has been investigated in detail. SEM shows that tin incorporation in WO$_3$ structure results in the morphology evolution from nanosheet, nanorod, and then into nanosheet. XRD and Raman show that Sn-doped WO$_3$ induces the phase transformation from monoclinic WO$_3$ to monoclinic WO$_3$. UV-vis spectrum shows that the implantation of tin incorporation results in the increase of the bandgap and the shift of absorption edge. Sensing experiment shows that the sensitivity towards 500 ppm ethanol increases with the increase of Sn contents, while the response time decreases continually. However, recovery time decreases firstly and then increases at 4 at.% Sn-doping. The results reported in this study will be useful in formulating optimum doping process to enhance desired gas-sensing properties.

**U-P15**

**Synthesis and phase transition properties investigation of W-doped vanadium dioxide**

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In order to effectively protect the environment, various efforts have been devoted to develop energy-efficient materials for the intelligent energy-efficient windows. In recent years, the vanadium dioxide (VO$_2$) has been found to be a good candidate serving as the intelligent energy-efficient materials. VO$_2$ undergoes a reversible metal-insulator transition from metal to monoclinic insulator, accompanying a structural transition from high-temperature rutile VO$_2$(R) to low-temperature monoclinic VO$_2$(M). In addition, it has been revealed that the phase transition temperature for VO$_2$ can be modulated through doping certain content of special elements such as W and Mo. However, some problems have not been resolved for the practice use. Because the radius of the doped W is quite larger than that of V, the doped W atoms cause severe lattice distortion in VO$_2$ and degrades the mechanical and some of the other properties, because of the high annealing temperature, synthesized VO$_2$ particles were sintered together seriously. So, it is still a challenge to explore an effective and safe scheme of producing durable VO$_2$ material serving as the energy-efficient windows at room temperature. More efforts should be devoted to refining growth techniques, to enhancing the optical transmittance by doping or developing multilayer structure with other oxide. In this work, we developed a new synthesis method for VO$_2$ nanoparticles with good dispersion. Effects of the sol-gel synthesis parameters containing air pressure, annealing time and annealing temperature on the structural phase transition and phase transition temperature of vanadium dioxide were investigated. Pure M phase W doped and un-doped vanadium dioxide was successfully synthesized. Excitingly, a large transition temperature adjustment are obtained by this method. This provides a promising perspective for the VO$_2$-based material serving as energy-efficient windows. The mechanism of microstructure and phase transition property changes are also discussed.
NiTi shape memory alloys (NiTiNOL) have been widely used in different fields of aerospace and medicine because of unique shape memory effect and superior mechanical properties. Since the as-cast NiTiNOL ingot is not ductile enough and does not show significant shape memory effect, the hot working, which can effectively reduce the working load, break the cast structure and enhance the ductility, is a necessary process during the NiTiNOL manufacture, which has been a hot research focus recently. However, the hot compression deformation test was widely applied for the details of flow stress behavior and microstructure developments of NiTiNOLs, the clear microstructure characteristic and evolution of NiTi alloy during the hot deformation are still limited.

In this paper, the mechanisms of plastic deformation and dynamic recrystallization (DRX) in a 50Ti-47Ni-3Fe alloy are studied with processing maps and electron backscatter diffraction (EBSD). The compression tests are carried out at temperature of 1023-1323 K with strain rates of 0.01 - 10 S⁻¹, the total strain of 0.7. The stress behavior can be described by constitutive equation with the Zener-Hollomon (Z) parameter, which is the factor of strain rate of compensated with temperature, \[ Z = \exp\left(\frac{Q}{RT}\right) = A[\sinh(\alpha \sigma)]^n \]. Where \( \sigma \) is strain rate (S⁻¹), \( A \) and \( \alpha \) are material constants, \( n \) is the stress exponent, \( Q \) is activation energy (J·mol⁻¹), \( R \) is gas constant and equal to 8.3145(J·mol⁻¹·K⁻¹), \( T \) is the deformation temperature(K). The average \( Q \) of 252 KJ/mol is obtained which is comparable to the early reports. The relationship between \( Q \) and deformation conditions reveals that the activation energy for hot deformation is quite sensitive to the deformation conditions, as it increased with the raise of temperature 800°C to 950°C and strain rate. With the temperature increasing, the rearrangement and annihilation of dislocation easily occur to improve DRV, which delays and inhibits the recrystallization occurs, and the start energy for recrystallization was elevated. The increasing of activation energy means the recrystallization is the main factor of activation energy before 950°C. Similarly, the increasing of strain rate might induce more tangled dislocation structure as barriers to dislocation restoration due to the relatively lesser amount of time for dislocation polygonization, which also reduced the retardation of recrystallization.

The processing map of NiTiFe alloy was built and shows an unstable region and two energy dissipation peak areas. The peak energy dissipations in the processing map are only about 30%, which strongly indicated the dynamic recovery was control the microstructure evolution. The microstructure of deformed samples was carefully observed by OM and EBSD. Under the low temperature (750°C) and high strain rate (10s⁻¹), which was the unstable region in the processing map, the shear bands formed by severe flow localization was found. While, a clearly evidence of dynamic recrystallization was obtained by EBSD in the energy dissipation peak areas, 950°C, 0.01s⁻¹ and1050°C, 10s⁻¹. The dynamic recrystallization mechanism and the microstructure evolution was tracked by the change of low angle boundaries (LABs) and high angle boundaries (HABs) in different grain orientation spread (GOS) value grains shows the track of the microstructure evolution of deformed grains, and the CDRX model is confirmed based on the development of recrystallizing grain boundaries.
The microstructure, phase transformation and shape memory properties of Ti-30Zr-xNb (x=5, 7, 9, 13 at.%) alloys were investigated. The Ti-30Zr-5Nb alloy was composed of hcp $\alpha'$-martensite with a high martensitic transformation start temperature of 776 K, and the corresponding reverse martensitic transformation start temperature was 790 K. The Ti-30Zr-7Nb and Ti-30Zr-9Nb alloys were predominated by orthorhombic $\alpha''$-martensites, while the Ti-30Zr-13Nb alloy consisted of a single $\beta$ phase, indicating the $\beta$-stabilizing nature of Nb in Ti-30Zr-xNb alloys. For the Ti-30Zr-7Nb and Ti-30Zr-9Nb alloys, the martensitic transformation temperatures decreased with the increasing Nb content, and the $\omega$ phase transformation occurred upon heating. Among all of the alloys, the Ti-30Zr-9Nb alloy showed the lowest critical stress of 300 MPa in tension and the maximum shape memory effect of 1.61%.

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Internal friction behaviors of dual-phase Ni-Mn-In magnetic shape memory alloy with two-step structural transformation
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Shape memory alloys (SMAs) undergo reversible diffusionless solid-to-solid transformations between two distinct phases in response to changes in external fields, such as temperature, applied stress or magnetic field, in which the atoms orderly rearrange to create internal interfaces moving through crystals. As for the Heusler-type Ni-Mn-Z (Z=In, Sn, Sb) magnetic shape memory alloys (MSMAs), they are different from traditional, thermally activated SMAs because of a strong magnetoelastic coupling during the magnetic field induced martensitic transformation from ferromagnetic austenite to paramagnetic/antiferromagnetic martensite. The unique structural transformation leads to their multi-functionalities, such as large magnetic-field-induced strain, inverse magnetocaloric effect, giant magnetoresistance effect and high magnetothermal conductivity, extending many practical applications in high-performance actuators, and environment-friendly magnetic refrigerator, magnetically controlled damper, etc. More recently, another emerging use for the MSMAs is in energy harvesting, that is, capturing energy from waste, environmental, or mechanical sources and converting it into a usable form, such as mechanical vibration energy at low frequencies during walking, because of a significant magnetization change in the MSMAs as a response to changes of external fields.

It is clear that all of the abovementioned applications are associated with the creation and motion of the internal interfaces, which can be characterized by the internal friction (IF) behaviors. Therefore, a knowledge of the IF behaviors is crucial for a deeper understanding of the physical mechanisms behind the multifunctional properties of the MSMAs.

In recent years, much effort has been put to extend the study of the IF behaviors in Ni-Mn-Ga alloys by means of dynamic mechanical analysis (DMA). In the off-stoichiometric Ni-Mn-Ga alloys, the IF behaviors exhibit strong dependences on transformation temperatures, stress amplitude, frequency, and temperature rate. Conventionally, these alloys can be classified into three groups according to the transformation temperatures, of which the IF behaviors are thus different both in the martensitic state and within the transformation region. For Group I alloys, the transformation temperature ($T_t$) is well below room temperature, certainly is far below the Curie temperature ($\approx 380K$). Therefore, they undergo the premartensitic transformation from the austenite phase to a micro modulated cubic premartensitic phase, which exhibits a weak first-order precursor phenomenon associated with the phonon softening, resulting in an IF peak and a minimum of the elastic modulus. For single crystalline alloys of Group III ($\gamma$), some intermartensitic transformations (IMT) are presented on cooling, but this is not the case for fine grained
polycrystals, due to the higher accommodation stresses at grain boundaries than that of single crystals during the transformation. Alloys belonging to Group II (close to room temperature) do not show such well-defined behaviors due to their high sensitivities of thermomechanical treatments, microstructure and external fields. These early studies have proven that the IF behavior is a powerful tool that to detect the existence of transformation phenomena and throwing new light on their structural mechanisms.

Compared with the well-studied Ni-Mn-Ga alloys, the study of the IF behaviors in Ni-Mn-In alloys is rare because of their inherent brittleness. Fortunately, in our previous work, a good ductility of 6.6% was achieved in dual phase \((\beta-\text{Ni}_{51.8}\text{Mn}_{31.4}\text{In}_{16.8} \text{ and } \gamma-\text{Ni}_{62.4}\text{Mn}_{32.4}\text{In}_{5.1})\) Ni_{52}Mn_{32}In_{16} alloy prepared by directional solidification. Interestingly, an IMT from 10 M to 14 M modulated martensite was also presented in this alloy. This kind of two-step structural transformation also sets the IF responses apart from that of Ni_{2}Mn_{Ga}-type MSMAs. More recently, we reported that a high isothermal IF over a large temperature range is obtained in the dual-phase Ni-Mn-In alloy. In this work, the low-frequency IF behaviors of the directionally solidified Ni_{52}Mn_{32}In_{16} alloy are systemically investigated to determine their dependences on external fields including the frequency and the heating/cooling rate. The effects of the second phase \((\gamma)\) on the IF responses are qualitatively discussed.

\[\text{Ni}_{51.8}\text{Mn}_{31.4}\text{In}_{16.8} \text{ and } \gamma-\text{Ni}_{62.4}\text{Mn}_{32.4}\text{In}_{5.1})\] Ni_{52}Mn_{32}In_{16} alloy prepared by directional solidification. Interestingly, an IMT from 10 M to 14 M modulated martensite was also presented in this alloy. This kind of two-step structural transformation also sets the IF responses apart from that of Ni_{2}Mn_{Ga}-type MSMAs. More recently, we reported that a high isothermal IF over a large temperature range is obtained in the dual-phase Ni-Mn-In alloy. In this work, the low-frequency IF behaviors of the directionally solidified Ni_{52}Mn_{32}In_{16} alloy are systemically investigated to determine their dependences on external fields including the frequency and the heating/cooling rate. The effects of the second phase \((\gamma)\) on the IF responses are qualitatively discussed.

**Prepare Chitosan/SMA/ Semi-Coke Responsive Membrane on pH for Adsorption Copper Ions from Wastewater**

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Chitosan/SMA/Semi-coke Composite membranes were prepared by coke modification and chitosan/SMA(styrene maleic acid copolymer) crosslinked for removal and recovery of Copper(II) from wastewater. Chitosan was used for trigger by pH responsive, then semi-coke was used for vessel of adsorption reactor, SMA was responsive membrane.

The Cs/SMA/Sc was prepared from chitosan, SMA, semi-coke network gel by casting method. A 2% acetic acid solution of chitosan, SMA, semi-coke powder was mixed at a given temperature, then distilled, and activated by 4% sodium hydroxide solution. Adsorption and desorption of copper ions from wastewater were tested by using composite membrane and change pH of solution.

Some effects of factors were studied on making composite membrane. The adsorption experiments were carried out to investigate the effect of different adsorption parameters, such as contact time, pH, initial concentration and temperature in state system. The effect of solution pH on the adsorption of copper ions was studied. The results shown that Cu(II) removal yield was increasing with pH increase until pH 8, and decreasing slightly with pH increase. The pH effect in chitosan was drastic with Cu(II) removal close to 90% at pH 8 in contrast to 6% at pH 10. The kinetic and equilibrium data were well described by pseudo-second-order and Langmuir models, respectively. The result shows that semi-coke/chitosan composite membrane have a synergistic effect for Copper(II) removal from wastewater. The prepared membranes were characterized by FTIR, XRD, SEM and BET.
analysis. Thermodynamic parameters were evaluated to obtain the nature of adsorption process onto the Sc/Cs composite micro-membrane. The Cs/SMA/Sc composite membrane is an effective copper ions sorbent, and is most effective in the pH range 8-10. The maximum capacity of Cs/SMA/Sc was 87.15 mg of Cu(II) per gram of composite membrane. The Cs/SMA/Sc membrane can reused five sorption–desorption cycles, and have promising potential use.

Synthesis of biotinylated pH-sensitive Glycopolymers for controlled release of Bortezomib
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Two pH-sensitive Glycopolymers with the same components but with different construction tailored biotin functionalities were developed for controlled release of bortezomib (BTZ). The initiator brominate biotin and glyco-monomer were synthesized precedentely to produce the block- and random- biotinylated poly(2-Gluconamidoethyl methacrylate)-poly(2-Diethylaminoethyl methacrylate) (block/random Biotin-PGAMA-PDEA) via atom transfer radical polymerization (ATRP). The construction and composition of compounds and polymers were characterized by 1H NMR Spectroscopy. The block copolymer self-assembled into micelle according to the pH-response ability of the copolymer, the size of the assembly of two copolymer aforementioned characterized by dynamic light scattering. Based on the dynamic complexing between boric acid group and glyco-segmer, as well as the functionality of micelles to deliver drugs, the performance of copolymers mentioned-above about the loading and controlled release of BTZ was studied, and it indicated that the drug carriers comprising GAMA and DEA have high loading efficiencies and achieve the controlled release, moreover the complexing between BTZ and GAMA is the major mechanism of the loading and release.

Constitutive analysis of the hot deformation behavior of NiTiNb shape memory alloy
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General Research Institute for Nonferrous Metals

The characteristics of isothermal deformation behavior of Ni_{47}Ti_{44}Nb_{9} shape memory alloys were investigated by thermal simulation tests, which were performed on Gleeble-3500 thermal simulation machine. The range of deformation temperatures was 800°C to 1050°C and that of strain rates was 0.01s^{-1} to 10s^{-1}. The stress-true strain curves were corrected by considering deformation-heating and friction. There are notable difference between corrected stress and uncorrected stress under strain rate of 1s^{-1} and 10 s^{-1} or and 800°C and 850°C. The results show that the flow stress increases with the decrease of deformation temperatures or the increase of strain rates. The constitutive relationship of hot deformation was established on the basis of the Arrhenius equation and the average activation energy of 206 KJ/mol was obtained.

Crosslinking Degree of the pH-Responsive shell cross-linked micelles with tunable cross-linking strategy for the Loading Efficiency and Loading Content of Doxorubicin
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Detailed studies were performed to probe the effects of the crosslinking degree of pH-responsive shell cross-linked (SCL) micelles with tunable cross-linking strategy on the loading efficiency and loading content of doxorubicin (DOX). Well-defined poly[(ethylene glycol)-block-2-(dimethylamino)ethyl methacrylate-block-2-(diethylamino)methacrylate] (PEG-b-DMA-b-DEA) triblock copolymer was synthesized via atom transfer radical polymerization (ATRP) by successively polymerization of DMA and DEA monomers using a PEG-based macrominitiator, and obtained copolymer was then converted to be PEG-b-P(DMA-co-QDMA)-b-PDEA copolymer with “clickable” moieties in the middle block by the quaternization with propargyl bromide. These triblock copolymers dissolved molecularly in acidic solution; micellization occurred at alkaline solution to form three-layer “onionlike” micelles comprising DEA cores, DMA inner shells, and PEG coronas. Two types of cross-linker bearing azide group: 1, 6-bisazidehexane and bis-(azidoethyl)disulde were prepared and then utilized to prepare a series of crosslinking degree SCL micelles by cross-linking the self-assembly of PEG-b-P(DMA-co-QDMA)-b-PDEA copolymer via click chemistry at basic aqueous media, respectively. The results show SCL micelles possess excellent stability at physiological condition (Dh ≈ 80 nm by DLS) and admirable swelling property at acidic solution (Dh ≈ 130 nm by DLS), but exhibit tunable disintegrated behaviors by introduction of different cross-linkers bearing stable, cleavable, or degradable covalent bonding at mimicking tumor microenvironment. Otherwise, as the crosslinking degree increase, the average hydrodynamic diameter two types of SCL micelles (SCL micelles 1 were cross-linked by 1,6-bisazidehexane and SCL micelles 2 were cross-linked by bis-(azidoethyl)disulde) were almost no change. In addition, the size of the two kinds of SCL micelles were similar at the same crosslinking degree, and it clearly proof no variation of loading efficiency and loading content of doxorubicin (DOX) when SCL micelles 1 or SCL micelles 2 with different crosslinking degree were used as drug delivery nanocarriers, respectively. However, the load capacity of SCL micelles 1 was more outstanding, since the alkyl group has better hydrophobicity than the sulfur bond. These studies have some guidance for the future research on the effects of the crosslinking degree on controlled drug release.

Preparation and Characterization of Stimuli-responsive Poly(N-isopropylacrylamide)/Sodium Alginate Hydrogel Fiber by Microfluidic Spinning

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Smart hydrogel is a kind of new soft and wet material which can be responsive to external stimuli. Hydrogel fiber owning one dimension size can significantly improve response speed. Also, it can be easily formed into higher-order assemblies, which has many potential applications such as delivery of drugs or cells, artificial muscle and tissue engineering. In this paper, Poly (N-isopropyl acrylamide)/calcium alginate (NAC) hydrogel fiber was prepared by microfluidic technique and subsequent off-chip free radical polymerization. A new kind of microfluidic device combining glass capillary and poly (dimethyl siloxane) (PDMS) connector was fabricated for forming a stable coaxial laminar flow of two fluids. The NIPA/SA pre-gel solution for core fluid and CaCl2 solution for sheath fluid were introduced into microfluidic device respectively. At the interface of both fluids, sodium alginate in core fluid met with Ca2+ and solidified quickly by ionic crosslinking, thus forming as-spun fiber in the outlet pipe. Then NAC hydrogel fiber was prepared through off-chip free radical polymerization of NIPA in the presence of calcium alginate. Finally, NAC hydrogel fiber was immersed in Na2CO3 solution to prepare Poly(N-isopropyl acrylamide)/sodium alginate (NA) hydrogel fiber. By regulating core and sheath flow rates, the diameter of hydrogel fiber could be altered. The structure and morphology of the hydrogel fiber were
characterized by FTIR and SEM. The temperature-/ electro- response behavior were also investigated. The results show that the NA hydrogel fiber has a circular cross-section and three-dimensional network porous structure. The VPTT of the hydrogel fiber is about 32°C. Meanwhile, the hydrogel fiber shows bending behavior under a non-contact DC electric field. The smaller the diameter of the hydrogel fiber is, the faster it bends.