## ADMINISTRATIVE INFORMATION

1. **Project Name:** Development of Bulk Nanocrystalline Cemented Tungsten Carbide Materials for Industrial Applications

2. **Lead Organization(s):** University of Utah,
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5. **Date Project Initiated:** April 1, 2004

6. **Expected Completion Date:** March 31, 2007

## PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The project will investigate, develop and deploy processes for synthesis of nanocrystalline tungsten carbide and cobalt composite powder and the consolidation of nanocrystalline WC/Co powders into bulk nanocrystalline materials. The overall goal is to develop a process that can produce bulk materials with true nanoscale grain sizes (<100 nm) and demonstrate the potential of mechanical properties of cermet materials with a microstructure scale that has never been achieved before at a consolidated bulk state.

8. **Technical Barrier(s) Being Addressed:** Nanocrystalline WC-Co was among the first group of materials that demonstrated the potential of nanocrystalline materials. The advances in nanoscale powder producing technologies raised hopes for dramatically improving mechanical properties. However, further development of nanocrystalline WC-Co materials are currently stalled because of the lack of sintering technologies that could produce *bulk* WC-Co materials with true nanometer grain sizes (<100nm). The lack of success with the sintered materials affects adversely the further development of the powder synthesis processes. Consequently, cost/benefit ratios of nanocrystalline WC-Co powders produced by existing technologies are still unacceptable to the industry.

9. **Project Pathway:** The project pathway consists of three steps. The first step is to develop a new powder synthesis method based on a chemical vapor synthesis method that holds promise to produce nanocrystalline powders with less energy and more control. The second step of project which will be carried out in parallel with the first step will focus on developing a ultrahigh pressure sintering technology that can produce fully consolidated bulk nanocrystalline material. During the last portion of the project, mechanical properties of the cermet material with true nanoscale grain sizes will be characterized. Engineering components will be manufactured and tested in real industrial applications.

10. **Critical Technical Metrics:** The technical targets of the project are two folds: produce nanocrystalline WC/Co composite powder via CVS approach and produce fully consolidated WC-Co materials with grain sizes below 100 nm. The energy savings by implementing the new powder synthesis and consolidation technologies will be up to 17 trillion btu annually.

## PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** Not applicable, projects initiated in FY04.

12. **Future Plans:**

***1. Powder synthesis process studies*** Experiments will be carried out to determine the effects of several reaction conditions on the formation of WC-Co nano-particles by the co-reduction of mixed metal chlorides by a methane-hydrogen mixture. The experimental variables will include temperature, $WCl_6/CoCl_2$ ratio, $CH_4/H_2$ ratio, partial pressure of diluent gas (either nitrogen or argon), and total gas flow rate (residence time in the hot zone). Planned completion Date: 3/31/2006

***2. Ultrahigh Pressure Rapid Heating and Consolidation Process development*** Success of the proposed ***Ultrahigh Pressure Rapid Heating and Consolidation*** (UPRC) process hinges on the development of rapid heating techniques. Two approaches will be experimented. For both the direct heating and the 2-step heating techniques, the formulation of the pressure media must have adequate thermal conductivities and must not react with the parts during the process. Initial experiments will be carried out in collaboration with Kennemetal. A small unit will be built in the PI's laboratory. The lab unit will have a pressure cell of approximately 30 mm in diameter and a pressure capacity of 800 MPa. Building of this unit will be complete within 6 months. Specific steps are:

1) Select and prepare fluid die and pressure media materials,
2) Set up the direct plasma heating unit,
3) Design and set up induction heating unit,
4) Design and build the laboratory ultrahigh pressure press unit,
5) Integrate the rapid heating and the ultrahigh pressure press set-ups,
6) Consolidate samples and study effects of pressure on sintering of nanocrystalline WC/Co powder. Planned Completion Date: 3/31/2005

***3. Comprehensive analytical evaluations and process optimization***

***Instrumental Analysis*** The morphologies, particle sizes and phases of the products from the synthesis tests and sintered samples will be analyzed by SEM, TEM and XRD. ***Analytical modeling and optimization*** will be conducted based on the data collected in the previous tasks. First, models based on physics of the process and experimental observation of mechanisms during powder synthesis and sintering will be established. Depending on the specific situations, software tools for numerical modeling will be utilized for process optimization. Planned Completion Date: Continuous through the project period.

***4. Characterization and study of mechanical properties*** Detailed mechanical properties of the nanocrystalline WC-Co will be characterized. The results will be compared with those of the conventional WC-Co materials to establish a comprehensive understanding on the advantages of using nanocrystalline WC/Co powder. The study will examine deformation and fracture mechanisms in the nanocrystalline WC-Co. The role of nano grains of WC and Co phases during

crack propagation will be revealed. The dependence of mechanical behavior on the cobalt content and the effects of grain growth inhibitors will also be investigated. Planned Completion Date: September 30, 2006

***5. Component fabrication, functional testing, and field tests*** Proof-of-concept field tests in a real life application environment will be carried out as a verification of the R&D results. This task involves the design of field test components, the selection of specific material compositions, and the specification of optimized processing procedures. This task will be accomplished by close collaboration with Smith Tool and Kennametal. Planned Completion Date: March 31, 2007

13. **Project Changes:** None.

14. **Commercialization Potential, Plans, and Activities:**
Efforts and activities toward the technology transfer are planned throughout duration of the project. This task will be accomplished by
- Communications with industrial partners through project reviews and technical collaborations,
- Disseminate research results through website as well as professional technical conferences,
- Proper management of intellectual properties.

15. **Patents, Publications, Presentations:** None to date.