Summer 2005

CISP

Center for Innovative Sintered Products

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China – The Opportunity to Collaborate

John Johnson & Sharon Elder

Having international connections, assessing implications, amending strategies, and knowing where to go for a good quality powder source are all part of functioning productively in an international environment. A team from CISP recently completed a fact-finding and future collaborations mission to China under a National Science Foundation International Planning Visit Grant. Senior Research Associate John Johnson, graduate student Ryan Koseski, and Sharon Elder spent ten-days in mid-June assessing facilities, equipment, and research collaboration efforts. Although not part of the NSF grant, Judy King, CISP financial manager also accompanied the group. This grant is a two-year program, whereby Ryan or another designated student will be returning next summer to conduct a designed set of experiments (DOE) to evaluate parameters that control the size and shape of Ti and Ti-6Al-4V powders. The ultimate goal will be to put together a federal proposal on MIM orthopedic parts.

Dr. Yunxin Wu, Tsinghua University, Beijing was the principal organizer and host for this visit. Dr. Wu worked as a Visiting Research Associate at CISP during April 2001- June 2002. He took part in CISP projects such as the ATP program (Metal Powder Injection Molding of Large Parts) and NASA program (Gravitational Effects in Liquid Phase Sintering). Upon returning to China, Dr. Wu continued a collaborative relationship. He is working with CISP on the debinding and sintering of injection molded Ti. Our computer resource center with Dr. Wu's team already has some useful simulation results for molding behaviors of Ti feedstock and sintering behaviors of Ti compacts using PIMsolver, master sintering curve simulation, and the statistical approach.

The visit began with tours of the Tsinghua University facilities. The molding lab has 2 molding machines: one large JSW (Japan Steel Works) machine and a smaller Chinese machine with a screw approximately 20 mm in diameter, which is used for most of the work. These two machines are used only for Ceramic Injection Molding. Metal feedstocks are molded at USTB as will be discussed later.

The sintering lab has a graphite furnace/hot press capable of 2200°C for processing Si_3N_4, SiC, ZrO_2, a Dr. Sinter Spark Plasma Sintering machine for processing functionally graded materials (FGM's) and carbon nanotubes, and a gas pressure sintering furnace capable of 2000°C,100 atm. The microwave sintering lab has been moved to another university.

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PENNSTATE
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Research Projects 05-06

At the CISP Industry Member Meeting in April, members voted on the suite of precompetitive research projects to begin 1 July 2005. The Industry Council considered the votes, balanced the portfolio and made the final decision on the following projects to go forward :

- Press and Sinter Processing Realities with Nanoscale Powders (nano-P/M) - *Randall M. German*
- Technical and Economical Comparison of Micro Powder Injection Molding - *Seong Jin Park and Randall M. German*
- Microstructural Evolution in Liquid Phase Sintering – *Jianfeng Guo and Randall German*
- Binder Removal in Nitrogen/ Hydrogen Atmospheric Mixtures – *Lou Campbell*
- Detailed Linkages from Powder Characteristics to Properties in Press-sinter Processing of Parts- *Rand German with MSU collaboration*

All member companies are encouraged to become familiar with, and take advantage of, or mentor any research project. To mentor one of the projects, contact Sharon Elder (cisp@psu.edu)

Upcoming Events

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

Sept 26-28, 2005
ASM-Material Sc. & Technology
Pittsburgh, PA

Oct 18-19, 2005
Industry Member Meeting
University Park, PA

March 19-22, 2006
PIM 06 Conference
Tampa, FL

The forming lab has 1 CIP and one 1930's die press from the US. The hot microscopy lab houses a hot stage microscope (10X) for observing metal to ceramic joining up to 1800°C and a microtome for TEM preparation.

We met with Prof. Gai Guosheng, who heads up the Powder Processing Lab. He has built equipment to specially mill powders with unique structures. A picture of this mill is shown in Figure 1. The powders it is used to process include oxide dispersion strengthened copper, rounded Ti powders for injection molding, toner, graphite for batteries, CNT coated polyethylene for high conductivity, high strength composites, clay/polymer nanocomposites, fly ash/polymer composites, and polymer composites containing Chinese herbs and other botanical materials, e.g. cornstarch for improved biodegradability. For making composites with clay and fly ash, they are coated with nano $CaCO_3$ for better adhesion. In the case of fly ash, the $CaCO_3$ forms $CaSi_3$ to make a rough surface.

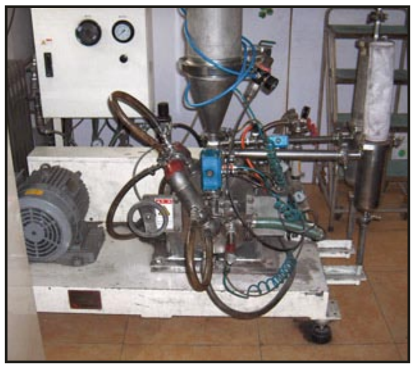

Fig. 1. Custom mill for processing powders

For rounding and coating of powders, the powder is fed into the top of the mill. A computer-controlled valve is closed and the powder cycles through the mill. After about 10 minutes, another valve opens to the collectors. Tsinghua has two rotors, one is stainless steel, the other is stainless steel with a SiC coating. The equipment is capable of running off of compressed Ar, a necessity for dealing with reactive metals like Ti. This piece of equipment will be used for trials to prepare Ti powder for injection molding.

Prof. Gai has other equipment that we did not see, including a jet mill in the basement and a spray dryer, as well as vibratory mills, roll mills (up to 100 m/s) and sedimentation. Prof Gai uses this equipment for several projects funded by NSF of China. These include fine grinding of Chinese herbs as low cost medicines for rural areas of China and shredding of tires to produce oils from their vapor.

Tsinghua's Mechanical Eng. Depart. has a large program in bone and tissue engineering. Rapid prototyping has shifted in recent years to biomanufacturing. Projects include rapid prototyping of hydroxyapatite and Ti/HA composites for bone and joint replacements. These materials have been tested in animals, but have not developed to human clinical studies. Porous Ti is produced by mixing binder, powder, and a foaming agent. Samples are slurry cast, foamed and then refrigerated, which causes the polymer-ceramic mixture to phase separate. Another rapid prototyping technology is metal extrusion molding, which heats a strand of material to build up a 3D structure. Despite the name, most work was done with ABS.

After the tour, Dr. Johnson gave a presentation entitled "P/M Materials for Biomedical Applications." Sharon Elder gave two presentations entitled "Areas for Research, Education and Service Collaboration in Powder Injection Molding " and " Identifying Research Possibilities-the Decision Process". About 50 students and faculty were in attendance.

We met with Mr. Chen Xiao Xian, manager of the Tshinghua Science Park Service Center. The Tsinghua Science Park is being set up to help companies establish business relationships with Tsinghua University. It serves both start-ups and multi-national conglomerates, such as Sun Microsystems, Schlumberger, NEC, and P&G. About 60% of the companies in the Science Park have collaborative efforts with university departments. Of these companies, there are two types. The first type is set up by Tsinghua faculty to commercialize their research. The second type is co-located by outside enterprises. Because of the high desirability of the location, some companies have chosen to set up in the Science Park even though they do not have direct interaction with the University. Floor space is fairly expensive for China up to 4.5 RMB per day per m^2 ($1 US = 8.2RMB). Construction is financed by a combination of funding from the university, the government, and private investors. Construction of the main 570,000 m^2 area began in 2000.

We were hosted by Prof. Haiqing Yin of the Institute of Particle and Powder Metallurgy at the University of Science and Technology, Beijing (USTB). We began with seminars on CISP research. Dr. Johnson gave a presentation entitled "PIM Applications and Market Opportunities." Sharon Elder gave two presentations, entitled "PIM Technology-A Status Update" and "US Research and Development". About 60 students and faculty were in attendance. Several of the students are involved with P/M research. One lesson learned was to present less material and to speak more slowly, as the students and faculty struggled with English. The interest from the group was lively and questions ranged from the technical to how we get industry to join and participate in our research center to how was it possible for Sharon to make a career change from her degreed training to Executive Director of CISP. One student had just finished a Ph.D. on MIM of Ti-6Al-4V. The abstract was in English and most references were from English publications. Following a question and answer period, we were given a tour of USTB's P/M facilities.

USTB Laboratory of Powder Injection Molding

For compounding, USTB uses a custom designed "noodle extruder." It consists of a single screw with alternating mixing and conveying segments. An Ar blanket can be used for compounding reactive metal powders. The mixer was partially disassembled for repairs.

The lab has two molding machines made in China. One is set up to apply a magnetic field during injection molding of magnetic materials, such as bonded magnets. FeNdB in a polymer matrix has been processed with an energy product of 16 MGOe.

Solvent debinding is performed in tanks of trichlorethylene (C_2HCl_3). No special containment procedures were employed. In the same room is a HIP capable of 10 MPa and 1700°C. Its chamber is 120 mm in diameter and 200 mm long. Thermal debinding is performed in small pusher-type furnaces. Several parts were seen in various stages of debinding. These included Kovar "buttons," 316L gear shafts, and tool steel sheep shears. Chinese-made tube and bell furnaces were used for sintering. The tube furnace has a sliding hot zone for quick cooling.

Just this year, USTB purchased a Shimadzu vacuum furnace from Japan. This furnace, shown in Figure 2, is capable of 0.1 to 0.5 Pa at 1600°C. It has a hot zone measuring 300 mm by 300 mm by 1 m. It is capable of sintering 100 kg of stainless steel parts. USTB will install a SPS furnace soon.

Fig. 2. Shimadzu vacuum furnace at USTB

Tour of the MIM Plant of Advanced Technology & Materials (AT&M)

AT&M is the largest MIM company in China. We were given a tour by He Jianjiu, Vice Director, and Prof. Cao Yongjia, Technical Director. Prof. Cao studied in Russia and is a leading P/M expert in China. He is semi-retired from the Central Iron and Steel Research Institute (CISRI), and serves as President on the P/M Committee of the Chinese Society of Metals as well as Associate Chief Editor of *P/M Technology*. He was instrumental in getting the article "China – US Sintered Material Market Opportunities" published in the Chinese *Powder Metallurgy Technology* journal (No. 5, 2004) (in Chinese) by Sharon Elder and Y. Wu.

AT&M is located in an industrial park outside of Beijing. The facility and roads are modern. The MIM facility is 2700 m^2 and employs 270 people. It was started by CISRI in 1998 with a total investment of 47M RMB. Sales have increased from 12M RMB ($1.5M) in 2003 to 40M RMB ($5M) in 2004 with an expected 50M RMB ($6M) in sales for 2005. The plant has capacity to produce 120M parts per year. More than 90% of AT&M's products are exported. Customers are now located in Japan, Singapore, Germany, and Taiwan.

Materials processed include 316L, 440, 630, Fe-Ni, W-Ni-Cu, W-Ni-Fe, and WC-Co. AT&M has the capability of producing MIM Ti parts. Customers have inquired about MIM Ti, but AT&M has not considered the parts they have been asked to quote to be good.

Although there are about 15 other MIM manufacturers in China, only three are capable of high volume production. These three each have about $1-2M in annual sales. They are located in Shandong Province (Shandong Jinzhu Powder Injection Manufacture Co.)

(continued top page 4)

China – Tour of the MIM Plant of Advanced Technology & Materials (AT&M) (cont. from page 3)

Changsha, Hunan Province (Central South University Powder Metallurgy Research Inst. Incubation Center), and Shanghai (Fuchi PM).

MIM production in China began in the early 1990's. Chinese engineers are not familiar with the technology. The Chinese MIM product is not mature. The total MIM market in China is estimated by Prof. Cao at about $20M, but is growing fast as evidenced by AT&M's growth. Like in the U.S., MIM research is growing more rapidly than production and a key barrier is the lack of customer knowledge of the advantages and limitations of the technology. The automotive market is limited. GM makes one car in China that uses one MIM part.

Operations

AT&M has Mitsubishi wire and plunge EDM machines for precision tooling. These are among the best in China and cost about $4M RMB. Lower precision molds are outsourced.

AT&M makes feedstock in a two stage process. First the material is prepared on one of two roll-type compounders. Then the material is transferred to one of two kneader mixers, which compound under vacuum.

AT&M's facility has 12 molding machines. Two Arburg 320C 600-250 machines are used for high precision components. Neither of them was running. The remaining machines are made in China by Cosmos and TMC at half the price. Only 5 of these machines were running. Two machines were running the same part, a tungsten heavy alloy cell phone weight. This part looked like it could be die pressed. Instead a circular insert with 16 cavities was manually inserted into the machine, which injected, packed, and cooled the parts in 4 seconds. The insert was removed and parts were manually pressed out, while another insert was loaded for molding. Total cycle time was about 15 seconds to make 16 parts. Other parts being molded included a pick and place attachment for IC circuits, a razor component, and one stainless steel part for a customer who did not disclose its use. None of the parts were particularly complicated and all probably could have been die pressed. AT&M's extreme low cost and speedy production allow it to make MIM competitive.

At least 2 workers manned each running machine. Several workers were performing various maintenance activities on the idle machines. After molding, parts were carried upstairs to a sorting/finishing area. Here 70 workers, all female, deflashed, poked holes, etc. to the various parts.

Solvent and thermal debinding are performed in a separate building that we were not shown. AT&M has 27 debinding furnaces. Debound parts are taken back to the main shop floor to sintering furnaces across from the molding machines.

Three vacuum furnaces are used for WC-Co, Fe-Ni, and stainless steel. Only one furnace was in operation. The largest furnace was made by Vac-Long in Taiwan. The two other vacuum furnaces were made by Shimadzu in Japan and are very similar to the one at USTB although they were a slightly older model. Prof. Cao noted that vacuum industry furnaces from the U.S. are better than the Shimadzu furnaces but cost $100K more.

In addition to the vacuum sintering furnaces, AT&M has 12 high temperature hydrogen continuous furnaces made in China by Mo-Win. These are dual tube furnaces and were in high use processing the WHA cell phone vibrator weights. They were set at 1350°C. The parts are sintered in wet hydrogen. W parts are packed in trays and run through the continuous furnace in less than 1 hour. Two trays are inserted every 7 minutes in both tubes.

The sintering furnaces are manned in three 8 hour shifts. Injection molding and other operations are performed in two 8 hour shifts, 5 days a week. In special cases, the workers can be asked to work up to 12 hour shifts and earn overtime pay. The work is considered desirable. Unskilled workers earn about $100 a month. This is considered an average wage compared to other plants. Workers with 5 or more years of service earn more. The female workers live in a company apartment. If they are married, they pay rent for housing near the plant. A job agency helps place workers at AT&M. Sometimes whole classes are placed. Offices were air conditioned for the engineers and administrative personnel. AT&M has 8 engineers.

Future plans

The next step is to have a student spend 30 days working in the labs at Tsinghua and USTB. This will occur next June. A project on MIM Ti, as planned in the initial program, still appears to be the best area of collaboration. Some difficulties were encountered with control of oxygen content during sintering of titanium. Ideas were exchanged on the use of vacuum, ultra-high purity argon, and getters for sintering. Having a student work in the labs will enable demonstrations and comparisons of these techniques. Another concern is with the cost of gas atomized powders. Even in China, gas atomized Ti powder costs 1600 RMB per kg ($194/kg), about the same as from Sumitomo in Japan or Crucible in the U.S. Hydride-dehydride (HDH) powder can be purchased in China for 300-400 RMB per kg ($36-48/kg), also similar to costs in the U.S. Prof. Guo's powder milling equipment may make such powder suitable for MIM. Oxygen content will remain a key concern. Oxygen contents of about 0.5 wt.% seem typical for Tsinghua sintered material. So far only vacuum sintering has been used.

Sharon Elder: (cisp@psu.edu)

Metallography Award

Congradulations to Lou Campbell, CISP's Senior Research Technologist for his recent 1st place Award from the PM^{2}Tec - APMI Metallography Competition poster in the Method Development catagory. Great Job !

Rand German appointed the new CAVS Director

Rand German has been appointed the new Director of the Center for Advanced Vehicular Systems (CAVS), CAVS Endowed Chair, and Professor of Mechanical Engineering at Mississippi State University. Dr. German will be replacing Professor Donald Trotter, who retired on 1 July. Dr. German will continue at PSU for the next several months and will assume his new duties at MSU in late fall. Although he will assume the position at CAVS, he will continue to advise his graduate students at PSU through degree completion while finishing out his current research projects.

CAVS and CISP have a history of collaboration that began last year on a NSF-ERC effort. Professor Mark Horstemeyer from MSU, along with faculty from Northwestern and Georgia Tech just submitted a proposal to the National Science Foundation Engineering Research Center for multiple-scale virtual manufacturing. We are currently exploring a collaborative agreement to formalize cooperation between PSU and MSU.

The Engineering Science and Mechanics Department and the College of Engineering at PSU is strongly supportive of the continuation of CISP as a Center of Excellence for the powder metallurgy industry. A transition leadership team comprising Rand German, Sharon Elder, Ivica Smid and Judy Todd (ESM Department Head) are developing a transition plan. Dr. Ivi Smid has been appointed as Interim Director when Rand leaves Penn State.

Rand has established CISP and the ESM Department as a global leader in the powdered materials and sintering fields, in addition to his many contributions to our cutting-edge research and educational programs. While he will be truly missed at Penn State, we anticipate a new era of cooperation with Mississippi State University. We wish Rand every success in his new career.

MPIF PM²Tec Montreal 19-23 June

CISP recently participated in the PM²Tec conference in Montreal, Canada. It is always curious to see who is in attendance, which is noticeably absent and what is the buzz in the presentation halls and exhibit area. Registration figures listed over 1000 attendees, more than 50 technical sessions and nine programs of special interest. The CISP team presented on various topics.

- Verifying the Master Sintering Curve on an Industrial Furnace
- Computer Modeling of Distortion and Densification Control during Liquid Phase Sintering of High-Performance Materials
- Metal and Ceramic Injection Molding-Technical Status and Future Challenges
- A Model for the Consolidation of Ultrafine Metal Powders
- Residually Stressed Multiple-Layer Tungsten Heavy Alloys by Metal Injection Molding
- Critical Learning from Microgravity Sintering of Tungsten Alloys: Implications for Extraterrestrial Fabrication and Repair
- Bi-Material Components Using Powder Injection Molding: Densification, Shape, Complexity, and Performance Attributes
- The Influence of the Thermal-Contact Resistance on Thermal Behavior of Copper-Carbon Composites
- CISP at Penn State - A Report on the Education, Research, and Service Program Serving the Sintered-Materials Field
- Cutting Edge Sintering Techniques
- Properties and Applications for Tough-Coated Hard Powders
- Innovative Process to Die-Compact Injection Molding Powders
- Processing of MIM Co-28Cr-6Mo

New Interim Director Appointed

Dr. Ivi Smid has been named interim director of CISP effective 1 October 2005. His areas of interest are: Powder Metallurgy; Particulate Composites; Coating of Particles; Refractory & Hard Metals; Carbon Nanotube Reinforced MMC's; and Structural & Thermal Modeling. He has a Ph.D. in physical chemistry and an M.S. in chemical engineering from the University of Vienna. He has studied and developed novel hard metals at Metallwerk Plansee, Tyrol/Austria and at the Institut National des Sciences Appliquées in Rennes, France. His post-doctoral work included investigation and qualification of materials and braze-joined composites at Juelich, Germany and research at Sandia National Laboratories, Albuquerque, NM. Dr. Smid was formerly employed by Austrian Research Center-Seibersdorf as project leader at the Department of Materials Technology, working on high melting and refractory alloys, materials for fusion, modeling, and thermal shock testing. He has coordinated international research efforts in electronic packaging and material selection.

Dr. Smid joined PennState in January 2002, as Associate Professor in the Engineering Science & Mechanics Department. He has published more than 150 papers and technical reports in the areas of high performance materials and composites, hard metals, components and processing, and numerical modeling, plus many program evaluations for government agencies.

Ivi Smid (smid@psu.edu)

Fourth International Powder Metallurgy Conference

Sakarya University, Turkey –18-20 May 2005

The Turkish Powder Metallurgy Association holds an international meeting every three years. The 2005 conference attracted over 200 people from nearly 20 countries. It included a day of keynote presentations (Rand German of USA and Koichi Niihara of Japan). The co-chairs were Profs. Fehim Findik and Cuma Bindal of Sakarya. The TPMA is headed by Prof. Suleyman Saritas (Dean of a new university, TOBB Economic & Technology University in Ankara, Turkey.

Pictured from left to right; Arzu Asan (Production Manager for Sinter Metals Technologies), Rand German (Penn State), Olgun Tanberk (President of Sinter Metals Technologies) and Mehmet Turker (Gazi University).

Some brief facts;

- iron powder consumption in Turkey was well over 5,000 tons in 2004
- powder metallurgy production value out of Turkey was over $250 million (heavily weighted by diamond tool segment since this gives $50/kg which is unreasonable for iron so reflects the high value diamond tool production)
- Turkey is in top 10 of countries in automobile production (no domestic firms, VW, Toyota, Renault, ...)
- Turkey is in top 4 of countries in stone production at over 6 million cubic meters per year, so the diamond cutting tools are a major business for powder metallurgy
- over 50% of the powder metallurgy production is for export
- Sintek Toz is one of the larger press-sinter ferrous firms
- Tozmetal is the second largest press-sinter firm, and they have customers around the world; many of their parts were familiar from plants in St Marys, PA for example, lawnmower, automotive, bearings, oil pump gears, shock absorbers - they export the majority of their production
- Sinter Metal Technologies is the largest press-sinter firm and is often the leader in new applications with capabilities well over 1 kg, both batch and continuous furnaces, and two injection molders
- Middle East University has set up a first-class rapid solidification program and would be a good spot for contract powder production, especially lower temperature alloys
- Maksan (Tayfun Tezanlar) is in production on MIM parts
- Teknik Dokum ve Mehendislik (Ahmet Henden) is in production on MIM components with a few products on display
- Teknoser (Yuksel Placi former PSU visitor) is in pilot production of MIM parts using AMP feedstock, CM batch
- Marmara Research Center (Halil Bakan former PSU Postdoc) is into support work on PIM and doing some military projects; it has 700 employees
- Sonmak Diamond Tools is a very profitable firm with first-class product offering for saws, grinders, ropes, profilers, and finishers (Turkey controls 40% of the marble production)
- Gazi University in Ankara has a powder metallurgy program with efforts in high temperature superalloys, especially iron-based alloys
- PM Labs exist at several universities (Gazi, Middle East Technical, Istanbul Technical, Sakarya, Marmara, Suleyman Demirel, and Kocaeli)

Rand German (rmg4@psu.edu)

Aeromat Conference, Orlando, FL, 6-9 June 2005

This conference focused on the fabrication and properties of aerospace materials. The conference was attended by about 600 participants. The main topics were in titanium, superplastic forming, friction stir welding, affordable structures, light alloys, and nondestructive evaluation. Don Heaney gave a paper on the net shape processing of refractory metals for propulsion applications.

National Space & Missile Materials Symposium (NSMMS) Summerlin, NV, 27 June -1 July 2005.

NSMMS is an ITAR restricted conference that brings together the nation's materials and processing leaders to review the critical, technical challenges facing materials, processing, and associated manufacturing of US space and missile systems. Don Heaney presented on rocket throat fabrication techniques.

Dunk Sintering Furnace

Extreme rapid heating and minimizing grain growth during sintering are touted as benefits of microwave sintering. A CM tube furnace has been modified to simulate the rapid heating rates in a conventional furnace and compare with microwave capabilities. The dunk furnace is capable of rapid sintering up to 1450°C, 100% hydrogen capable and heating rates above 500°C/min.
Tracy Potter (tjp4@psu.edu)

Modified CM tube furnace with thermally shock resistant pusher apparatus

Sixteenth Plansee Seminar, Reutte, Austria, 30 May to 3 June

The original Plansee Seminar program was started after World War II by Paul Schwarzkopf, to bring together the world interested in refractory metals, cemented carbides, and powder metallurgy. On a four year cycle, this was the16th offering in Reutte, with over 510 people pre-registered from 35 countries with a total of 228 scheduled presentations. This was the first time without simultaneous translation and the proceedings were available upon arrival at the conference. Rand German<rmg4@psu.edu>

Trends

Cemented Carbides

- Downsizing is happening in the use of carbides, where only the working tip WC-Co, the bulk of the drill, bit, or cutter is steel or other lower cost material - multiple materials in a single device are a common trend
- Coatings, net-shaping, and more cost efficiency are major challenges
- Dry machining, higher temperatures, and more thermal fatigue are reasons products have shorter lives, shorter development times, but this allows for more testing and opportunities to introduce new products
- Matrix modifications are constantly going on such as W-Ni-Cr modifications
- New hard phases such as SiC-Ti(N,C)-AlON are showing promise
- The identified gains in WC-Co from nanoscale microstructures will be in wear, especially at low temperatures and strength, but not creep or any high temperature property
- With even 200 nm WC grains, the ligaments between grains will be nanoscale and that might be fruitful in many applications
- Several people are looking for alternative matrix phases to cobalt suitable for suppressed grain growth in a cemented carbide; these include Fe, Cr, and other alloys
- Custom designed microstructures, functional designs are common; includes custom assembled
- Color coating is needed to help the user identify surfaces that are used
- Molybdenum disulfide is now included in coatings for reduced wear
- The Catholic University of Leuven showed impressive results with a dual resistance and microwave sintering technology, using SiC heating elements for resistance heating while also providing microwave susceptibility
- Korb of the Austrian Research Center is showing new results via hot pressing without the need for fluid bed and chemical vapor deposition coating
- Element Six is putting together a thrust into hard materials for cutting applications
- Sandvik has clearly shown the property gains and predicted maximum properties that might be attained with nanoscale WC-Co; they expect a peak 6500 VHN if defects can be minimized during processing; their claim is that the barriers are novel manufacturing processes for nanoscale, not a need for novel powders
- Fracture surface analysis is critical to understanding nanoscale materials and possible defects that limit strength - data should follow Weibull statistics
- The drilling of electronic printed circuit boards is now the most demanding application for WC-Co and drills are as small as 20 micrometer in diameter
- Ball milling is not effective for nanoscale powders and planetary milling with a high content of small balls is possibly more effective
- Rare earth additions to WC-Co and WC-VC-Co powders prior to milling help control grain size and properties after sintering

Refractory Metals

- Global production of tantalum capacitors for 2004 reached 25 billion, consuming 2 million kg of powder at roughly $800 million in powder sales; they account for 13.5% of capacitors, largely for high reliability and high quality uses
- Several groups showed refractory metal PIM demonstrations, so it is now a commonly accepted technique
- Rudi Zauner at the Austrian Research Center is doing microminiature PIM with a few successes, including an alumina hearing aid component-0.04 g mass and $0.30 price, giving $7,500 per kg
- Military ammunition and green ammunition programs have generated much interest, including new studies on plastic deformation of tungsten heavy alloys and novel compositions (such a doping with 0.1% yttrium), but overall the mechanical property combinations and deformation results look similar to prior work of 10 years ago
- 61% of tantalum powder sales go to capacitors, 10% to electronics, and 5% to sputtering targets (for copper isolation from silicon) - applications are mobile phones, automobiles, computers, playstations, and similar consumer products (1700 capacitors in an automobile, 700 in a personal computer, 315 in a game controller, 260 in a cell phone)
- Niobium capacitors are now used in cell phones, laptop computers, and USB ports
- Trends in electronics tend to push refractory metals the most in purity, component size, and uniformity
- Xeon lamps, LED lights, and ultra-high pressure Hg discharge lamps (135 lu per W) are major drivers on lighting uses
- First wall reactors are consuming tungsten and should reach 10 ton per year with current designs, but are far from commercial
- Direct data comparison between vacuum hot pressing and spark plasma sintering on Ta and Ru do not show any significant difference.

Other Powder Metallurgy

- SWOT analysis shows some areas of emphasis and some large problems such as efficiency in production but a requirement for high skills in tool design and die setting
- Largest payout comes when PM is applied to final shape production
- As material cost increases, PM has an improved cost advantage
- Some benchmarks for the future are precision, net-shape, complexity, performance, composites (functional

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Matrix homogenization in W-Ni-Cu

Densification and distortion in tungsten heavy alloys are critically dependent on transient microstructural phenomena during liquid phase sintering. Several factors affect microstructural changes when the liquid first forms, such as particle size, skeletal density, and solubility. Prealloyed Ni-Cu powders are generally preferred to isolate these effects because of their narrow melting range. Premixed Ni-Cu powders provide a less expensive alternative. This study compared the homogenization of a premixed Ni-Cu matrix with a prealloyed Ni-Cu matrix. The base composition for the study was 88W-8.4Ni-3.6Cu. The homogenization of the matrix can be looked at by observing the melting range of the system. If there is a single melting event during the heating cycle, it implies that the matrix is homogenized. Differential Scanning Calorimetry (DSC) was performed on both premixed and prealloyed Ni-Cu with W in compact form, with a green density of 60% theoretical. The Figure below shows the DSC heating curves of the two powders. There is almost no difference in homogenization levels of the premixed and prealloyed powders within the ±10°C error. No individual melting of Ni or Cu is observed. Instead, a single melting event of a Ni-Cu alloy is observed in both cases. The matrix amount was doubled and quadrupled to confirm the signals observed in the DSC curves. The solidus and liquidus temperatures related to this melting event were 50°C higher than the literature values from the Ni-Cu phase diagram. This increase in the temperatures was due to the presence of W, which has solubility in Ni. In conclusion, any composition of W-Ni-Cu using premixed Ni-Cu powders can now be prepared to study the microstructural changes during LPS. Guneet Sethi (gsethi@psu.edu)

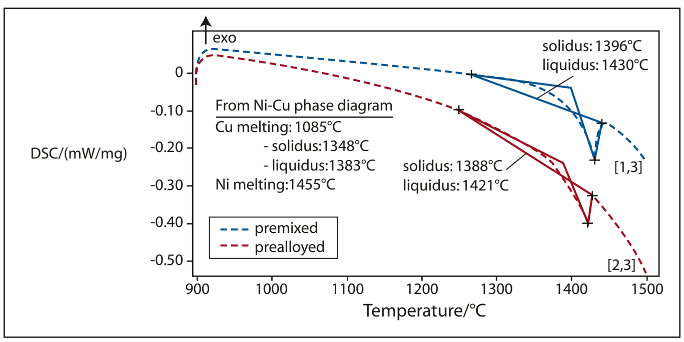

Fig.1 Differential scanning calorimetry heating curves (10°C/min) of compacted 88W-8.4Ni-3.6Cu, using premixed and prealloyed Ni-Cu powders.

Guten tag Debby Blaine

Debby Blaine (CISP Ph.D. graduate and post-doctoral researcher until April 2005) has joined Bleistahl Productions, a German P/M producer of press-and-sinter valve seat inserts and valve guides. Debby will be located in Cape Town, South Africa as Manager of R&D for Bleistahl South Africa from January 2006. Currently she is getting to know her German colleagues, learning German, and training on the production line and in the R&D labs in Wengern, Germany. Bleistahl is the No. 2. producer of valve seat inserts and valve guides worldwide, and the leader in Europe. These specific automotive parts need to be wear-resistant, especially at the high temperatures at which engines operate. This means that careful and innovative material development is the keystone to designing competitive parts.

Plansee Seminar *continued*

Other Powder Metallurgy

design) and multiple materials, magnetic and wear materials

- Powder forging might be into serious decline and has taken on a niche character
- Globalization increases the overall market size, yet reduces the cost and lower profits
- Market gains are more realistic for smaller parts, and 2 to 3 kg appears to be an economic barrier for PM parts
- The FCC Cambridge process is still a promise and no real effort at commercialization; only a few materials have moved to the kg production stage; comments out of the UK suggest this is becoming a lifelong research project with no serious intention for commercialization, Cr and Fe can be fabricated, but there is no economic merit
- Plasma quench synthesis of nanoparticles is well understood and practiced with many systems using a thermodynamic model coupled with a computational fluid dynamic model
- Discrete element analysis is being used to simulate particle fill into die pressing tools and the subsequent compaction using new mechanical dynamic models; results suggest we might be able to treat powder as a viscous fluid in die filling
- A new belt furnace has won great approval in sintering to 1180°C with no belt failure, by use of a walking beam in the high temperature portion to lift the belt and avoid tension
- Data on one ferrous powder metallurgy plant with 70 presses and 6 continuous sintering furnaces (but only three are electric) is an energy consumption of 1.2 MJ, or about $200 per hour electric cost
- Surface micro engineering is relying on inter-acting laser beams to build up surface stripes, grids, dots, or other structures

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