TITLE: PROCESSING, MICROSTRUCTURE AND CREEP BEHAVIOR OF MO-SI-B-BASED INTERMETALLIC ALLOYS FOR VERY HIGH TEMPERATURE STRUCTURAL APPLICATIONS

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PROGRAM INTRODUCTION: RATIONALE AND OBJECTIVES

This research project combines a novel processing, experimental and modeling approach, with detailed quantitative analysis of the influences of microstructure, in a basic study of the creep behavior of the next generation of refractory alloys based on the Mo-Si-B system. Through these studies, we will gain insight into the high-temperature creep behavior of these materials, including the effects of microstructure and the associated deformation, damage and failure features. A model Mo-rich Mo-Si-B alloy has been chosen for study, since it is representative of the new class of ductile-brittle systems, which, owing to their promising properties, are receiving evaluation for very high temperature structural applications. This project, which is closely coupled with ongoing activities at the Air Force Research Laboratory (AFRL) and Oak Ridge National Laboratory (ORNL) on these materials, focuses on three key areas to address issues related to the creep behavior: 1) basic materials processing and microstructural studies; 2) evaluation of the creep phenomenology and establishment of the constitutive behavior of the three-phase alloy and the individual phases within the alloy, including the effects of microstructure; and 3) theoretical modeling of the creep behavior based on analysis of associated creep data, creep mechanisms, damage processes and microstructural parameters. Microstructures will be analyzed in detail to provide quantitative information on aspects such as volume fraction, length scales, morphology and distribution of the second-phase intermetallics, the nature of their interfaces with the matrix, and the deformation, damage and failure processes during creep and this information coupled together with those of the creep properties and phenomenology to rationalize and theoretically model the observed creep behavior.

ACCOMPLISHMENTS DURING THE CURRENT PERIOD OF PERFORMANCE

During this period of performance, we have studied the microstructure and mechanical properties of a three-phase Mo-3 wt.% Si-1 wt.% B (Mo-8.9Si-7.71B in at.%) alloy that was supplied by UES/AFRL. A powder metallurgy route was used by Plansee (Austria) to process this material into bulk form. Microstructural observations of samples in various conditions were conducted using back-scattered electron imaging in a scanning electron microscope. The Mo-3Si-1B alloy was observed to be three-phase, consisting of α-Mo, Mo_3Si and T2-Mo_5SiB_2 phases, with the combined volume fraction of the latter two being ~30%. Samples for mechanical testing were prepared by electro discharge machining. Bend tests revealed that the elastic limit strength of the alloy remained quite high until 1200°C with a value of 800MPa, but dropped rapidly thereafter to a value of 220 MPa at 1400°C (Fig. 1(a)). Compression creep tests were conducted under inert atmosphere at 1200°C at stress levels of 250, 300, 400 and 500 MPa in an Applied Test Systems creep frame equipped with computerized data acquisition. The results showed that the creep rates at 1200°C were quite high and varied nearly linearly from a value of 3.58 x 10^{-5} min^{-1} at a stress of 250 MPa to 8.04 x 10^{-5} min^{-1} at 500 MPa. The stress exponent was ascertained to be ~1.18 from this data (Fig. 1(b)), which is near the value of 1 expected for diffusional creep mechanisms or recrystallization. This value of the stress exponent differs from the values of 2-7 reported for similar alloys by other investigators. Microstructural observations of post-crept samples indicated shape change and deformation of the α-Mo grains, together with the presence of many voids in these grains. A few cracks in the intermetallic particles and along their interfaces with the α-Mo matrix were also observed. These observations suggest that the bulk of the deformation and strain during creep is carried by the α -Mo.

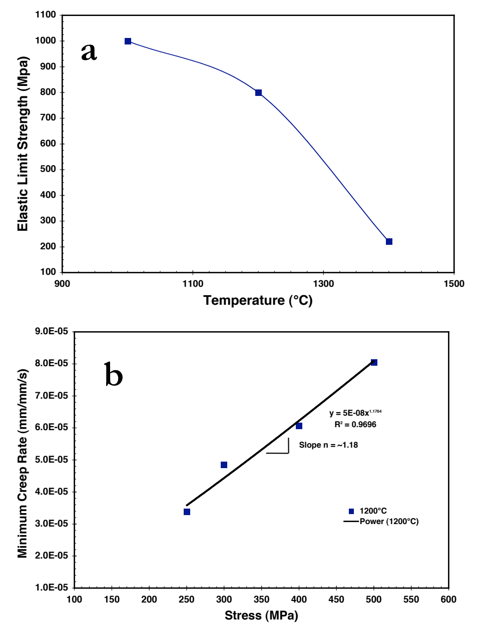

Figure 1—(a) Elastic limit strength versus temperature and (b) Minimum creep rate versus stress at 1200°C of the Mo-3Si-1B alloy.

PLANS FOR THE NEXT YEAR/PERIOD OF PERFORMANCE

- Complete analysis of microstructure of Mo-3Si-1B samples crept at 1200°C to rationalize the creep behavior and observed stress dependence of creep rates.
- Complete compressive creep testing of the Mo-3Si-1B three phase material at 1100 and 1300°C and analysis of microstructure and damage processes.
- Characterize microstructure and deformation structures in tensile-creep-tested samples of Mo-20Si-10B (in at.%) alloy supplied by Dr. Joachim Schneibel from ORNL
- Conduct compression creep testing of Mo-20Si-10B (in at.%) alloy samples with varying volume fraction of α–Mo supplied by Dr. Joachim Schneibel from ORNL
- Conduct tensile creep testing of Mo-3Si-1B alloy at selected temperatures and stresses.
- Prepare pure phase α-Mo and Mo_3Si materials and conduct compressive creep testing of these at selected temperatures and stresses matching those used for the three-phase alloy.
- Conduct work on microstructure representation and time-dependent FEM of creep in these materials.

LIST OF PUBLISHED JOURNAL ARTICLES, COMPLETED PRESENTATIONS AND STUDENTS RECEIVING SUPPORT FROM THE GRANT

Publications and Presentations

None during this period of performance; a paper will be submitted for presentation at the TMS Fall Meeting in Pittsburgh, Oct (2005).

Students Supported Under this Grant

Brian Riestenberg, Ph.D. student, Dept. of Chemical and Materials Engineering, University of Cincinnati.