Summer 2003

Center for Innovative Sintered Products

CISP

The Pennsylvania State University
CISP Lab, 147 Research West
University Park, PA 16802-6809

Phone: (814) 865-2121 • Fax: (814) 863-8211 • E-mail: CISP@psu.edu • Web: http://www.cisp.psu.edu

Adapting to Change

Sharon Elder – Executive Director

We are now beginning our fourth year and find quite a different world from the one we envisioned in the planning stages of 1998. Forces that are not of our making constantly affect us. If I needed to sum up everything with one word, it would be "change". In many instances we are no longer able to predict change – nevertheless, we must respond to it. We must become an adaptive enterprise, where planning one day at a time is as critical as long-term planning. Today's business environment is rapidly changing: powerful enabling technologies, customers no longer loyal to one brand, price as a driver, greater customer expectations, relationships that can be initiated or terminated faster than ever before, shorter product lifecycles, and increasing globalization all demand constant adaptation.

Over the past several months, I have been pleasantly surprised by the number of companies that have contacted us seeking to begin company-specific projects. We see companies using their Center membership as the perfect opportunity to gain a competitive advantage. This desire for continuous innovation shows that companies have evaluated their options and responded positively. I am amazed by the number of requests from companies that we have not worked with before – combined with those where we do have a history, this makes for an interesting portfolio. Collaboration is a key aspect in adapting to the new marketplace. Companies realize that developing new capabilities internally is too slow and expensive a process to allow them to compete in this global market. This is where the Center offers value, as it makes sense to collaborate with those who have the capability or who can help develop the capability. These are the areas where we excel and can provide the most value.

Penn State Materials Researchers Ranked Tops

Penn State was recently recognized as the most dominant university in the field of materials science by ISIHighlyCited.com, a subdivision of Institute for Scientific Information (ISI), an organization that monitors scientific citations worldwide and whose rankings are a respected indicator of quality across scientific disciplines. According to ISIHighlyCited.com, Penn State alone accounts for nearly 5 percent of all citations, the largest percentage to date of researchers in a given category based at a single institution. Penn State's twelve University faculty members in ISI's list of most cited researchers amount to twice as many representatives as the next institution, the University of Texas, Austin.

PENNSTATE 1855

Center for Innovative Sintered Products

Researchers Ranked Tops cont.

Congratulations to CISP Director Rand German for appearing on this list. Dr. German is *the* expert on powder metallurgy, ceramics, and particulate materials processing. His career has been dedicated to the promotion of high-performance engineering materials via net-shaping techniques. His contributions have provided basic

scientific underpinnings to emerging manufacturing technologies that have now reached significant economic levels in the US. He has authored 12 books and edited 19, been awarded 21 patents, and has 680 papers in technical literature. His book *Powder Metallurgy Science* (soon to be in its third edition) is the basic university textbook. For the full PSU research faculty listing see: http://live.psu.edu/index.php?cmd+vs&story+3103

Upcoming Events

July 14, 2003
MPIF–Basic Short Course
University Park, PA

September 14-17, 2003
Sintering 2003
University Park, PA

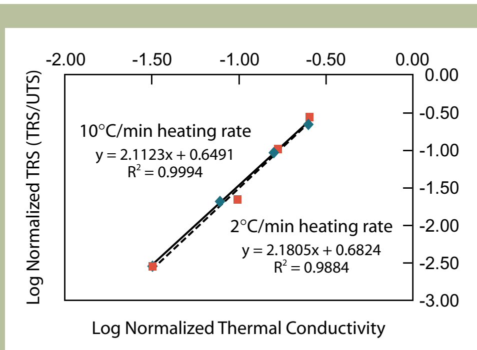
September 24, 2003
PM Fracture Short Course
DuBois, PA

October 20-21, 2003
CISP Industry Member Meeting
University Park, PA

Thermal Conductivity During Initial-Stage Sintering

Maj. Connie Schlaefer, USAF, has recently completed her doctoral thesis research on thermal conductivity during initial-stage sintering. The hypothesis of the work was that thermal conductivity would provide a means of indirectly assessing the strength of a P/M system during initial-stage sintering. Research was conducted on low-density die-compacted, high-density die-compacted, and injection-molded nickel systems. Thermal diffusivity was evaluated via the Anter Flashline™ 5000 laser flash system. This information, combined with material density and specific heat, was used to calculate thermal conductivity. Three-point bend testing was used to evaluate strength of each material.

The hypothesis was based on the assumption that both strength and thermal conductivity were dominated by the area of the interparticle contacts during initial-stage sintering. Specifically, each property was modeled as a square function of the neck diameter (X) normalized by the particle size (D). Experimental results verified that the two properties were indeed both functions of X/D, but that the relationship for thermal conductivity was a linear function of X/D and strength was a function of $(X/D)^2$. This relationship becomes evident in the figure below, where the slope of the strength-versus-conductivity curve is approximately two. Note that the relationship is consistent between two different heating rates. As a final product, an integrated relationship between the two properties was constructed, demonstrating the ability to predict the magnitude of strength of a given system. Connie Schlaefer (ces947@psu.edu)



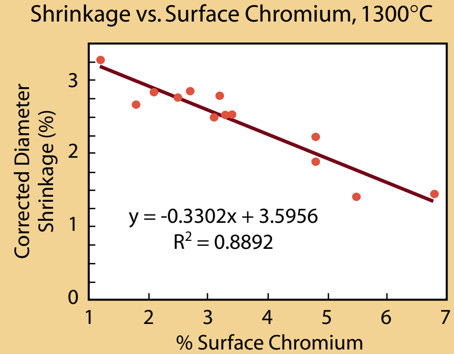
Normalization strength versus thermal conductivity for PIM Ni, 2°C/min and 10°C/min heating rate, H_2 atmosphere

◆ 10°C/min heating rate
■ 2°C/min heating rate

Sintering Shrinkage of Compacted 316L

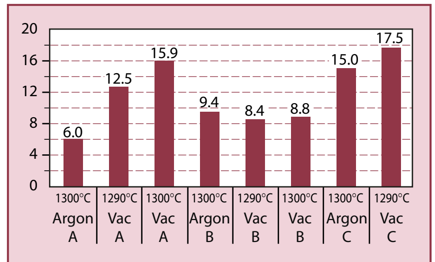
The effects of particle size, bulk chemistry, and surface chemistry on sintering shrinkage have been investigated for compaction grade -100 mesh 316L stainless steel. Thirteen different lots were evaluated for sintering shrinkage at 1150°C and 1300°C. These results were used to generate a linear regression model for sintering shrinkage. The model was tested with three additional grades not included in the regression model. The sintering temperature, particle size, surface Cr, bulk Ni, and bulk Si contents had the most profound effects on sintering shrinkage at both temperatures. The figure (right) shows a plot of surface Cr vs. shrinkage at 1300°C, after a correction factor has been added to each to negate the particle size effect. Similar effects were observed at 1150°C. Neal Myers (nsm104@psu.edu)

Shrinkage vs. Surface Chromium, 1300°C



Ductile Titanium in KYK

Titanium has successfully been sintered in the KYK Oxynon™ furnace. Results were compared to sintering in an all-metal hot-zone vacuum furnace. Initial results suggest that pure titanium can be densified to 4.2 to 4.4 g/cc while sintered in the Oxynon furnace. Also, ductility greater than 10% is obtainable.



In the graph, the letter signifies a powder type and argon signifies sintering in the KYK Oxynon furnace.

Note: 6% elongation for powder A in argon is suspected to be low due to sodium contamination during sintering.

This 225 mm wide (9 in) graphite belt furnace capable of 2000°C sintering is the first installation of this technology in the USA. The equipment is available to companies for experimental purposes. Donald Heaney (dfh100@psu.edu)

Conference Call Business

An increase in conference calls is a new trend at CISP. Two years ago this was a rarity usually exercised as a last resort. While most of this change can be attributed to September 11, the ability to quickly share knowledge and adapt to customer desires is a clear driver. This new approach creates a structure to working together more strategically with customers. We are seeing five or more calls per week to our group. We have been successful in defining and implementing the requests of customers from entirely different parts of the country or the world using the conference call approach. Sharon Elder (cisp@psu.edu)

New Image-Analysis System Installed

CISP has installed a new digital image-analysis system, designed for evaluating microstructures of materials. The system is Clemex Vision PE software coupled with an automated stage/focus control on a Nikon inverted metallograph. The primary image source for the system is the optical metallographic microscope, but any digital image from any source can be analyzed as long as the calibration factor is known.

Image analysis is a frequently used tool at CISP, but its primary drawback until now has been the length of time taken to generate a statistically relevant amount of data. A typical application is to measure grain size and shape distributions in sintered parts. Before, this measurement required 16-20 hours of trained-operator time to produce data on 500 grains on a small section of the sample. The new system can perform the same analysis on more than 1,000 grains in about 10 minutes, once the routine has been developed. We have already analyzed entire metallographic cross-sections for porosity, thus eliminating errors from examining only part of a sample, and keeping track of every pore location to identify gradients.

Myriam Savard from Clemex trains students on the new image-analysis system. Pictured from left: John Gurosik (MS student), Nick Erhardt (PhD student) and Matt Kelly (BS student).

Analysis routines, once developed for a particular application, can be used by more than one person without inducing operator errors, improving precision. The Clemex system exploits recent advances in color digital cameras and computing power, giving us the ability to analyze color images, which will help a great deal in working with sintered composite materials where color is a key microstructural factor. Finally, the dedicated image-analysis computer is faster than the old system, allowing real-time image manipulation and use of more complicated processing algorithms.

The new system will significantly accelerate and improve the generation of microstructural data for a myriad of projects. Lou Campbell (lgc102@psu.edu)

Thermal Debinding Success

The Thermal Debinding Project has been successful in simulating four different mathematical models: basic debinding, two-phases, multi-component, and 3D. These simulations use Visual C++ to predict the pressure build-up in porous green bodies during binder removal. The four models vary in complexity. The basic debinding model considers the formation of only a gas phase during the binder burnout. The two-phases model considers the formation of both a gas and a liquid phase during debinding. In the multi-component model, two binder components are included, such as wax and polymer. And recently, a 3D model was programmed to describe the pressure build-up in the three dimensions of a porous body with one binder component. We are now creating computer software where the user will be able to study and simulate each model by altering a few constant values. Experimental evaluations of crack formation at different heating rates are also performed for the validation of the models. Any members interested in evaluating this software at the end of the summer should contact Chantal Binet (cub9@psu.edu)

'03 Sintering

The International Conference on the Science, Technology & Applications of Sintering will take place at the Penn Stater Conference Center, University Park, PA on 15-17 September 2003. Organized and hosted by the Materials Research Institute and the Center for Innovative Sintered Products, the program is chaired by Professors Randall M. German and Gary L. Messing, both of Penn State, and coordinated by an international organizing committee of recognized experts in the field. This three-day conference will explore new developments in the applications of sintering processes for the fabrication of powder/particulate-based materials. New modeling of densification mechanisms will be investigated and novel alternative processes to conventional sintering will be explored. A special feature of the meeting will be a session devoted to future needs in the field of sintering. More than 250 investigators and practitioners from the international sintering community are expected to attend with over 100 oral and poster presentations. Read more at www.mri.psu.edu/sint03

Students' Corner

Ben Smarslok

Ben Smarslok is a senior at Penn State studying mechanical engineering. He is originally from North Huntingdon, about 30 miles southeast of Pittsburgh, PA. Ben began his college career at Penn State Erie, The Behrend College. After two years there preparing for his degree in mechanical engineering, he transferred to the main campus. Ben joined the CISP lab as an undergraduate research assistant in October 2002. He enjoys applying the knowledge he has gained in class to real-life situations at the lab. On graduating next spring with a major in mechanical engineering and an engineering mechanics minor, Ben intends to acquire a position in the field of mechanical analysis and design. His future plans also include continuing his education to achieve a master's degree.

Nick Erhardt

Nicholas Erhardt joined CISP as a graduate research assistant in August 2002 and is working towards a PhD. He received his B.S. in Physics from Northern Arizona University. He is originally from Tucson, Arizona where he worked at Raytheon Missile Systems as a project test engineer. Nick is now working on a NASA-funded project, currently performing quenching experiments to investigate the microstructural evolution in liquid phase sintering systems, namely W-Ni-Fe.

NSF REU Students

Ten students representing eight university sites across the United States are taking part in the National Science Foundation Research Experience for Undergraduates (REU) program at CISP. Now in its third year, the program attracts undergraduate engineering and materials science students to participate in the Center's research projects. The program also engages students in technical content seminars, instruction in research methods, and an introduction to industry via industrial tours.

Participants for this summer's program. Back row: Michael Huff (University of West Virginia), Jon Voss (Taylor University), Brent Selby (Carnegie Mellon), David Katcher (SUNY Binghamton), Eric Paszkowski (Penn State Behrend). Front row: Kevin Waggoner (UC Santa Cruz), Jeremy Gabler (Penn State Dubois), Will Schmitt (Carnegie Mellon), Devon Scott (Penn State University Park), and Matthew Lewis (Penn State University Park).

CISP Summary

- **P/M Lab established 1991**
- **CISP established 2000**
- **20,000 sq. feet (1,858 sq. meters)**
- **Membership levels:**
  - Affiliate - Associate - Partner
- **Company supporters:**
  - 11 Fortune 500 companies
  - 6 Global 500 companies
  - 90+ members
- **75+ off-campus presentations annually**
- **Over 30 publications annually**
- **Equipment capabilities:**
  - **3 injection molding machines**
    - computer control, up to 60 clamping force
  - **4 powder compaction presses**
    - 4 to 100 ton mechanical and hydraulic fully automated
  - **9 batch furnaces**
    - 1500°C max. temp., H_2, N_2, Ar, He, air atmospheres
  - **4 vacuum batch furnaces**
    - 2200°C max. temp., metal, ceramic, and graphite zones
  - **1 CIP**
  - **1 HIP**
  - **1 powder atomizer**
  - **1 continuous belt furnace**
    - Oxynon™ all-graphite 4 zone 2000°C max. temp. N_2, Ar atmospheres, 9" belt
  - **1 continuous pusher furnace**
    - CM 5 zone 1700°C max. temp. H_2 atmosphere, 2.5" wide
  - **1 continuous twin screw mixer**
  - **2 batch mixers**
  - **1 CNC milling**
  - **2 rheometers** (torque and capillary)
  - **1 dilatometer**
    - 1500°C max. temp. N_2, H_2, Ar atmospheres
  - **2 DTA/TGA**
    - thermal analysis in N_2, H_2, Ar atmospheres
  - **1 laser diffusivity** (1500°C max. temp.)
  - **3 mechanical testers**
  - **3 hardness testing**
    - macro, micro, and nano
  - **2 metrology** (optical and manual)
- **Testing services:**
  - **microscopy**
  - **rapid prototyping**
  - **metallography**
  - **porosimetry**
  - **powder characterization**
  - **chemical analysis**
- **CAD/CAM platforms supported:**
  - AutoCad, Pro Engineer, MasterCam

Center for Innovative Sintered Products
The Pennsylvania State University
CISP Lab, 147 Research West
University Park, PA 16802-6809
visit us on the web at: *www.cisp.psu.edu*
Phone: (814) 865-2121 • Fax: (814) 863-8211 • E-mail: cisp@psu.edu

Randall M. German, Director
Phone: (814) 863-8025
E-mail: rmg4@psu.edu

Sharon L. Elder, Exec. Director
Phone: (814) 865-1914
E-mail: cisp@psu.edu

CISP Newsletter
Published four times per year

Managing Editor
Sharon L. Elder

Associate Editor
Christine Doran

Graphic Designer
Rick Sharbaugh