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| **TITLE:** | SUPER-HIGH TEMPERATURE ALLOYS AND COMPOSITES FROM Nb-W-Cr SYSTEM |
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| **GRANT NO.:** | DE-FG26-05NT42491 |
| **PERIOD OF PERFORMANCE:** | September, 2007 - April 2008 |
| **DATE:** | April 10, 2008 |

## 1. ABSTRACT


### Program Introduction: Rationale and Objective

A substitute for the nickel base superalloys must be found in order to enhance the temperature capability of high temperature applications. An alloy from a metallic system will most likely be able to have necessary ductility so that formability and its room temperature processing is not an issue. Nb-W-Cr system has been chosen because of the high melting points (2469, 3422, and 1863$^{o}$C respectively) of the 3 metals and Nb has comparable density (8.57 gm/cm$^{3}$) to nickel (8.9 gm/cm$^{3}$) so that a Nb base alloy will not be heavier than conventional nickel base superalloys. Besides, all 3 metals have a BCC crystal structure making them stronger alloys on a comparative basis. The objective of this research was to characterize the oxidation properties at high temperatures from 1000 to 1500$^{o}$C in air for a period of at least 168 hours or one week. Initial oxidation studies were conducted using alloys Nb-20W-5Cr (single phase alloy) and Nb-20W-10Cr (2 phase alloy). The presence of $NbCr_2$ as a second phase particle was believed to enhance the oxidation resistance.

### Accomplishments Achieved During the Current Period of Performance

The Cr concentrations of the alloys have been modified to 15, 20, 25 and 30% while the W concentration has been reduced to 10%. The alloys still have the two phase microstructure consisting of an $\alpha$ phase and intermetallic compound, $NbCr_2$. Second phase has been found to be present both as finely dispersed particles and continuous phase at the grain boundaries in the as cast structures. This was confirmed by the presence of Cr in the x-ray maps obtained in FESEM. However, the amount of the second phase appears to increase with Cr concentration. This observation agrees well with the ternary isothermal sections of the Nb-W-Cr phase diagram at 1100 and 1500$^{o}$C from the Metals Handbook.

The oxidation curves (weight gain/unit are versus oxidation time) at various temperatures indicate the improved resistance to oxidation with increase in Cr concentration at 1200, 1300, and 1400$^{o}$C. This is presumably due to increased amount of $NbCr_2$ phase in the microstructure. The curves clearly indicate that for oxidation time more than approximately 4 days the samples turn in to complete powder. Curves for all the alloys show stabilization in weight gain per unit area at longer oxidation times. The XRD patterns show the presence of $Cr_2O_3$, $Nb_2O_5$, and $CrNbO_4$. The oxidation products show powders, chunks and fragmented pieces. It must be noted that the even though the intermetallic compound formation improves the oxidation resistance it greatly reduces ductility. 0.1% addition of B and C do not offer much improvement in oxidation resistance. XPS and EDS on FESEM work is in progress and a better insight in to the mechanisms of oxidation can then be obtained.

**Plans for Remaining Period of Performance**

The work planned for the remaining phase of this research program includes the following tasks:

- Long Term Oxidation (LTO) involving exposure of alloys to air in a range of temperature from 1000 to 1400$^{o}$C for 168 hours.
- Complete the Short Term Oxidation (STO) involving exposure of alloys to air in a range of temperature from 1000 to 1400$^{o}$C for 24 hours.
- Another series of oxidation studies has been initiated where samples will be oxidized for less than 24 hours at the same temperature intervals.
- Characterize the oxides formed at the surface and in the powdered form using XRD and EDS on FESEM.
- Determine the effect of Cr on the super-high temperature oxidation behavior of the alloys.

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

**Journal Articles**

- "Exploration of Nb-W-Cr Alloys for High Temperature Applications in Air", Benedict Portillo, Purushotham Kakarlapudi, and S.K. Varma. Journal of Metals, pp.46-50, vol. 59, no.6, 2007.

**Conference Presentations**

- Characterization of Oxidation Products in Ternary Alloys Containing C Modifiers, Maria D. Gonzalez, Purushotham Kakarlapudi, Benedict Portillo, and S.K. Varma, MS&T 2007, Fundamentals and Characterization: High Temperature Materials Systems, Detroit, Michigan, September 20, 2007.
- Effect of Boron on High Temperature Oxidation Resistance of Alloys from Nb-W-Cr System, Benedict Portillo, Purushotham Kakarlapudi, and S.K. Varma, MS&T 2007, Fundamentals and Characterization: High Temperature Materials Systems, Detroit, Michigan, September 20, 2007.
- Oxidation Behavior of Alloys from Nb-W-Cr System Containing C Modifiers, Maria D. Gonzalez and S.K. Varma, TMS 2008, 137th Annual Meeting and Exhibition, Refractory Metals 2008: Properties of Refractory Metals, March 13, 2008.

**Students Supported Under This Grant**

- Maria D. Gonzalez (Ph.D.) and Clemente Parga (M.S.), graduate students in the Department of Metallurgical and Materials Engineering, The University of Texas at El Paso.