Microstructure evolution and creep properties of a zone molten Mo-Si-B alloy

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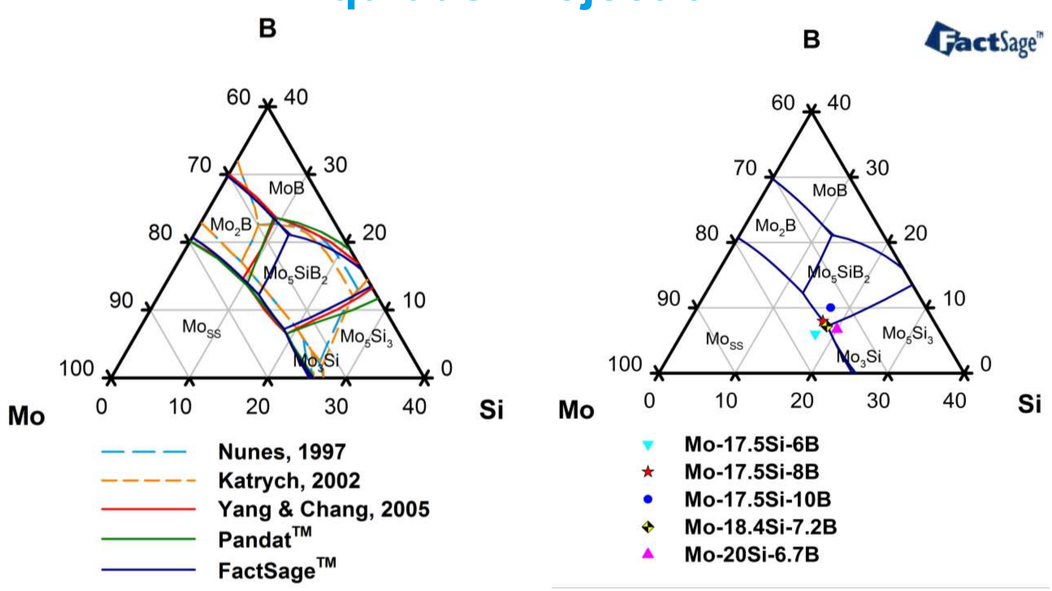
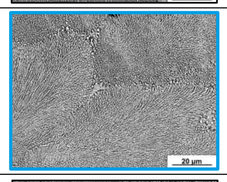
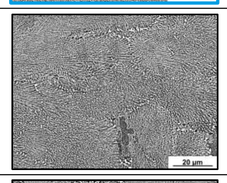
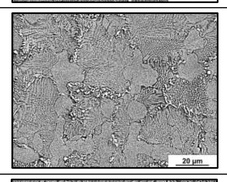
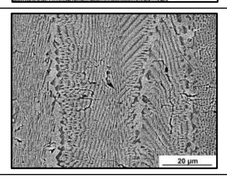
Abstract

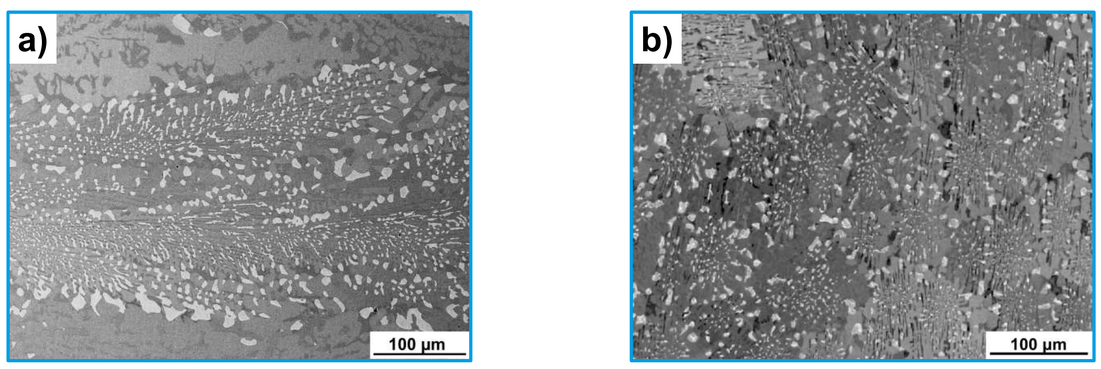
Multiphase Mo-based alloys are potential candidates for applications in aerospace engines and the power generating industry due to their excellent creep behavior and acceptable oxidation resistance at ultrahigh temperatures. The resulting microstructure as well as the material's properties of Mo-Si-B materials, strongly depend on the manufacturing process. In the present work we report on a new eutectic alloy Mo-17.5Si-8B which was processed by arc-melting and crucible-free zone melting (ZM) from cold pressed elemental powders. The composition of the three-phase eutectic region consisting of a Mo solid solution (Mo_{SS}), and the two intermetallic phases Mo_5SiB_2 and Mo_3Si was investigated using EPMA measurements which were compared to calculated liquidus projections and isopleth phase diagrams. Different alloy compositions in the Mo_{SS}-rich field of the Mo-Si-B system were additionally prepared by arc-melting to get detailed information of the solidification path and phase evolution. The mechanical properties of the eutectic ZM alloy at high temperatures were investigated in terms of compressive creep strength in the temperature range from 1100-1400 ºC. The results were evaluated and compared with a commonly used Ni-based superalloy and a powder metallurgical (PM) processed Mo-Si-B material. The creep resistance of ZM materials was found to be substantially improved due to the relatively coarse directionally solidified microstructure with homogenously distributed intermetallic particles and/or fibers. Thus, ZM alloys show great potential for applications at targeted application temperatures of around 1200-1300 ºC.

Liquidus Projection



Nominal Alloy Composition	As-Cast Microstructure	Microstructural Features
Mo-17.5Si-6B		primary Mo_{SS} dendrites with Mo_3Si regions and ternary eutectic grains
Mo-17.5Si-8B		ternary eutectic of $Mo_{SS}/Mo_5SiB_2/Mo_3Si$
Mo-17.5Si-10B		binary Mo_{SS}/Mo_5SiB_2 and ternary $Mo_{SS}/Mo_5SiB_2/Mo_3Si$ microstructure
Mo-18.4Si-7.2B		primary Mo_3Si and binary Mo_5SiB_2/Mo_3Si eutectic with minor ternary eutectic portions
Mo-20Si-6.7B		binary Mo_5SiB_2/Mo_3Si microstructure

ZM alloy Mo-17.5Si-8B

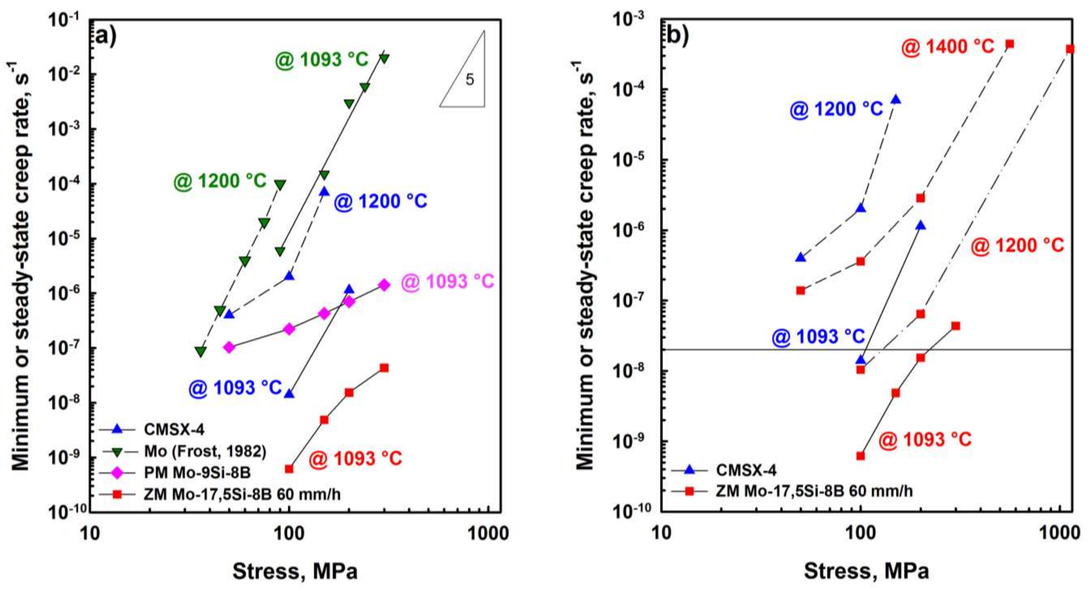


SEM-BSE images of a) longitudinal cross-section and b) transversal cross-section with colonies of ternary eutectics directionally solidified at 60 mm/h (Hasemann, 2014)

Chemical Analysis

	at% Mo	at% Si	at% B
after ZM (ICP-OES)	75.5	17.6	6.8
ternary eutectic regions (WDX)	74.5	17.5	8

Creep Properties



Summary

- The literature provides controversial results of liquidus projection in the Mo-Si-B system, so attention has to be paid while simulating and designing multiphase Mo-rich alloys for possible high temperature applications.
- Arc-melter buttons were used to investigate the solidification pathway of alloy compositions near the ternary eutectic point of the Mo-Si-B system.
- The results were interpreted by using FactSage calculations and were compared with literature data of liquidus projections.
- The alloy Mo-17.5Si-8B was identified as the ternary eutectic composition by using metallographic analysis and WDX measurements and it was therefore chosen for zone melting and creep tests.
- Outstanding high temperature creep properties of the ZM alloy Mo-17.5Si-8B compared to PM and a commonly used Ni-based superalloy could be obtained.

Acknowledgments

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