Fall 2005

CISP

Center for Innovative Sintered Products

The Pennsylvania State University
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Endings and New Beginings

Sharon Elder – Executive Director

Since Rand German's late June announcement of his new position at CAVS, Mississippi State, many people have asked my thoughts and what will become of CISP. Over the past few months, the transition team consisting of Don Heaney, Interim Director Ivi Smid, Department Head Judy Todd and myself have been diligently examining several fronts to continue and expand this great effort. Rand's departure leaves large shoes to fill but CISP and CAVS will continue to collaborate in several key areas. I continue to be amazed on how supportive and important CISP is to the industrial world. It would be impossible for me to sum up the impact and tremendous opportunity that Rand has afforded me. I came to this position hearing the word "sintering" for the first time and would have spelled it wrong in a spelling bee. As Rand was packing to leave he gave me a copy of an article he has carried in his briefcase since he was a graduate student at U.C. Davis. I am not sure who the author was but it gives me courage to forge on.

> *Endings are an integral part of many life processes. There is a time when it is natural to end or leave … a relationship, a way of relating to someone, a role, a work, a view of life, a value. Growth is intimately related to the willingness and courage to leave what is no longer alive and engaging. Most people feel confused, frightened, and guilty about separation, despite its natural function and beauty. The guilt and fear become especially powerful in young adulthood. At this time, most of us stop leaving; our lives remain on a plateau (often for a lifetime) defined by leavings we delayed, avoided and refused to face. In time, this plateau is called "adulthood" and the fears of separation are rationalized into values that label leaving as selfish, immature, and impulsive. Thus the collective "adult" world, generation after generation, stands against change.*
>
> *Because of the personal and social resistance against separation, to leave something requires wisdom, confidence, trust and much courage.*

We are continuing with a new leadership team and will experience many changes as we transition into a new program. For me one of the principal things that will not change is the significance of the voice of industry. I welcome your comments, suggestions and involvement.

Sharon Elder <cisp@psu.edu>

PENNSTATE

Center for Innovative Sintered Products

NSF Spanish Award

CISP and the Universidad Carlos III de Madrid (UC3M), Madrid, Spain was recently awarded an International Research Experience for Students in Innovative Sintered Materials (IRESISM) by the National Science Foundation. This grant will foster new skills, industrial knowledge, international links, and the process knowledge for young engineers and scientists in sintered materials. This $104k grant is a three year summer program whereby we will send five graduate/undergraduate students from MS State, PSU and SanDiego State to Spain for a six week period. The European effort will be under the direction of Dr. José Torralba, Vice Rector of Research and Innovation and the American effort will be under Dr. Randall M. German.

Upcoming Events

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

December 6, 2005
Secondary Operations Course
Penn State, DuBois, PA

February 7-8, 2006
Int. Conf. on Tugsten, Ref. & Hardmetals
Orlando, FL

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

Atmospheric Oxidation-Corrosion of Sintered Artistic Bronze

Copper alloys, dating from 5000 BC, are some of the first alloys used by mankind. Up to now, five main copper alloys have been cataloged and the natural patina on each is documented to assist in nondestructive analysis of archeological discoveries. These patina layers are the product of long-term corrosion, yet can be created in the laboratory. Of the copper alloys, bronze artwork associated with the Bronze Age dates from as early as 1500 BC. Many of the bronze archeological objects contain lead, with the general suspicion that the lead was needed to improve fluidity of the melt. Today, powder metallurgy techniques offer an alternative to lead-containing bronze, since melt fluidity is not required if a slurry casting route is used. However, the durability of sintered (and porous) copper-tin bronze alloys is not established with respect to ambient corrosion.

Fig.1

During the recent years, there has been the emergence of sintered bronze art objects. Figure 1 shows an example of a typical product. The fidelity of the surface finish and preservation of the artistic detail with minimized finishing costs are clear benefits. Further, new alloying rules can be applied to sintered bronze. For example, a high tin content can be used and lead can be avoided (since casting fluidity is not an issue). Also, chemical segregation associated with castings is avoided, so the absence of microgalvanic cells in the microstructure reduces the overall corrosion rate. Thus, a powder approach gives fewer production steps, removes concerns over lead toxicity, and allows selection of higher tin content alloys for improved corrosion resistance. However, there is a concern that the sintered composition might have degraded resistance to environmental exposure, especially in light of the high temperature exposure and surface-connected open pores.

The production of bronze art objects by sintering was commercialized by the former State College firm, Aesthetic Materials in 1998. Aesthetic Materials was started by Rand German, Julian Thomas, Sundar Atre and artist Mark Pilato. The early process named after Mark Pilato, the Pilato Process built on a CISP rapid tooling patent relying on injection molding grade bronze powder. After a silicon rubber mold is created from the master object, a low pressure slurry casting technique is used to fill the cavity. Heated wax is the binder and rapid debinding is achieved using wicking. Final sintering is performed at a peak temperature near the solidus in nitrogen.

An immediate concern was to determine if changes in alloy, processing (especially the high temperature nitrogen sintering), and residual porosity might influence resistance to corrosion and oxidation. One of the first successes was the production of a sintered bronze chess set, shown in Figure 2. This was fabricated using 90Cu-10Sn prealloyed bronze powder with a median particle size of 22 μm, mixed with paraffin and microcrystalline waxes as the binder, slurry cast into silicone rubber molds at a solids loading of 64 vol. %. After cooling the pieces were removed from the molds, packed in alumina wicking powder, and sintered with a peak temperature near 840°C, giving a final sintered density of 7.79 g/cc (about 13 % porosity). The technique was applied to components up to 40 kg in mass.

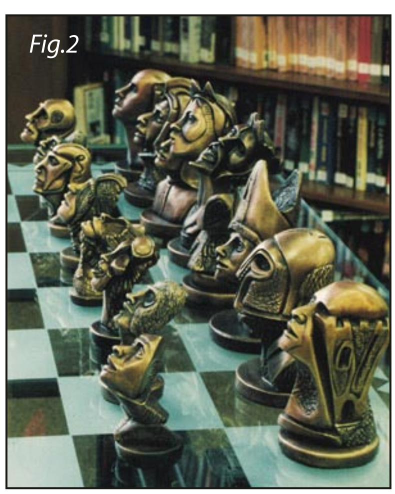


Fig.2

Fig.3

The first production chess piece was placed into long-term outdoor exposure. The pawn, shown in Figure 3, weighed 236 g and was exposed without protection or patina to normal cycle weather cycles for 2400 days in State College (latitude of 40 degrees N and longitude 77 degrees W). Typical liquid equivalent (rainfall and melted snow) was 980 mm per year. The average annual temperature was 9.6°C, with an average high of 15°C and low of 4°C.

Monthly visual inspection showed a slow, progressive discoloration. There were no signs of spallation, nor was the glass table on which the pawn rested discolored. After exposure the pawn was dull and dark brown in color, as shown in Figure 4. A few turquoise patina spots had emerged, but the general coloration was dark brown. The analysis involved nondestructive investigation using scanning electron microscopy with energy dispersive x-ray analysis. At low magnif-

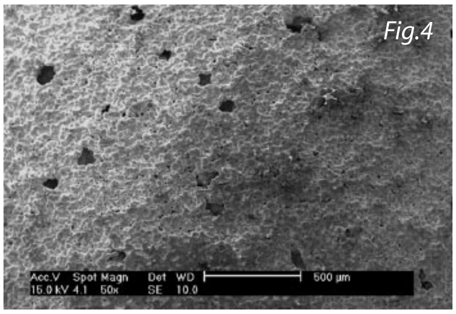


Fig.4

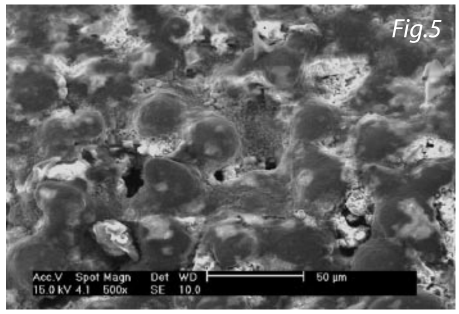


Fig.5

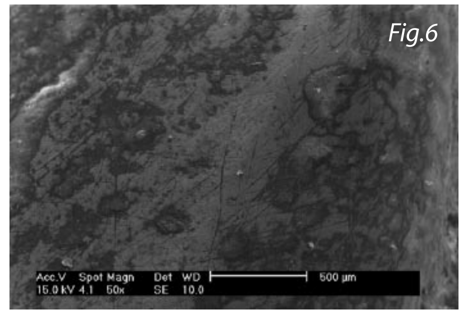
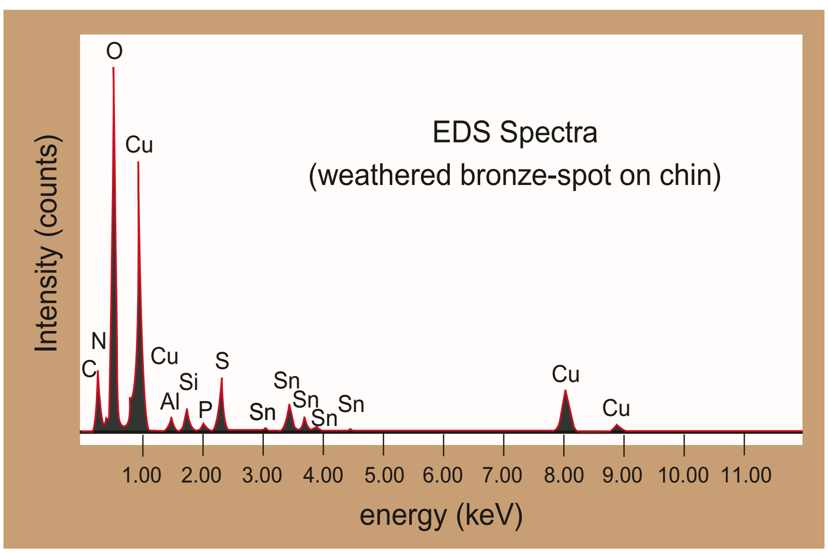


Fig.6

cation the surface showed a rough surface and residual pores. At higher magnification a residual corrosion product could be observed in those open pores as shown in Figure 5. The original particle shape is evident in this image. For comparison, the surface of a sintered bronze object that was surface burnished and given an artificial patina is shown in Figure 6. Note the burnishing treatment seals the pores and the patina leads to a nonuniform surface coating. Typical to prior findings from archeological and laboratory studies, the surface consists of a combination of oxides and carbonates. Figure 7 is an example chemical analysis, in this case taken from the chin of the pawn. It shows Cu, Sn, C, O, and some S and N compounds. These are in agreement with prior findings that showed oxides and carbonates in both accelerated laboratory tests and retrieved archeological artifacts. Thus, the sintered bronze is in the early stages of a fairly traditional corrosion process that is typical to bronze, suggesting the final product will exhibit a turquoise patina. Most likely the corrosion product will continue to fill the pores to essentially form a tenacious and protective coating.



In conclusion, a sintered 90Cu-10Sn bronze with 13% porosity shows discoloration after 2400 days of outdoor environmental exposure in cycles that involve winter to summer, wet to dry, and many combinations in between. The condition of the sintered bronze artwork was better than expected and appears to be on a standard corrosion trajectory seen in prior laboratory tests and archeological bronze samples. This probably reflects the positive gains from the higher than normal tin content - 10 wt. % versus 5 wt. % in much of the ancient bronze. In contrast with many archeological bronze objects, the Pilato Process avoids the need for lead alloying to improve casting fluidity (which dictates the overall alloy chemistry), allowing use of a higher tin content. Also, the sintered microstructure formed from a prealloyed bronze is chemically homogeneous, thereby avoiding microgalvanic cells. These gains from a homogeneous microstructure and higher tin level might be sufficient to offset the degradation expected from open pores.

Because of residual open pores, we cannot anticipate the sintered bronze to be as long-term corrosion resistant as standard cast bronze. But the more homogeneous microstructure and higher tin content might be favorable offsetting factors. Also, comparison to a finished component (burnished and coated with an artificial patina) shows possible gains from the closed pores and protective layer. Thus, it is possible corrosion resistance might be improved by a burnishing or polishing surface treatment coupled with patination and coating with a chemical such as benzotriazole. Rand German <german@cavs.msstate.edu> and Lou Campbell <lgc102@psu.edu>.

Pilato's Sculptures

Bronze Moves to New Levels

Mark Pilato is a noted sculptor whose work can be found in the CBS Collection, White House Collection, and the PA Academy of Fine Arts Fellowship Collection, among others. Mark was a regular at the CISP lab during the late 1990's when he was perfecting what he termed the Pilato Process. He, along with Rand German, Julian Thomas, and Sundar Atre were part of the State College firm, Aesthetic Materials. The Pilato Process built on a CISP rapid tooling patent relying on injection molding grade bronze powder. After a silicon rubber mold is created from the master object, a low pressure slurry casting technique is used to fill the cavity. Heated wax is the binder and rapid debinding is achieved using wicking. Final sintering is performed at a peak temperature near the solidus in nitrogen.

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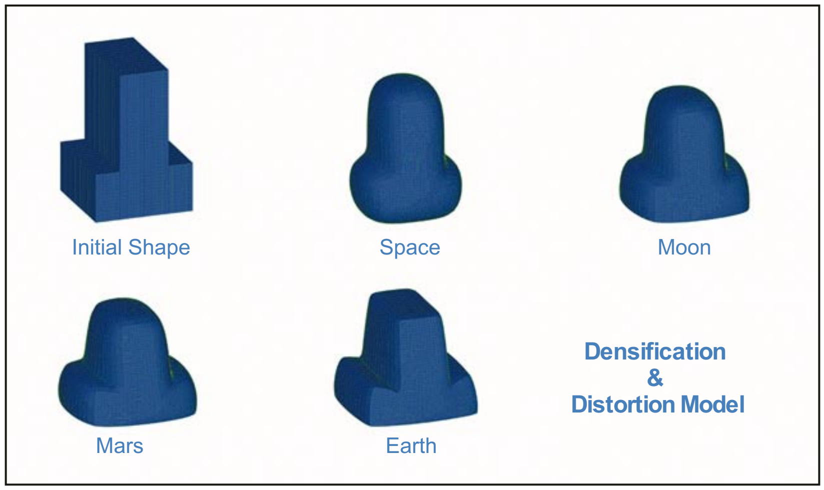
Pilato's Sculpture continued
Bronze Moves to New Levels

Mark finished what he fittingly calls his most important scuplture to date, "Ascent" just hours before the fourth anniversary of the 9/11 tragedy. This statue is two 10.5 foot (3.2 meters) statues which comprise one piece, a sculpture in memory of the World Trade Center tragedy. The first casting of this monumental work is reserved for prominent placement in lower Manhattan.

"Ascent" is now installed outside the Pilato home in Halcotsville, NY. "Ascent" sits on a foundation of a long gone ice house overlooking Lake Wawaka. It will sit there for two months before it goes on a journey to towns across the country "Ascent" will then be donated to New York City by Pilato Studios.

See more of Marks work at: http://www.pilatostudios.com/

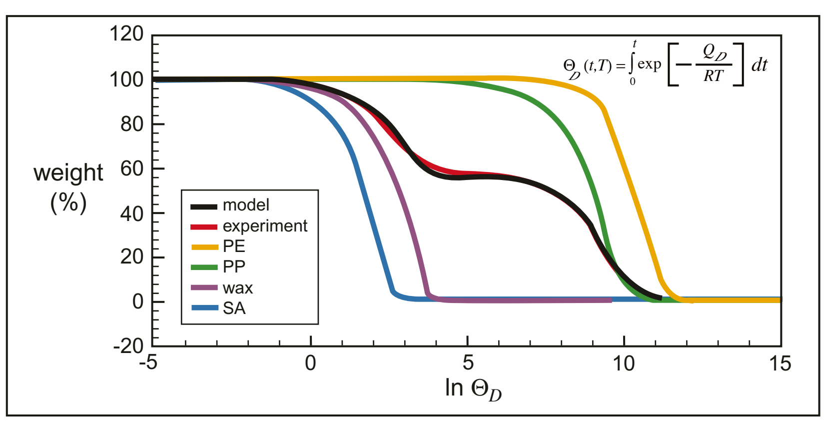
Modeling Gravitational Distortions



A model has been developed to be able to predict densification and distortion during liquid phase sintering under reduced gravity conditions. The model is based on constitutive laws of deformation, which are incorporated into a finite element simulation. Continuum models are useful for making macroscopic shape predictions with relatively little computing time. This model is used to explore the effects of different gravitational levels on the distortion of 88W-8.4Ni-3.6Fe during liquid phase sintering. Data from ground-based experiments provide one end-point while the microgravity experiments provide the other. The figure shows predicted results for sintering on the Moon and Mars in comparison to on Earth and in space. Lunar and Martian sintering will give noticeably different distortion behaviors than seen in any prior experiments. Different gravitational levels may require different sintering pathways for achieving full density without distortion. Seong-Jin. Park< sup13@psu.edu> and R. M. German

Master Decomposition Curve for Binders in PIM

Thermal debinding is one of the crucial steps in the powder injection molding processing. In order to systematically analyze and design the thermal debinding step, the CISP modeling team has formulated and constructed the master decomposition curve (MDC) based on intrinsic kinetics of organic pyrolysis. The Kissinger method is used to estimate the activation energy from TGA experiments. Overall thermal decomposition was synthesized from MDCs of individual components of binder systems with experimentally good agreement as shown in the figure, which can help process designers to change the composition without additional experiments and can predict the remaining amount of each binder component during the debinding process.
Seong-Jin Park <sup13@psu.edu>, Gaurav Aggarwal and Benjamin Risser



Desification Behavior of Tungsten Heavy Alloy (MSC)

The master sintering curve (MSC) theory is modified by substituting the densification ratio (Φ) for the densification parameter (Ψ) to identify regions where shrinkage is taking place by a similar combination of sintering mechanisms. This identification enables the extension of the MSC concept to sintering processes in which a change of phase is happening, such as sintering of W-Ni-Fe heavy alloys (WHAs). Applying the modified MSC theory to analyze dilatometry experiments conducted with WHAs, in which a phase change occurs during sintering, leads to the identification of three regions (fig. 1).

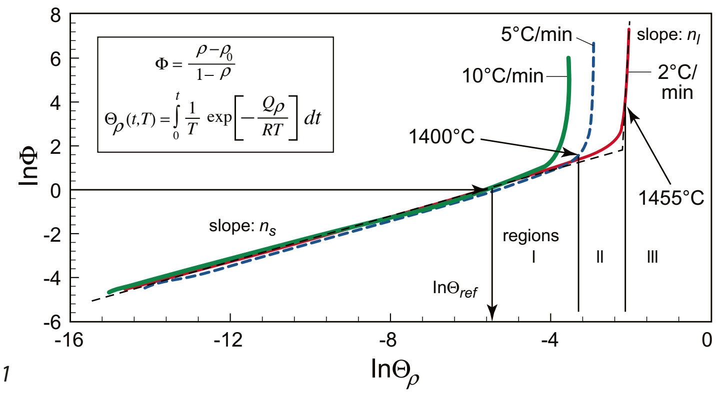
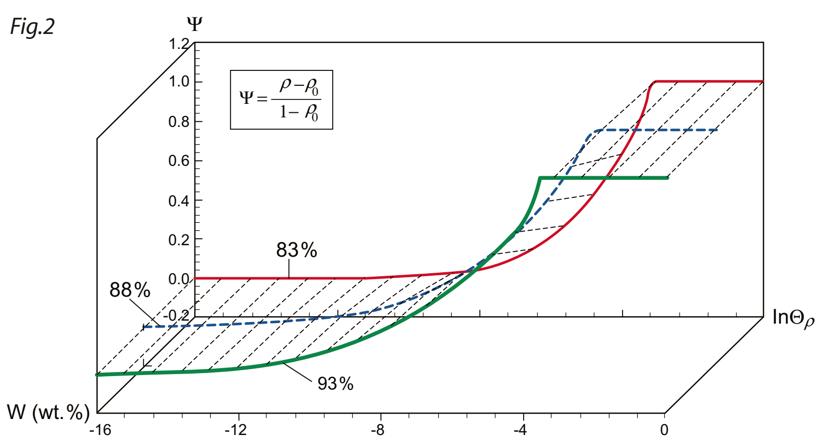


Fig.1

Apparent activation energies for sintering in solid state and liquid phase are calculated based on MSC. These activation energies are compared with experimental values for diffusion and other mass transport phenomena to identify the dominant mechanisms in each region. For sintering of WHAs at temperatures up to 1400 °C (Region I), densification occurs in solid state through a combination of both lattice diffusion of W in the additive phase (FCC Ni-Fe-W) and W grain boundary diffusion. At temperatures above 1455 °C (Region III), dissolution-precipitation of the W particles through the Ni-Fe-W liquid phase is the dominant densification mechanism. Between 1400 °C and 1455 °C (Region II), the MSC shows a transition region in which a combination of the solid state and liquid phase mechanisms is active. The densification function, *n*, defined as the slope of the MSC in fig. 1, is a parameter related to the densification rate. This parameter during both solid state and liquid phase sintering increases as the amount of W decreases. A series of MSCs for varying W contents are developed into a master sintering surface that includes tungsten content and integral work (fig. 2). Densification behavior can be predicted for 83 to 93 wt.% W heavy alloy by quantifying and interpolating the MSC parameters into the master sintering surface. Seong-Jin. Park <sup13@psu.edu>, J. M. Martin <jmm64@psu.edu>, and J. F. Guo <jxg957@psu.edu>

Fig.2


Spanish Exchange Gets Top Marks

Currently CISP has two PhD students from Universidad Carlos III de Madrid, Spain that are just completing a three month rotation. Under the Carlos III's PhD program, students complete a portion of their experiments in another foreign university for a duration of two to three months each. The student exchange with the Carlos III is now in its third year and has been a good experience for both universities. The success of this program precipitated CISP to apply to the NSF Global Scientists and Engineers program so our American students can also build global networks. We were recently awarded a $104k grant for three years to begin in October 2005.

Maria Luisa Delgado *is a visiting researcher in her third year of studies. She is originally from Cordoba, Spain. She was a researcher at CISP in the fall 2004 and was so impressed by the facilities she returned for an additional three months. She is a student in chemistry with her doctoral theses on the liquid phase sintering on aluminum alloys. Maria is interested in metal matrix composites, particularly aluminum matrix composites. It was this interest that brought Maria to CISP to study the sintering process the atmospheric conditions to eject during the manufacturing process of her material.*

Beatriz Gomez *is also a visiting researcher in her second year of PhD studies. A student in chemistry, Bea is interested in liquid phase sintering in iron based composites reinforced with carbides particularly the contact between the ceramic and metallic phase. While at CISP she has been able to research the effects of high temperature on the mechanical properties of her materials.*

Contact Maria and Bea at:

Maria Luisa Delgado <mdtienda@ing.uc3m.es>

Beatriz Gomez <bgomez@ing.uc3m.es>

Dr. Rand German and former CISP researchers, Drs. John Johnson and Debby Blaine, attended the Sintering 2005 conference in Grenoble, France from 28 August to 1 September. There were over 170 people preregistered (probably reached 200 total) from 28 countries - about 10 people from the USA.

The Program echoed some key themes - functional gradients, damage, modeling, novel techniques, grain growth control, and nanoscale. Kawasaki from Tohoku University is in the lead on functional gradients and seems to rely on spark sintering for many demonstrations, including thermoelectric contacts. Pressure assisted sintering did not see much attention. In the spark sintering arena, apparently there are now several new vendors of these machines, so prices are falling rapidly as new German and American companies have entered the market previously dominated by Sumitomo.

Computer Modeling of sintering, microstructure, and component size-shape are favorite topics. Pan out of University of Surry is very active in this area. His size-shape predictions are mathematically complex. He is now promoting a power concept for analysis of sintering events. Most of the models have settled on treating sintering with a viscous flow model, where viscosity depends on grain size, density, temperature, so on, but are uncertain on the sintering stress. Disagreements arose over the zero creep tests for sintering stress, since the models rely on pure Newtonian concepts, yet most of the findings indicate this is in error. As one presentation showed, if your have the right mass in the box (green body), then sinter to near full density, you get a good size-shape prediction independent of the model used. Likewise, predictions of grain size, microstructure, and even properties are mostly following empirical models. Debby Blaine had good interest in her master sintering curve concepts - they are less exact yet more easily used. True predictions require too much material data to be accepted or useful - one set of simulations showed over 44 material specific parameters. Further, since factors like grain boundary diffusion vary with grain misorientation, the models simply assume average parameters (average over the microstructure and time). Unfortunately, this is an error, since the grain growth events might lead to a change in grain misorientation as relaxation occurs. For example, the grain boundary energy varies with misorientation, so under the misorientation torque the grains rotate into preferred orientations over time, resulting in a change in average grain boundary configuration and diffusion rate, even with isothermal sintering. Such complexity is largely ignored by the modeling community. Monte Carlo simulations are now truly three-dimensional. The surface evolver program and NIST free object oriented modeling software were used to make interesting pictures and predictions. However, most models still ignore gravity, substrate friction, thermal gradients, surface tension (outer body traction that rounds corners and edges), and other realities. Hence, most of the size-shape predications are incorrect at a practical scale. Some of the sintered industrial products are now reaching one micrometer final tolerances or about 0.01 %, but the sintering size predictions might be in error by 10 %

Microfocus radiation and x-ray tomography were used to follow individual particles and necks during sintering - images were shown for copper and glass. The results give neck size and coordination number, and allows imaging of pores. However, some of the results do not make sense. For example, glass sintering shows a delay then acceleration over time, contrary to all prior work and the models which anticipate a decay over time. One guess is the experimental technique (heat for awhile, cool, image, reheat, ...) contributes stress or crystallization that makes the data invalid.

Anisotropic Shrinkage was one area of attention, but the origin of this phenomenon was under much dispute. One group showed pressing neck size effects (computer simulations) and another showed pore shape effects. The neck size and anisotropic sintering stress group could not explain swelling in the axial direction while shrinkage occurs in the radial direction. Damage in sintering was treated in various models, but largely the problem goes away when the compact is dense and heated slowly.

Aluminum Sintering had some good papers on , but largely showing similar results of Mg needed to break the oxide and nitrogen being the best atmosphere. One group produced a strength of 130 MPa and 10 % elongation with 2.66 g/cc density.

Microwave Sintering was a topic of much discussion. It appears the Swiss Federal Institute will become the lead in the science and application. Kennametal is in production with a small system that takes about 200 inserts per run, but they report no gains from microwave. Fraunhofer showed some data with a hybrid system and this tends to be favored by most of the community - use a metal hot zone for lower temperatures (thermal burnout) and supplement with microwave at high temperature. The Kennametal unit runs about 33% of high temperature power from microwave and 67% for conventional. Temperature measurement is being achieved using infrared sensors, and thermal imaging, but most useful is use of a radio antenna (radiometer) to pick up electromagnetic radiation from inside the furnace at about 10-12 watts. The Catholic University is using SiC heaters that also are microwave absorbers, so less direct microwave heating. They report minor gains in sintering

WC-Co. All in all, the microwave sintering of WC-Co does not look very favorable from the perspective of several groups. With diamond-cobalt composites, Fraunhofer shows an ability to couple to the cobalt and control its decomposition during sintering.

Liquid Phase Sintering is alive and well, but often ignored by the modeling community. One interesting discovery was from Dariel of Ben Gurion University on sintering monocarbides (TiC, HfC, ZrC) and the role of a surface carbon deficiency on decreasing the sintering temperature. This might be an alternative to creating coated powders, since the carbon gradient is induced by reacting titanium hydride with TiC powders. Considerable discussion on novel sintering techniques (especially microwave, spark sintering, and laser sintering) generally resulted in the scientists being frustrated that their discoveries were not taken up by industry. Industry on the other hand says that the ideas are immature, not backed with real successes, and often only part of the story is presented. Unfortunately, many of the projects seem to be new "processes" while industry is interested in new "products". Rand German <german@cavs.msstate.edu>

Secondary Operations Course

The basics of secondary operations that are performed on powder metal components. The discussion will include introductions to machining, heat treatment, and surface finishing.

December 6, 2005
8:30 a.m. 12:30 p.m.
Penn State DuBois

Instructor: Don Heaney
Contact: Betsy Carlson
bsc11@psu.edu

Micro Metal Injection Molding (μMIM)

Microscopic metal alloy instrumentation is needed in almost every modern technical field. Recently, there have been significant advances in the field of powder micro metal injection molding (μMIM). Nicholas J. Koseski (2005-2006 AMETEK scholarship recipient) in collaboration with Dr. Donald F. Heaney has initiated research involving particle size and its influence on μMIM. Experimental observations show that particle size has a direct correlation with sintered surface roughness. An explanation of the correlation between particle size and surface/feature resolution is being made. Utilizing advanced MIM technology, components with lithographic features can be precisely fabricated from most powders. This effort is to prove the physical relationship and incorporate findings into fabricating more precise, smaller, and therefore more useful instrumentation for a multitude of technical fields including biomechanics. Nickolas Koseski <njk904@psu.edu> and Don Heaney<dfh100@psu.edu>

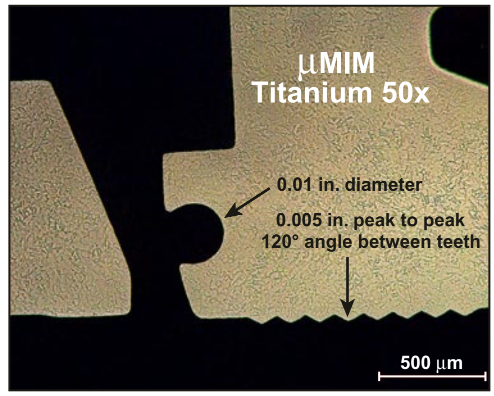


Figure: Feature resolution of a μMIM component fabricated from photolithography tooling.

Testing & Services

Testing & Services (Lab Services) was developed as a non-profit way to offer technical testing for industry and the research community, especially within the state of Pennsylvania. Inside CISP, Lab Services provides funding for basic supplies, equipment maintenance, and student training. Lab Services' jobs consist of straightforward testing at a fixed cost and without engineering advice beyond straight interpretation of the results. Jobs are generally short in duration (days or weeks) until completion. Much of the incoming work originates from available equipment capabilities as listed at http://www.cisp.psu.edu/testserv/pricelist.htm. Types of jobs performed in the past range from routine quality control tests to fast turnaround process troubleshooting tests to new material/process evaluation.

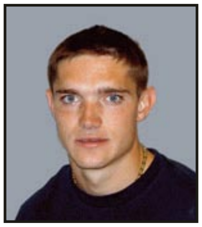
Examples of current and/or past Lab Services work include:

- Brittle/ductile fracture detection (metallographic preparation, SEM analysis)
- Thermal analysis on powders or parts to detect melting, phase changes, weight loss (DSC or DTA/TGA)
- Thermal conductivity (laser flash method)
- Debinding and sintering (to 1600°C (2912°F) in H_2, N_2, Ar, air, vacuum atmospheres) permeability/fluid flow
- Porosity and analysis on designed porous parts
- Detection of phases (XRD) or elements present (EDS) within samples
- Raw material powder characterization for quality control
- Mechanical testing on prototype components

Members of the Center for Innovative Sintered Products receive a discount on work handled through the Lab Services depending on their level of membership. Contact Lou Campbell <LGC102@psu.edu> or Kristina Cowan <KCC126@psu.edu> (814) 865-2121 to inquire about additional capabilities or to send samples.

Scholarship awards announced

CISP recently announced this year's recipients of the AMETEK and Clayton Family scholarships from the Center for Powder Metallurgy Technology. The AMETEK scholarship has been awarded to Mr. Nicholas Koseski. The Clayton Family scholarship has been awarded to Mr. James Allen for the fall semester and Mr. Luke Breon for the spring semester.



Nick Koseski is a senior majoring in Mechanical Engineering. He has been employed at CISP for the past two and one half years and has demonstrated a great interest in the PM process and its applications. He has worked on binder system design, feedstock creation, injection molding and thermal and chemical debinding, and various testing areas.

James Allen II is a senior majoring in Mechanical Engineering. He has been employed at CISP for more than a year under the guidance of Dr. Johnson, Dr. Smid and Dr. Heaney. He has worked on many projects from developing thermal debind and sinter cycles to bubble point testing of porous titanium filers. He is a senior and will be graduating in December.

Luke Breon is a junior majoring in Engineering Science and Mechanics. He is interested in the application of resonance testing. In the summer of 2004, he worked with Dr. Joe Rose on green part testing of powdered metals.

Development Center Attracting Interest

The Development Center is an extension of Testing & Services with regards to the size and deliverables on a project. Typically the T&S is the performance of a test or a test run, whereas the Development Center involves a combination of the T&S test to accomplish a larger task and requires engineering/result interpretation. The Development Center has 2-3 of these projects running at any one time with costs of $2,000 to $50,000. Example activities involve proof of concept material fabrication or geometry fabrication for certain applications.

Current Activities:

Sputtering Target Fabrication
Tape Cast Ceramic Debinding and Sintering
Controlled Density Materials Formulation

Pending Activities:

Lubricant Validation
Coated Particulate Fabrication

For more information contact:
Don Heaney <dfh100@psu.edu>
or phone: 814-865-7346.

KYK Oxynon Furnace For Sale

A KYK Oxynon continuous furnace capable of heating to 2000°C was installed at the Center for Innovative Sintered Products at The Pennsylvania State University, University Park, PA. After evaluating the furnace and finding that the furnace is adequate for certain applications, specifically brazing and high temperature sintering, KYK desires to sell the furnace into a parts producing company. This unique furnace allows the sintering and brazing of metals and alloys at a reduced oxygen partial pressure without the use of vacuum or hydrogen. This is particularly desirable for sintering and brazing of materials with high-vapor-pressure elements such as chromium and manganese.

Furnace Key Features

- 2000°C with 4 hot zones
- Graphite composite belt
- Opening size 10" wide x 4" high
- Gases: nitrogen, argon, and potentially helium

Interested parties can contact:
CISP: Donald F. Heaney: dfh100@psu.edu
KYK: Rich Seymour: rhseymour@juno.com

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