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Program

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Zoom-Meeting
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Meeting ID: 878 1441 7432
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16^{00}	09^{00}	**Welcome notes**
16^{10}	09^{10}	**Zahra Sabeti** Investigation of the microstructure and mechanical properties of directionally solidified novel eutectic V-Si-B alloys
16^{35}	09^{35}	**Lars Thielemann** Temperature-dependent mechanical properties of heat-treated eutectic V-9Si-6.5B+Cr alloys
17^{00}	10^{00}	**Dennis Zang** Powder metallurgical investigations on Mo-V-Si-B alloys doped with titanium
17^{25}	10^{25}	**Ievgen Solodkyi** Alloy formation and microstructure evolution in the Mo-Ti-Si system during SPS
17^{50}	10^{50}	**Break**
18^{00}	11^{00}	**Shiquan Zhang** Microstructure and mechanical properties of Ta-Ti alloy by plasma-activated sintering
18^{25}	11^{25}	**Junfeng Du** The effects of microstructure on the tensile properties and micro-fracture behavior of MoSiBTiC alloys at room temperature
18^{50}	11^{50}	**Shuntaro Ida** Elastic moduli and toughness of B1-type (Mo, Ti)C_x in Mo-Ti-C ternary system
19^{15}	12^{15}	**Discussion and remarks**
19^{30}	12^{30}	**End of the first session**

Investigation of the microstructure and mechanical properties of directionally solidified novel eutectic V-Si-B alloys

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For years, refractory-based materials, such as the Mo-Si-B alloy system, have been studied as a substitute for Ni-based superalloys attributed to their high-temperature strength and oxidation resistance and demanding for possible applications in aerospace and gas turbine engines [1,2].

V-based alloys gain attention of the scientific community due to their improved mechanical strength and relatively low density. They have the potential to be an alternative to Mo-based alloys for high-temperature applications [3].

The microstructure of V-Si-B alloys has prominent similarities to the Mo-Si-B system. Both alloy systems form a ternary eutectic in the metal-rich region of the ternary system consisting of a metallic solid solution phase (Me_{SS}) and the two intermetallic phases Me_3Si and Me_5SiB_2 [4,5].

This project focuses on the microstructural formation and resulting properties of directionally solidified eutectic V-Si-B alloys. By directional solidification, the growth of the eutectic can be controlled along the solidification direction [6] which results in orientation-dependent mechanical properties such as strength and creep resistance [7]. Therefore, the zone melting process will be examined and analyzed ex-situ and the liquid-to-solid phase transformation during directional solidification will be investigated in-situ by using high-energy X-ray diffraction at DESY, Hamburg. These experiments can offer new insights into phase compositions and microstructural formation during solidification [8].

The mechanical properties of the directionally solidified ternary eutectic V-Si-B alloys will be tested from room temperature to high temperature near 1100°C.

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Temperature-dependent mechanical properties of heat-treated eutectic V-9Si-6.5B+Cr alloys

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In recent years, there has been increased research activities focussing on vanadium-based alloys due to their balanced strength and ductility, as well as their low density. These alloys have been considered as promising candidates for replacing nickel-based superalloys as potentially new lightweight high-temperature materials. Of particular interest is the eutectic alloy V-9Si-6,5B in the V_{ss}-V_3Si-V_5SiB_2 phase region, which exhibits a vanadium solid solution (V_{ss}) major phase with embedded intermetallic phases (V_3Si, V_5SiB_2). However, the oxidation behaviour of these alloys is still a critical issue due to the high volume fraction of the V_{ss} phase. The aim of this work is to investigate the influence of Cr on the mechanical properties, in particular on the solid solution strengthening. Therefore, the eutectic alloy is additionally alloyed with 10-30 at.% Cr. Besides the improvement of the mechanical properties, Cr can also lead to better oxidation resistance. The alloys were analysed in both the as-cast state and after a heat-treatment at 1400 °C for 100 hours in Ar atmosphere.

The results indicate that the addition of Cr has no effect on the microstructure. It was shown that Cr substitutes the lattice sites of V of each phase present in the alloys investigated, contributing to further solid solution strengthening. Consequently, the compression tests conducted at higher temperatures (500-1100 °C) show an increase in compressive yield strength with increasing Cr concentration at the same test temperature. Additionally, it was shown that the addition of Cr leads to an increase in brittleness of the V-9Si-6,5B+Cr alloys. In this case, the V_{ss} phase serves as the primary carrier of plastic deformation and leads to hinder crack propagation at the brittle-ductile phase boundary due to crack deflection and bridging.

Powder metallurgical investigations on Mo-V-Si-B alloys doped with titanium

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Multiphase Mo-Si-B alloys have a great potential for replacing nickel-based superalloys in the aerospace and energy sector due to their excellent mechanical properties and acceptable oxidation resistance provided by the intermetallic Mo-silicide phases. However, the oxidation behaviour of such alloys is still a critical issue, since catastrophic oxidation failure occurs locally at the Mo solid solution phase at intermediate temperatures [1]. It was shown that the addition of V to Mo-Si-B alloys leads to a significant density reduction and an increase in fracture toughness [2]. This phenomenon is directly related to the high solubility of V in Mo and the respective Mo-silicides, while V has no effect on the phase fractions of the Mo_{ss}-Mo_3Si-Mo_5SiB_2 triangle. Ti, on the other hand, acts as an oxygen getter and causes strengthening as well as ductilisation.
In this work powder metallurgical milling studies on Mo-40V-9Si-8B and Mo-40V-9Si-8B-5Ti were carried out in order to evaluate the best milling time for these alloys and to optimize the stress-strain properties even further. After different milling times the powders were analyzed with regard to their microstructure (XRD and SEM), oxygen concentration and microhardness. After a heat treatment the intermetallic phases $(Mo,V)_3Si$ and $(Mo,V)_5SiB_2$ precipitate homogeneously within a (Mo,V) solid solution matrix phase.

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Alloy formation and microstructure evolution in the Mo-Ti-Si system during SPS

Ievgen Solodkyi, Manja Krüger

Mo-based materials show great potential for high-temperature structural materials, radioactive shielding materials etc. However, low-temperature brittleness and poor oxidation resistance are the main concerns for their practical use. Metal matrix composites (MMCs) reinforced with ceramic particles can eliminate most of the disadvantages of metal matrixes, as they provide strength, stiffness, wear resistance, and thermal and oxidation resistance compared to conventional metals and their alloys. To manufacture bulk Mo matrix composites, powder metallurgy is mainly used instead of casting due to the high melting point of Mo (2610 °C) and the heterogeneity in the nature of the matrix and reinforcing inclusions. However, the sintering of Mo matrix composites as well as Mo is dominated by the process of bulk diffusion with an associated activation energy of 405 kJ/mol. The high activation energy requires a high sintering temperature of more than 1800 °C with a long holding time to obtain a residual porosity of less than 10%.

In this work, two approaches were used to obtain high-density composite materials for the Mo-Ti-Si system. (I) The composite powders with a core-shell structure, where the shell is Mo and the core is Ti_5Si_3 ceramic are synthesized. Next, the synthesized powders were compacted by spark plasma sintering (SPS), which allows for high-density materials at fairly high heating rates and short holding times, which allows for better control of the microstructure and phase composition of the composite. (II) Also, commercial powders and activation of the sintering process with nickel were used to obtain composites in the Mo-Ti-Si system through the in-situ formation of chemical, phase composition, and microstructure. For this purpose, powder mixtures of Mo-Ti_5Si_3 with different contents of titanium silicide were used.

Core-shell Ti_5Si_3-Mo powders were successfully synthesized by reducing of ammonium molybdate (para) tetrahydrate with hydrogen and glycerol, respectively. As a result, the Ti_5Si_3 core was coated with submicron and nanosized Mo particles. The synthesized powders were densified by spark plasma sintering (SPS) at a temperature of 1500 °C. It was shown that powders with a core-shell structure are densified up to a temperature of 1330 °C, while the mechanical mixture of commercial powders at this temperature only begins to densify. Fractographic studies have shown the presence of a pseudo-brittle nature of the fracture mechanism for the metal matrix composite, which was sintered by SPS of the core-shell Ti_5Si_3-Mo powder synthesized by reduction with glycerol. Powders with a core-shell structure where the shell is Mo and the core is ceramic may have a significant prospect for obtaining high-density high-temperature MMCs.

After SPS of the composite powders Mo+1 wt.% Ni+X wt.% Ti_5Si_3 (X=20; 30; 40; 50), it was found that during the densification process, the reaction interaction of the initial powders with the formation of phases occurs: $(Mo,Ti)_{ss}$, $(Mo,Ti)_3Si$, $(Ti,Mo)_5Si_3$. The quantitative composition of the phases depends on the content of titanium silicate in the initial mixture and their sintering temperature. The oxidative resistance of the obtained composites was also evaluated.

Microstructure and mechanical properties of Ta-Ti alloy by plasma-activated sintering

Shiquan Zhang

Plasma-activated sintering (PAS) technology combines multiple advantages, such as higher heating rates, axial pressure, and field-assisted sintering, that it can be quickly densified at a relatively low temperature in a vacuum environment, and a sintered body having a uniform structure and excellent comprehensive performance can be obtained [1]. The mechanical properties of Ta-based alloy have been investigated at room temperature [2]. The addition of Ti promotes densification significantly. The higher affinity of titanium to oxygen elements is used to purify the grain boundaries and improve the densities of tantalum alloys. The TiO_2 formed is dispersed in the matrix to enhance the plasticity of the tantalum matrix. Ta-2Ti alloy has both high strength and high ductility. The ultimate bending strength can reach 1345.5 MPa and the strain reaches 15.5%. With the increase of the Ti content, the ductile fracture with more dimples was found on the fracture surface and gradually became a brittle fracture. Titanium reacts with oxygen has a lower Gibbs free energy and the titanium oxide is more stable. The ceramic phase particles generated by the reaction with impurity oxygen are uniformly distributed in the matrix which plays a role in purifying the matrix. Dispersion strengthening and second-phase strengthening of titanium are the principal strengthening mechanisms.

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The effects of microstructure on the tensile properties and micro-fracture behavior of MoSiBTiC alloys at room temperature

Junfeng Du and Kyosuke Yoshimi

The well-known first-generation MoSiBTiC alloy, 65Mo-5Si-10B-10TiC (at.%), was developed by introducing TiC into Mo-Si-B alloy. The first-generation MoSiBTiC alloys have a low density, remarkable strength, and exceptional creep resistance at high temperatures. The mechanical properties of MoSiBTiC alloys are attributable to the constituent phases of Mo solid solution (Mo_{ss}), Mo5SiB2 (T_2), TiC, and Mo_2C. However, room-temperature fracture toughness, which is one of the properties that need to be enhanced in MoSiBTiC alloys. Studying the role of microstructure on failure initiation and early propagation, and its effects on the aggregate mechanical properties, will contribute to the design and development of MoSiBTiC alloys.

A computational framework is developed to study the role of microstructure on the deformation behavior of MoSiBTiC alloys, as shown in Fig. 1. The material properties of phases in the alloys are determined by nanoindentation test and inverse estimation method [1-3]. The materials properties of interfaces are evaluated by nano hardness according to nanoindentation test [4,5]. The continuum elements and the cohesive elements are used to model the constituent phases and the interfaces for evaluating cleavage fracture within brittle phases and debonding at the interfaces. The deformation behavior of MoSiBTiC alloy is studied in terms of the simulated stress-strain response and evolution characteristics.

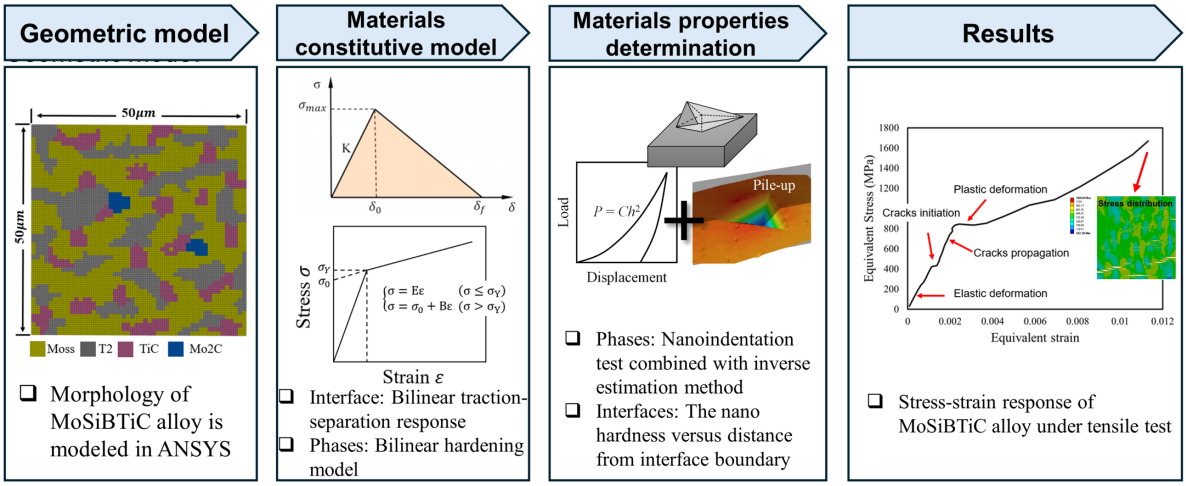

Fig. 1. The framework for evaluating micro-fracture behavior of microstructure.

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Elastic moduli and toughness of B1-type (Mo, Ti)C_x in Mo-Ti-C ternary system

Shuntaro Ida, Kotaro Yonemura, Kotaro Hosizaki, Xi Nan, Nobuaki Sekido and Kyosuke Yoshimi

B1-type MX ceramics are composed of transition metals (M) and C, N, and/or O (X) occupying the M and X sites, respectively, and having M–X nearest neighbor (NN) bonds and M–M and X–X next nearest neighbor (NNN) bonds, exhibit attractive material properties. One drawback of B1-type compounds is their brittleness. However, MX in equilibrium with metal phase can have high degrees of off-stoichiometry, such as in Mo–Ti–C ternary system [1]. Substitution of the elements at M site and the formation of structural vacancies at X site in MX_x can lead to novel properties. Therefore, elastic moduli and toughness of (Mo, Ti)C_x in equilibrium with Mo phase in the Mo–Ti–C ternary system were investigated [2]. The bulk modulus (K) of (Mo, Ti)C_x increased with increasing Mo fraction at Ti sites, whereas the Young's modulus (E) and shear modulus (G) remained almost constant. On the other hand, all the elastic moduli decreased with increasing the fraction of vacancies at C sites. They suggest that the M–X bond strength is the dominant factor in these moduli and the effect of M-M bond on K is greater than that of G and E. Alloys on a tie line in the TiC/Mo two-phase region exhibited higher toughness with increasing volume fraction of (Mo, Ti)C_x, suggesting that the brittleness of (Mo, Ti)C_x can be improved by off-stoichiometry.

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