1. **Project Name:** High Density Infrared (HDI) Fusion of Wear and Corrosion Resistant Cermet and Hardfacing Coatings

2. **Lead Organization:** Materials Resources International (MRi)
811 W. Fifth Street / Unit 2
Lansdale, PA 19446

3. **Principal Investigators:** Ron Smith, MRi
Ph: 215-631-7111/ Fax: 215-631-7115/Email: solution@voicenet.com

ORNL Investigator:
Gail Mackiewicz Ludtka: Ph: (865) 576-4652; Fax: (865) 574-4357;
email: ludtkagm@ornl.gov

4. **Other Project Partners/ In-kind Participants:**

Ametek	Richard P. Mason
Carpenter Powder Products	Lou Lherbier
Crucible Research Division	Andrzej L. Wojcieszynski
Lund International Corp.	Peter Zagaeski
St. Louis Metallizing	Klaus Dobler

5. **Date Project Initiated:** April 2002

6. **Expected Completion Date:** 6/01/05

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The objective of this project is to develop and evaluate coating-substrate systems that result in wear and corrosion resistant coatings. The specific goals of this project are: 1.) to understand the prominent material characteristics that influence coating-substrate fusion processes; 2.) to develop and/or utilize computational models to target and predict the thermal heat flux necessary to produce the structures that result in improved wear and corrosion resistant coating materials; and 3. to evaluate subsequent coating-substrate properties.

8. **Technical Barrier(s) Being Addressed:** HDI fusing of loose power base materials on a substrate is typically limited to approximately 40 micron. This is due to the fact that the HDI process is line of site and large convective stirring is not produced, which limits heat transfer to the underlying substrate. Therefore, if the power is applied too thick on the substrate, the process fuses the powder but not to the substrate. This is not observed with the thermal spray coatings due to sufficient heat transfer from the mechanical interlocking produced during the coating process. By understanding the fundamentals (liquid formation, convective stirring, wetting, heat transfer, and solidification) of these processes, thicker room temperature power spray and fuse coatings may be attainable.

9. **Project Pathway:** The HDI coating and materials process utilizes a unique technology to produce extremely high-power densities of 3.5 kW/cm^2 with a single a controlled and contained plasma lamp. The high power density from the lamp has been shown to be capable of performing rapid, localized and selective heat treatment of surfaces. The project's aim is to develop, evaluate and understand how high density infrared heating technology can be used to improve wear and thermal sprayed coatings. In the proposed work both applied and fundamental investigations will be conducted. The applied work is aimed at developing practical High Density Infrared (HDI) heating systems that can fuse carbide coatings for industrial applications such as agricultural blades, rolls for metallurgical processing, construction and mining vehicles, components for paper and polymer processing as well as for a range of crosscut applications. The engineering development focuses

on developing the process and equipment technology necessary to implement industrial HDI systems to fuse coatings on such parts. The fundamental research is aimed at understanding the interaction of HDI processing on the coating materials and the subsequent coating properties. The goal of this work is to develop the necessary materials and process knowledge to enable the control of the HDI process and the proper specification of coating precursors including spayed on suspensions and thermal spray coatings.

10. **Technical Metrics:**

- Coating porosity and the interfacial properties of thermally-sprayed coatings have limited the application of these coatings due to the ability of corrosive environments to penetrate the coating. In order to correct such deficiencies, the HDI process will be developed so that thermally-sprayed coatings can be fused and/or re-melted to obtain improved interface properties.

- The HDI process will be developed so that cermet coatings can be spray and fused without the degradation of the tungsten carbide. Room temperature spray processes will be developed to deposit WC and Cr_2C_3 with an alloy matrix on the surfaces of wear and corrosion-sensitive parts.

- Wear performance of the coatings developed in this project will be meet or exceed the wear resistance, and or corrosion resistance of coatings currently in use on existing parts.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** During FY2002 this project selected and evaluated a wide range of cladding materials that have the potential to produce wear resistance and corrosion resistance. Fusion processes were developed with varying degrees of success for a variety of coating/substrate material systems. Selected claddings included carbide reinforced suspensions and mats, tool steels, stainless steels and hard phase, self-fluxing coatings. Results from these evaluations showed that the High Density Infrared Lamp (HDI) processing can heat large surface areas and produce well-adhered and metallurgically fused claddings of various compositions. These HDI processed coatings demonstrated (HDI's) capability of fusing various coating-substrate material systems, but also, highlighted its intricacies and the need for improved process understanding. These developments have shown that there are distinct differences in behaviors of the cladding compositions and their structures related to the thermal and chemical properties leading to difference in wetting, adherence and densification by fusing behavior. These results underscored the need to focus on designing a fundamental and basic approach to understanding how the HDI process interacts with precursor layers and substrates to form corrosion and wear resistant coatings. In FY2003, an experimental plan was designed to develop and utilize computational models to predict heat flux processing parameters to optimize coating/substrate structures to provide wear- and corrosion-resistant coatings for a range of IOF industry applications. These models coupled with experimental results will provide a better understanding of the influence of the coating/substrate materials properties on the bonding characteristics and wear- and corrosion resistance of these materials. The project selected several "model" cladding systems, based on the first year test results, and began characterizing the thermophysical properties of these materials and conducted several selected well instrumented fusion trials. Initial test samples were prepared and fabricated to initiate measuring the thermophysical properties of the first set of model cladding systems. Continuing in FY 2004, basic materials properties (including thermal conductivity, thermal diffusivity, and specific heat capacity) have been determined for this first set of model cladding systems for input into computational models. During FY 2003 and 2004, a computational model was progressively developed that now incorporates and predicts the thermal flux heat transfer across the coating-substrate interface. The model can now predict thermal processing parameters that can be tested to achieve improved and optimized wear- and corrosion-resistant coating-substrate systems. The goal of this fundamental approach is to optimize the development of the fusing process. Also during FY 2004, thermal fusing trials have begun on industrial agricultural blades. Experimental trials pursuing alternate suspension binders have also resulted in the improved fusing of suspension coatings. Recently (April 2004) Lund has committed to providing agricultural blade blanks for spraying and fusing trials.

12. **Future Plans: (Please summarize the key milestones and deliverables with dates for the life of this project. A comprehensive activities schedule is not required.)**
    - Fundamental Studies: Complete thermophysical property measurements for input into model (contingent on receipt date of sprayed samples from industrial partner. (8/04 estimated based on 5/04 sample receipt date)
    - Coating Testing: The model predictions will be tested and utilized to optimize the HDI process to improve wear and corrosion resistance for selected industrial applications. (9/04)
    - Application Demonstration: Based on the results of subsequent wear and corrosion testing trials, the best coating-substrate candidates will be incorporated into Lund field testing. (12/04)
    - Final Report (6/1/05)

13. **Project Changes:** Process modeling simulations coupled with an in-depth evaluation of completed coating-substrate fusion experiments indicated the need to redefine the future experimental test matrix and supporting modeling effort to facilitate coating and process optimization. These upcoming experiments and modeling effort are defining the significant impact of the substrate thermal transport characteristics on the heat input (flux) needed to develop excellent bonding of the fused coating while minimizing the CTE effects. In addition, experiments are defining the critical temperature regime for the coating that needs to be maintained to guarantee optimal matrix fusion while leaving the carbides in the solid state condition to facilitate the wear performance needed in the final fused coating. These changes will enable accomplishing the most significant results for the budget and remaining duration of this project.

14. **Commercialization Potential, Plans, and Activities:** Describe the end-use application and market potential for the project, and the plans, progress, and partners for commercial application/adoption, where appropriate; identify what the product of the project will be and how this product will be introduced/disseminated to industry.)
    Currently, Lund International (a project partner) is preparing agricultural cutting blade samples for the application of thermal spray and suspension precursor layers. These blades will be HDI processed and installed into agricultural equipment and evaluated via industrial trials selected by Lund. Other applications that are of interest include 1.) Wear Inserts (e.g. for Steam valves); 2.) Rolls; and 3.) Aqueous Corrosion Resistant Thermal Spray Coatings. Successful completion of this project also would enable the application and repair of coatings in-the-field. This is extremely important to many vision industries, including Mining, Petrochemical, Pulp & Paper, Oil, Gas, and Metal Working. In addition, in many cases, more expensive alloys have to be utilized on larger structures due to the fact that wear or corrosion properties are needed in specific areas of the part. Consequently, this project would also allow the application of the appropriate wear or corrosion material just where it is needed.

15. **Patents, Publications, Presentations:**
    - <u>Paper Presented at</u> ASM/AWS Intl Brazing and Soldering Conference / San Diego CA / Feb 03.
    - <u>Papers Presented at</u> ASM Surface Engineering Conference / Columbus OH / Oct 02