Summer 2004

Center for Innovative Sintered Products

CISP

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Hot Growth

Rand German – Director

How do sintered materials stack up in the arena of business growth opportunities? Sometimes we are just too close to the trees to see the forest. Reports from CISP member companies range from running over capacity to running at 25% of capacity. The business landscape in sintered materials is not uniform. However, some of the top performers are doing extraordinarily well, exceeding $5,000 in annual sales per square meter of space (over $500 per square foot). This is impressive.

One of the things we have learned is the reality of the financial performance with respect to membership in CISP. Our member companies must be successful, so financial metrics are important to us, since membership in CISP is a discretionary expense that is easily trimmed in bad times. Can we suggest that only successful firms join CISP?

All of this leads to some interesting facts. Recently Business Week tabulated the 100 best US small companies in terms of hot growth (7 June 2004 issue). They selected 100 out of 10,000 small companies (top 1%). Not surprisingly, we have worked with some of these. The tabulation came out as CISP was going through a strategic planning process, with much discussion on where we need to go to provide students, training, research, and services that are properly positioned for future sintered materials fields. We see globalization and are positioning for a role in the global technical field as part of our direction. Also, we need to anticipate that our graduates will be working for 40 years using the knowledge imparted at Penn State. We feel that our goal is to provide knowledge for solving problems, not training in any one technology.

What caught my attention was a chance to determine whether technology-based manufacturing was a growth sector. Also, it was a chance to determine whether there were some regional differences, and so on - again, part of strategic planning. What became evident was that a good portion of the hot growth was in manufacturing. To simplify the analysis, I coded each company in the top 100 according to their product (service, manufacturing, software, training, and such), their region (Northeast, South, Midwest, and West to keep it simple), their customers (automotive, consumers, businesses, government, luxury goods, and such), and whether they are dependent on technology. To simplify about 20 pages of text, tables, and stories, this is what I see.

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PENNSTATE

Center for Innovative Sintered Products

Web-lecture reality

CISP recently participated in an online, real-time web-lecture conference hosted by the Technical University of Denmark. According to Professor Per Moller, this was the first time TU Denmark had connected a conference room in Denmark and a person in the US and the result was much better than expected. Rand German presented an e-seminar on corrosion characteristics of metal powder injection molded (PIM) stainless steels as part of a conference on post treatment and corrosion protection of sintered products. The conference used the program Hotcomm Conference Lite. This is an effective way to deliver a seminar to remote sites and is one of the themes for emphasis at CISP in the upcoming year.

Upcoming Events

October 4-5, 2004
Industry Member Meeting
University Park, PA

October 17-21, 2004
PM2004 World Congress
Vienna, Austria

April 4-6, 2005
PM Asia 2005
Shanghai, China

Aug 29-Sept. 1, 2005
Sintering'05
Grenoble, France

Hot Growth (continued from page 1)

This tabulation shows the number of firms in each business area out of the top 100 (same as percent) and the average ranking (top firm is #1 and bottom firm is #100, so a low ranking is good):

Business	%	Ranking
Manufacturing	43	60
Retail	27	46
Services	18	53
Training	6	17

An immediate first impression is that manufacturing is doing fine, in spite of rumors of its demise in the USA - 43% of the hot firms are into making something. However, there is a special situation for "for-profit" education labeled as training; it is far from the 50% median and looks like a special sector. So maybe CISP should provide training for manufacturing?

Another concern in our strategic planning discussions was regional growth. Stratification of the manufacturing firms (43%) in the 100 hot growth US firms shows the following breakdown:

Region	%	Ranking
Northeast	10	51
Midwest	14	67
South	6	70
West	13	56

This shows that manufacturing firms are not concentrated in California, contrary to expectation. Indeed, Utah and Florida were anomalously high. The bottom line is that manufacturing growth is taking place in all regions, and in the Northeast it leads to a better positioning (lower number in the ranking), but as noted above, manufacturing in general ranks slightly low in the top 100 firms (60% ranking versus the composite of all hot companies would be 50%).

So we see that manufacturing can be hot in the historical regions for sintered materials, and there are even some firms CISP deals with that are ranked as hot firms. Not so bad, contrary to early expectations. Now for some refined analysis. It turns out that 55% of the hot firms listed are not technology-based; instead they provide innovative services, outsourcing, distribution, retailing, or they might be niche restaurants. These are mostly in retail. But 45% of the firms do have a leaning toward technology. Filtering the manufacturing firms that use technology for a competitive advantage, we can then examine their target customers, and the big winners are in the medical and healthcare sectors. Of the 31 hot firms that actually manufacture something based on technology, 17, or over half, target medical, dental, drug, or healthcare products. They are followed by firms targeting food, government, and luxury markets. There was only one hot manufacturing firm that relies on technology that targets the automotive market. In a previous CISP newsletter we identified a need to better position CISP to address the medical field, and this statistic supports that long-term goal. Fortunately, we were able to attract Dr. John Johnson to the staff, who has already landed research in medical products.

From all of this an interesting direction becomes evident; maybe we should provide for-profit training for technology-based manufacturing that targets healthcare or medical markets. Those of you who know our history might recall that in 1991 Thermal Management Materials was formed out of the lab at Penn State, which was shortened to Thermat and subsequently became Thermat Precision, and then MedSource, and is soon to be part of UTI. What was initially a firm specializing in thermal management materials ended up making small medical components using injection molding.

Finally, some fun with the Business Week statistics. Manufacturing with a technology base leads to an average ranking of 59 (again a low number out of 100 is good). How do a few other fields stack up? Retail with no technology base targeted at the following markets stack up as shown here.

Market	Ranking
Health	9
Teens	19
Consumer	49
Luxury	49

Note there are two very high-performing markets, healthcare products and teens. Any of you that have teenagers will fully understand how expensive they can be, and the statistics clearly show selling to that market is one of the hottest prospects. The poorest year of my life was when I had one son at Syracuse University and one son at Cornell University, so it only gets worse when they need "training". This shows up in the statistics, since training "for-profit" is one of the hottest growth businesses. Anyone want to set up a new for profit sintered materials college? Rand German: rmg4@psu.edu

CISP is assisting in the organization of the fourth International Conference on Science, Technology and Applications of Sintering.

Aug. 29 to Sept.1, 2005

Centre des Congrès EUROPOLE - Grenoble, France.

http://www.emse.fr/sintering05

Master Sintering Curve of Densification – Power Law, Linearization and Sigmoid Models

CISP has developed three models for the master sintering curve of densification, with three different parameters. These models offer great advantages in making the construction of the master sintering curve and its database easy. CISP has a database with eight different sintering systems for the master sintering curve based on these models.

Three parameters:

(1) densification parameter

$$\psi = (\rho - \rho_0)/(1 - \rho_0)$$

(2) densification ratio parameter

$$\Phi = (\rho - \rho_0)/(1 - \rho)$$

(3) work of sintering

$$\Theta = \int_0^t k_0 \exp [- Q/RT] \, dt$$

Three models:

(1) power law model

$$\Phi = (\Theta / \Theta_{ref})^n$$

(2) linearized model

$$\ln \Phi = n \, (\ln \Theta - \ln \Theta_{ref})$$

(3) sigmoid model

$$\psi = \{ 1 + \exp[(a - \ln \Theta) / b]\}^{-1}$$

Contact: Debby Blaine dcb193@psu.edu and Seong Jin Park sup13@psu.edu

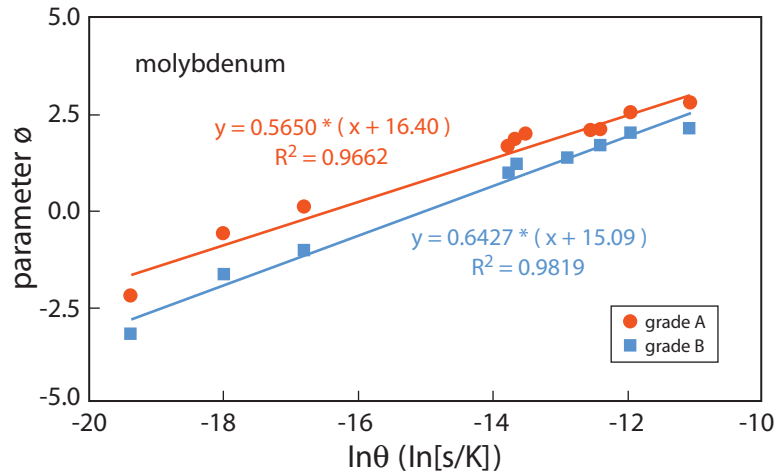


Figure 1. Linear form of master sintering curve with molybdenum

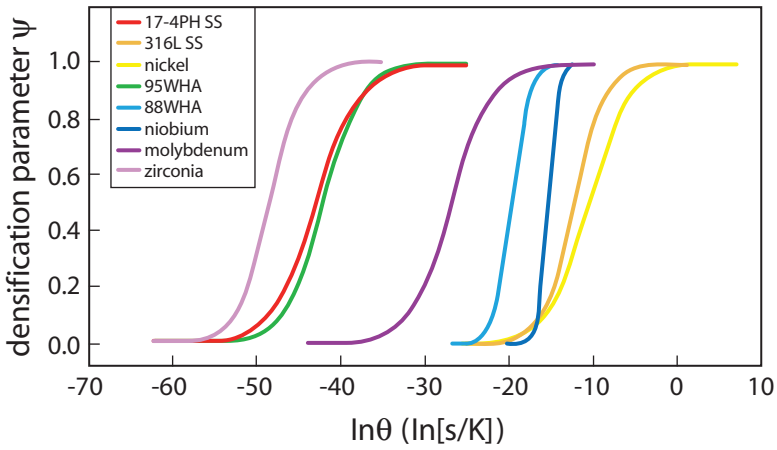


Figure 2. CISP database of 8 different master sintering curves for densification

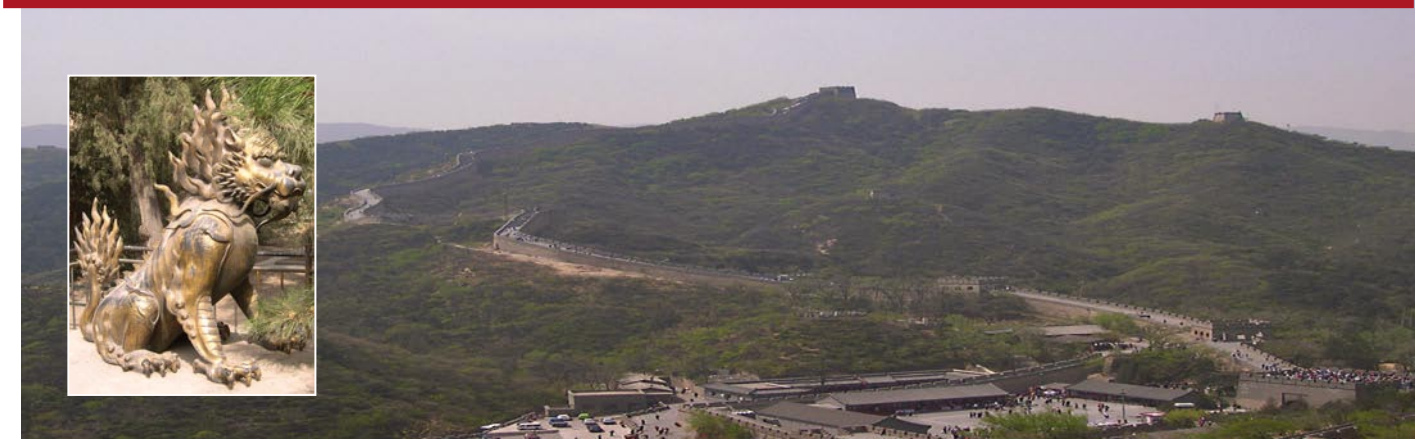
Industry Member Meeting – *An Information Link*

The biannual Industry Member Meeting of the Center for Innovative Sintered Products took place at the Penn Stater Conference Center on 10-11 May. Some highlights of the meeting were identification of the research portfolio for the upcoming year, dissemination of research results, networking with colleagues from industry and academia, information about NSF-SBIR innovation-through-partnership initiatives, assessment of opportunities and barriers of electrophoretic deposition, and a metal-casting and P/M perspective of dimensional precision. Over eighty delegates met at this excellent venue to hear reports on a wide variety of research topics as well as capability presentations from twelve member companies.

The Industry Council met immediately following the regular meeting. The key issue for the council was the balance and awarding of research projects slated to begin on 1 July 2004. (See page 5 bottom right for a list of the identified projects.)

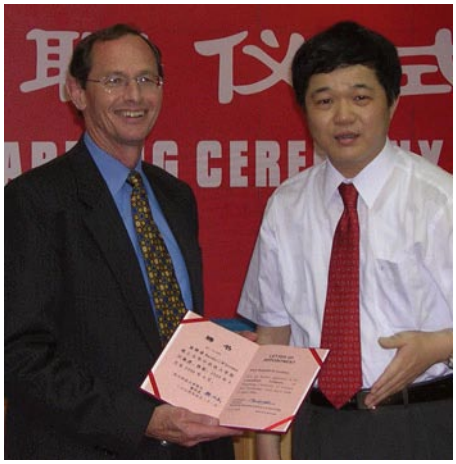
Positive feedback from delegates after this event confirmed its success. The Center offers a variety of services to help companies add value to their business. The next CISP Industry Member Meeting will be held on October 4 and 5 at the Nittany Lion Inn, State College, PA. To help guide and direct this program, contact Sharon Elder, Executive Director, at cisp@psu.edu.

Death of Distance



Advances in information and low-cost communication technologies make distance irrelevant – but how does this affect business, governments, and culture? The Internet has revolutionized the transmission of data. Transatlantic fiber-optic cable has reduced the price of a three-minute telephone call from New York to London from over $50 in 1990 to a few cents per minute today. Such advances have allowed poorer countries, such as China, to move straight into the digital revolution and skip the outdated technological steps. For example, China is now the world's largest mobile-phone market in terms of users: subscriptions rose to 296 million in April – more than the total US population.

Rand German, Director of CISP, visited China this April. He was greeted with dramatic changes made since his previous visit in 1985. The airport was modern, highways were jammed, signs were in English, buildings were taller, and people dressed about the same as on a US campus. Everyone seemed to have a cell phone and computer, but not many books were in evidence.



Dr. German and Vice President Cheng Wang of the Huazhang University of Science and Technology

Dr. German's ten-day trip began in Beijing with visits to Tsinghua University, Shandong Jinzhu Powder Injection Manufacture, University of Science and Technology Beijing, and Advanced Technology and Materials (a spin-off from Central Iron and Steel Research Institute). From there he went to Huazong University of Science and Technology, Wuhan; Central South University and State Key Laboratory for Powder Metallurgy, Chengsha, Hunan; and Zhuzhou Cemented Carbide Cutting Tools, Hunan.

The Central South University is one of the premiere PM universities in China. The campus of 80,000 students has 1000 undergraduates and 300 graduates in materials science and engineering. The university has a new P/M technology park with three new companies (carbon-carbon composites, friction materials, and extruded tungsten carbide rods). The largest of these reported $70 million in sales last year. The university is interested in new international cooperation and the government provides incentives to achieve this goal. In 1989 the current president of the university, Professor Baiyun Huang, helped found the State Key Laboratory in Powder Metallurgy – a small complex with many capabilities. Zhuzhou Cemented Carbide Cutting Tools is the largest cemented carbide fabricator in China, with 10,000 employees and annual sales of near $200 million. It is state owned and wants to do an initial public offering. The university program has less than 25 years of history, as universities were closed during the Cultural Revolution and faculty sent to work on farms. There are few books or libraries as they are too expensive, so much repeitition occurs as many things are rediscovered in research that are already published facts. Hence, most Chinese research is of the "new to you" type rather than leading edge.

Dr German's visit left him with several things to ponder. Is the rate of technology transfer from the USA to China increasing, reducing the time lag between when the US develops a technology and China takes over its production? One thing is certain: China has a rapidly increasing economy with an enormous workforce – reportedly 100 million unemployed, which is almost enough to take every job from the USA.

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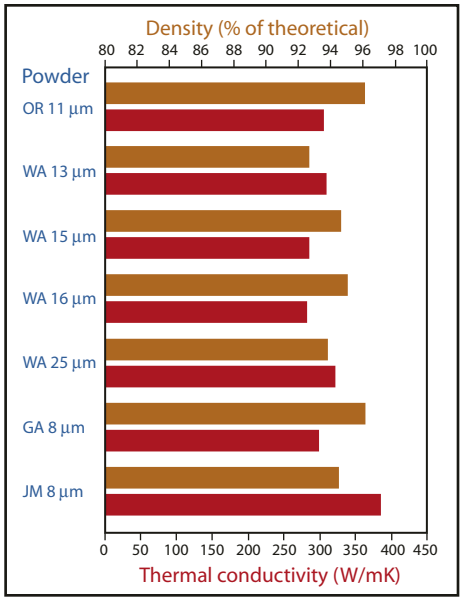
Metal Injection Molding of Copper Heat Sinks

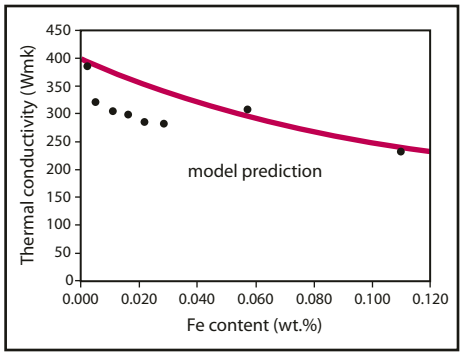
New thermal management solutions are needed to provide cost-effective means of dissipating heat from future generation microelectronic devices. Currently, aluminum is a common choice for heat sinks because of its relatively high thermal conductivity and ease of manufacturing. Copper is preferred for applications that require higher thermal conductivities than possible with aluminum, but it is more difficult to extrude, stamp, or cast than aluminum. Metal injection molding (MIM) can enable cost-effective manufacturing of new designs that provide improved heat dissipation.

Copper powders can be produced by several processes including oxide-reduction (OR), water-atomization (WA), gas-atomization (GA), and jet-milling (JM). Powders of each type, including four water-atomized copper powders, with mean particle sizes ranging from 8 to 25 µm, were evaluated for MIM. The gas-atomized and 25 µm water-atomized powders had the highest solids loadings, while the oxide-reduced powder had the lowest. All of the powders could be processed to densities between 93 and 96% of theoretical at 1050°C; however, the thermal conductivity varied with impurity content. The highest thermal conductivity as measured by the laser flash method was 385 W/mK for the jet-milled powder, which had the lowest iron content of 22 ppm. The conductivity decreased significantly for samples with 50 to 290 ppm, but at higher iron contents, the results followed predictions based on a combination of Nordheim's Rule and the Wiedemann-Franz relationship.

Future heat sinks are expected to need materials with thermal conductivities even higher than that of copper. Understanding the factors affecting the thermal conductivity of sintered copper provides guidance for the next generation of thermal management materials, such as copper-graphite and copper-diamond composites. John Johnson: jlj120@psu.edu



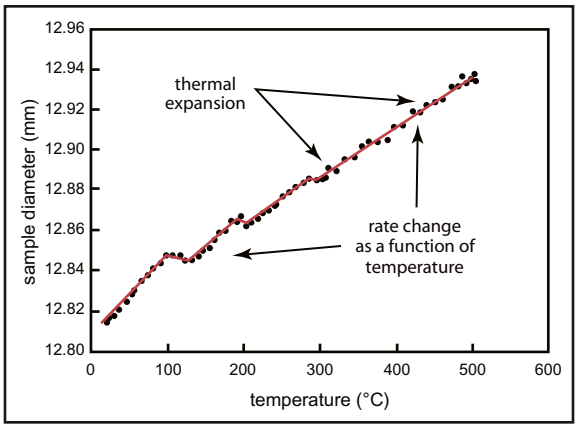
Effect of Cu powder on density and thermal conductivity after sintering at 1050°C.



Effect of iron impurities on the room-temperature thermal conductivity of copper.

In-situ, Non-Contact Measurement

Equipment has been built to monitor the dimensional change of powder compacts that contain lubricant or binder during thermal debinding and delubrication cycles. The measurement is truly non-contact, utilizing a laser dilatometer that is accurate to ±1µm in nitrogen at room temp and approximately 4µm in nitrogen at 500°C. The furnace is PID controlled. To date, stainless steel compacts with 1 wt% lubricant polymer have been measured during thermal delubrication. The results have shown the thermal expansion rates of the compacts that appear to change with remaining polymer mass. Work is currently being done to characterize the effect of this dimensional change with respect to polymer type, melting point, boiling point, and cycle temperature profile. An example of the data obtained and the method used to interpret it is shown. Ryan Koseski: rpk128@psu.edu



Research Portfolio Unveiled

With an emphasis on student training and research, member companies had an opportunity to vote on the suite of precompetitive research projects for the upcoming year. The projects identified as a top priority are:

- Multiple-Axis in-situ Monitoring of Dimensional Changes in Debinding, Delubrication, Sintering, and Heat Treatment
- Press and Sinter Processing Realities with Nanoscale Powders
- Fundamental Limitations and Capabilities of High-Density P/M
- Crack Detection in Green Compacts
- Oxynon Furnace Evaluation
- Application of Full Density Hard Coatings to Ferrous P/M Materials

New Face

John Johnson

The Center is pleased to welcome John L. Johnson as a Senior Research Associate effective 1 May 2004. Dr. Johnson obtained a Ph.D. in Engineering Science and Mechanics from Penn State in 1994, and has been closely associated with the Center for the last two years as R&D Manager of AMTellect, Inc. where his duties involved supervision of R&D of new powder injection molded (PIM) materials and products for medical, automotive, electronics, and aerospace applications. Prior to this, John held technical positions with Howmet Castings (now an Alcoa business) at the ceramic core facility in Morristown, TN. His responsibilities included developing and implementing new materials and manufacturing processes to reduce variation and cost of ceramic cores for investment casting of high-precision aerospace components.

John's research focus is on P/M processing of thermal management materials (copper, W-Cu, Mo-Cu, and diamond-copper), biocompatible materials (titanium, Co-Cr-Mo, and alumina), and unique structures such as controlled porosity, bi-materials, composites, and functionally graded materials. John Johnson: jlj120@psu.edu

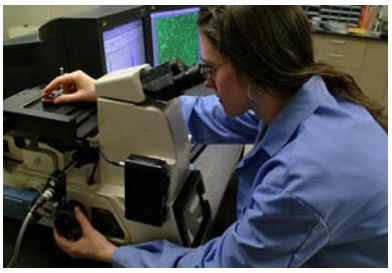
In With the New

The new Industry Council members for 2004-2006 are: Robert Balliett (H.C. Starck), Harald Bleier (Battenfeld), Jane Bryndel (Alpha Sintered Metals), James Dale (MPIF), Ulf Engström (North America Höganäs), John Frey (Air Products), Mark Greenfield (Kennametal), Anthony Griffo (Smith International), Kenneth Hanford (Intech PM Stainless), Daniel Henkel (Pall), John Kosco (Keystone Powdered Metal), Robert Loeb (PS DuBois), Deepak Madan (F.W. Winter), Donald Masisak (North Central PA Regional Planning), Rocco Petrilli (Plansee/Sinterstahl), Richard Seymour (KYK), Thomas Wolfe (Osram Sylvania), and Dean David Wormley, (PSU Chairman).

We would like to extend a special thank you to past members below.

Pictured left to right: Dan Henkel (Pall), Mark Greenfield (Kennametal), John Kosco (Keystone). Back row: John Frey (Air Products), Rich Seymour (KYK), Tom Wolfe (Osram Sylvania), Tony Griffo (Smith International), Bob Balliett (H.C. Starck). Absent: Bill Clark (St. Marys High School), Ulf Engström (NA Höganäs), Jack Krajcirik (Dorst America), Young-Sam Kwon, (CetaTech), Deepak Madan (F.W. Winter), K.S. Narasimhan (Hoeganaes), Jim Neill (CM Furnace), Mike Pohl (Horiba)

Testing & Services



The CISP Lab is well equipped to perform routine testing for particle characterization, thermal analysis, metallography, mechanical testing, and trial sintering runs. This allows companies to run short-term tests without investing capital in expensive equipment and personnel training required for performing the test in-house. The differences between lab service testing and contract project work are in scale and intellectual property. Lab service testing is typically small scale, and the reports contain only test results with immediate interpretation, no intellectual property transfer. Results and sample types are kept confidential. Testing that we perform regularly is for the purposes of new process /product development, quality control, and process troubleshooting. We have performed lab service testing for a wide variety of fields, including press and sinter, injection molding, electronics packaging, pharmaceutical, chemical processing, bioengineering, engineered ceramics. To see a listing of services and prices, please see our web site at http://www.cisp.psu.edu/testserv/pricelist.htm. Not all our services are listed here; if you are in need of testing and think we can help, please contact Lou Campbell or Kristina Cowan at (814) 865-2121 or e-mail to lgc102@psu.edu.

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