MERC 2006

Materials Engineering Research Colloquium

April 7, 2006

Department of Materials Engineering
University of British Columbia
Vancouver BC CANADA

Materials Engineering Research Colloquium Schedule

April 7, 2006

Presenter	Title
	Session I: (10:30 am – 11:50 am)
C. Albert	"Effect of cement pressurization on implant stability in revision hip replacement with impaction allografting"
M. Lane	"Alcan - UBC Horizontal Direct Chill Casting Model Development"
E. Young	"Materials engineering of semiconductor alloys for long wavelength light emission"
T. Chae	"Processing and Charterization of Hydroxyapaite-based Bioceramic Pastes"
	LUNCH (11:50 – 13:00)
	Session II: (13:00 pm – 14:20 pm)
M. DiCiano	"Primary Cooling in Horizontal Direct Chill Casting of Aluminum Ingots"
K. Jondhale	"Heat Transfer During Multiple Jet Impingement on a Moving Steel Plate"
X. Zhao	"Simulation and Optimization of the Electron Beam Cold Hearth Melting of Ti Alloys"
N. Chester	"Transient Cooling of a Hot Steel Plate by an Inclined Bottom Jet"
	To Be Presented at a Later Date
C. Cloutier	"The Recycling of Sodium Metaborate to Sodium Borohydride: Properties of Alkaline Aqueous Sodium Metaborate Solutions"

Effect of cement pressurization on implant stability in revision hip replacement with impaction allografting

Carolyne I Albert
Biomaterials Group; Goran Fernlund and Tom Oxland
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Department of Metals and Materials Engineering, University of British Columbia

Research Summary:

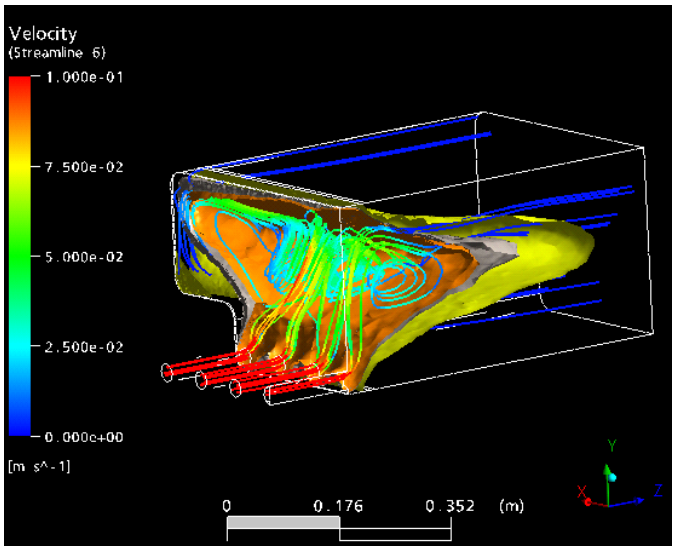
The failure of hip implants is often associated with bone loss in the femur. Revision surgeries are challenging when the bone loss is substantial. Impaction allografting (IA) is a revision technique that uses bone graft particles to reconstruct the femur before a new implant is cemented in place. IA offers appealing potential for reconstituting the bone stock - however, high levels of implant migration are reported and biopsies have revealed that the graft does not fully incorporate into new live bone.
It was recently shown that the cement penetrates deeper than expected into the graft, filling virtually the entire graft bed around mid-implant. The presence of non-biodegradable cement at the host bone interface can arguably be seen as a limiting factor for new bone formation. However, the importance of cement-host bone contact on implant stability is not known. The objectives of this study were to examine the effect of cement pressure on the cement-host bone contact and the initial stability of the femoral implant.
IA was performed on six pairs of cadaveric femurs. An implant was cemented into one femur from each pair using the conventional pressurized technique (pressure group), while in the other femur the cement was not pressurized (no-pressure group). The implant motion relative to the bone was measured while the specimens were subjected to simulated physiological loading. The specimens were then cross-sectioned and the cement-host bone contact was measured.
There was on average less cement contact in the no-pressure group. However, implant motion was much greater in the no-pressure group. While eliminating cement pressure in IA could increase the potential for bone incorporation by reducing the cement penetration into the graft bed, the results of this study indicate that implant primary stability would be compromised.

Alcan - UBC Horizontal Direct Chill Casting Model Development

Malcolm Lane
Metals Processing Group; Daan Maijer, Steve Cockroft
Frank Forward Building, Room 401B
Department of Metals and Materials Engineering, University of British Columbia

Research Summary:

Alcan's Alma works, located in the Saguenay region of Quebec, uses two, three-strand, Horizontal Direct Chill (HDC) casting machines. Currently, these machines are used to cast both pure aluminium and alloy A356. The machines produce 900 x 300mm t-bar (t-section ingots) at a casting speed of approximately 100mm/min. Since the HDC casting process is confined, visual observations and measurements are difficult to obtain thus making numerical modeling a powerful tool for process development. A 3-dimensional coupled fluid flow - heat transfer model has been developed using the commercial computational fluid dynamics (CFD) software CFX-10.0. The methodology of model development and current model predictions will be presented in this informative talk.



Predicted solidus (yellow), 30% fs (grey), liquidus (orange) surfaces are shown with streams (coloured based on velocity) for T-ingot casting of A356 in the z-direction

Materials engineering of semiconductor alloys for long wavelength light emission

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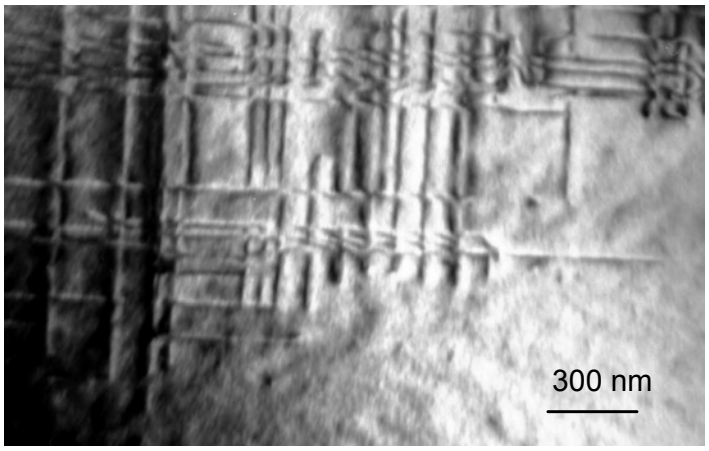
Research Summary:

Binary compound semiconductors (e.g. GaAs) based on elements from groups III and V of the periodic table are a technologically important class of light emitting materials. They have individual band gaps that correspond to light emission at wavelengths across the visible spectrum and beyond, from UV to infrared. Further substitutional alloying of III-V elements (Al, In, N, P, Sb, Bi) to create ternary and quaternary compounds allows optimum wavelength tuning to support applications ranging from lasers for telecommunication and medical imaging to solar cells and solid state light bulbs. The materials science of fabrication is considerable, as the required nanostructures must have compositions controlled at the ppb level, be free of structural defects such as grain boundaries and dislocations, and exhibit nearly atomically smooth interface and surfaces. This work focuses on overcoming the challenges associated with GaAs based alloys that that contain dilute amounts of nitrogen, grown by molecular beam epitaxy. Because the N atom is significantly smaller than the As it is replacing in the GaAs lattice, it acts more as an impurity than an alloying element. Certain implications for light emission are favourable, as the N pushes the band gap into the infrared. However the material quality, and thus the efficiency of photon generation is degraded as the N tends to cluster, causes surface roughness during growth, and introduces elastic strain into the lattice that can result in the formation of misfit dislocations upon relaxation. A number of approaches to improving the material quality have been explored. The use of a non-incorporating bismuth surfactant layer during growth was found to smooth surfaces, improve the N incorporation, and reduce clustering, all contributing to an increase in the observed luminescence efficiency.



Plan-view TEM micrograph of misfit dislocations lying along <110> directions in an InGaNAs film grown on an (001) single crystal GaAs substrate

Processing and Charterization of Hydroxyapaite-based Bioceramic Pastes

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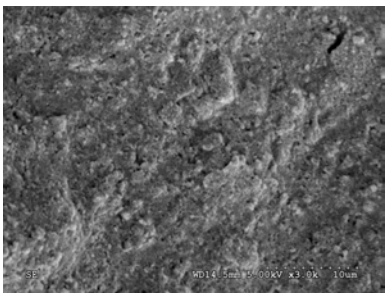
Research Summary:

Bioceramics are used to replace and reconstruct the hard tissues afected by external impacts or diseases. Injectable ceramic pastes, such as calcium phosphate cements (CPC) and hydroxyapatitie (HAP) pastes, are representative examples receiving lots of attention since calcium phosphates are biocompatible and osteoconductive and injectable pastes systems are easy-to-apply without massive surgical procedures. Recently, BoneSource and Ostim (HAP pastes) have been used as an alloplastic implant for supraorbital augmentation and maxillo-facial surgeries, respectively. However, "filter pressing" phenomenon, separating solid and liquid medium, and bad flowability of injectable ceramic pastes were reported by surgeons mainly due to the fact that the pastes should penetrate through a small diameter needle. Hence, understanding flowability of the pastes is required to achieve easy injection with enough solid loading for volumetric stability in a body fluid environment.

In this study, HAP-based bioceramic pastes were prepared by an intensive planetary ball milling (A) HAP +distilled water + tri-sodium citrate (TSC), (B) HAP + distilled water + ethylene glycol (EG) + TSC, and (C) HAP + poly(dimethyl siloxane) (PDMS). A novel syringe-based system for practical assessment of paste's flow and injectability was developed to correlate viscosity of each paste with their flowability. It was found that TSC reduced viscosity of the systems A and B. EG was also found to be helpful for homogenization of the pastes. On the other hand, PDMS produced poor mixing and increased viscosity of the pastes due to its high viscosity and hydrophobicity. The syringe-based practical viscometer can be easily used to assess flowability of pastes of very high viscosity.

Paste A: 1.12 g/ml paste
with 18.11 vol% EG and 0.26 wt% TSC

Paste B: 1.12 g/ml paste
with 41.89 vol % EG and 0.44 wt % TSC



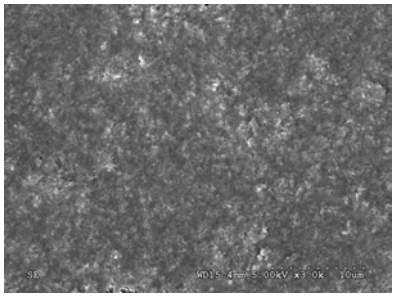


Figure - Surface of dried pastes with a same P(powder)/L(liquid) ratio but different amout of EG and TSC . A left SEM micrograph of the dried paste A shows highly agglomerated lump of HAP causing bad flowability and high viscosity compared to smooth surface of the dried paste B.

Primary Cooling in Horizontal Direct Chill Casting of Aluminum Ingots

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Department of Metals and Materials Engineering, University of British Columbia

Research Summary:

The primary focus of this work is to characterize the primary cooling heat transfer in HDC casting of Aluminum foundry alloy re-melt ingots. Although primary zone heat transfer has been studied for the VDC casting process, there are no reports in the literature regarding primary zone heat transfer in HDC casting of Al. This work is an essential tool and results from this study will serve two purposes: 1) as boundary condition data for HDC process models and 2) to increase our general knowledge of the physics of initial solidification in HDC casting machines (i.e. meniscus behavior). Additionally, it is generally accepted that many casting defects originate in the primary zone (i.e. the mould region) of a DC casting machine. Thus, a careful study of primary zone heat transfer and related phenomena may increase our knowledge of defect formation and thus help to decrease defect formation, thereby increasing overall process efficiency.

HEAT TRANSFER DURING MULTIPLE JET IMPINGEMENT ON A MOVING STEEL PLATE

Kailas V. Jondhale
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Research Summary:

The Run-out table (ROT) cooling is a key processing step for hot rolled steel strip. It determines the final microstructure and thus mechanical properties as well as flatness of hot band. The cooling process on the ROT is carried out by employing water jets, sprays or water curtains onto the steel strip or plate. The use of multiple jets results in interactions between neighboring water jets affecting the overall heat transfer rate. The heat transfer which takes place during cooling with multiple jets is fairly complex and the available knowledge is very limited.

The research work described here is mainly intended towards understanding the effect of varying nozzle-to-nozzle distance, varying speed of the plate and varying flow rate of impinging water on the heat transfer taking place on the ROT. Experiments are performed on a pilot scale run-out table using test plates moving at speeds of 1 m/s and 0.22 m/s. Each jetline consists of three circular jets, and one jetline is used in all experiment. The temperature of the cooling water is kept constant at 30 degrees C, for all experiments and the water flow rate is varied from 15 l/min. to 30 l/min. The effect of water flow rate, nozzle configuration and speed of the plate on cooling curves are examined. The results indicate that cooling efficiency increases with increasing flow rate and the cooling patterns are different in interaction zone from those observed in the impingement zones, below nozzle. The heat fluxes and heat transfer coefficients will be determined further, using IHC model. These experimental results will provide important information for the development of improved run-out table cooling models

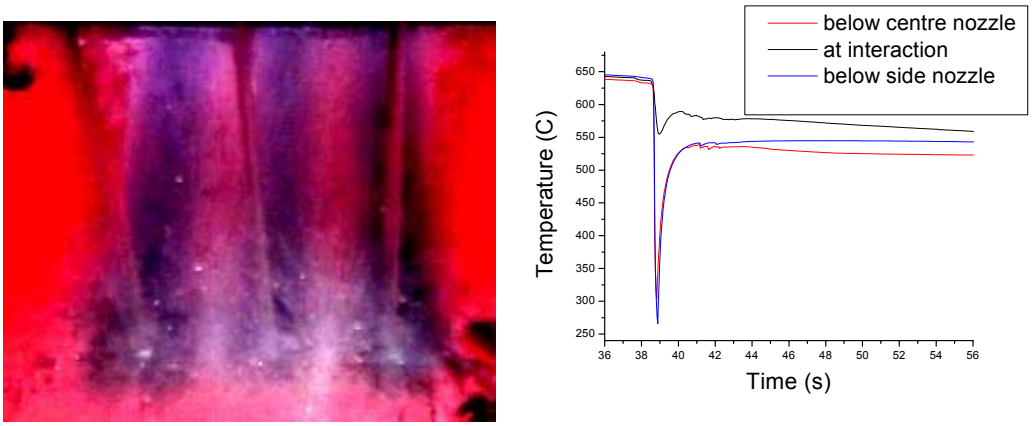

Figure: a. Three water jets impinging on moving hot steel plate;b. Cooling curves below nozzles and at interaction, for Flow rate = 30l/min, with two jets 3 inches apart and plate speed = 0.22m/s

Simulation and Optimization of the Electron Beam Cold Hearth Melting of Ti Alloys

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Research Summary:

The electron beam cold hearth melting (EBCHM) has emerged as an important process route for producing high quality Titanium ingots (both Rounds and Slabs). In the EBCHM technique, the melting/refining and solidification processes are conducted separately in a water-cooled copper hearth and a water-cooled copper mold, as shown in Figure 1(a). The process is carried out under vacuum because of the reactivity of Ti. Consequently, the casting process must be run in a batch mode, with an associated start-up phase, steady-state phase and final transient phase. Typical ingot lengths are of the order of 10m.

Despite its many advantages the process suffers from the evaporation of low-melting-point, high-vapor-pressure alloy elements, and the formation of voids in the top of the ingot during the final stages of solidification.

In order to solve these problems, mathematical modeling has been used for both process analysis and for the optimization of operating parameters in recent years. While extensive work has been done on modeling the cold hearth part of EBCHM, few models have ever been developed to describe the solidification of the ingot.

In current research, a three-dimensional thermal fluid model of the ingot in EBCHM has been developed. Various features of the casting process have been calculated and compared with experimental results - an example of which is shown in Figures 1 (b) and (c). It has been found that the casting speed has the most significant effect on the ingot sump depth, followed by the electron beam power. An optimization scheme will be proposed for EBCHM from the standpoint of control of casting speed and electron beam power, in order to minimize the ingot void formation.

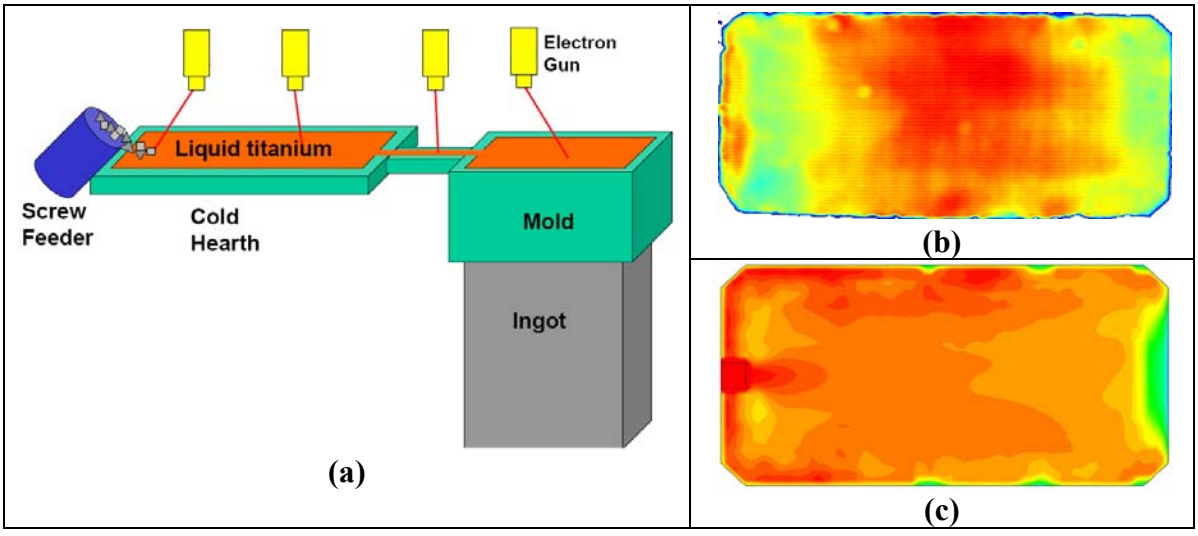

Figure 1: Schematic illustration of electron beam cold hearth melting (a), and temperature contors on ingot top surface from experiment (b) and model (c)

TRANSIENT COOLING OF A HOT STEEL PLATE BY AN INCLINED BOTTOM JET

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Department of Metals and Materials Engineering, University of British Columbia

Research Summary:

Controlled cooling on the runout table is a crucial component in the production of highly tailored steels since it has a strong influence on the final mechanical properties. High efficiency heat transfer in impinging jet cooling makes this an important method for heat transfer enhancement. The purpose of this study is to develop an experimental database for modelling of boiling heat transfer for bottom jet impingement that occurs during runout table cooling in a steel mill. Experiments have been carried out on a pilot scale runout table using stationary plates, with focus on the effect of water flow rate, strip speed, and nozzle inclination to the overall heat transfer rates. Volumetric flow rates, strip speeds, and inclination angles are in the range of 35-55 l/min, 0.3-1 m/s, and 0-30º, respectively. Temperatures on the test plates are measured internally very close to the surface during cooling for the purpose of reducing thermal lag and receiving better data responsiveness. These measurements are taken at the impingement point and several streamwise distances from the impingement point. From the above measurements transient cooling data on the hot steel plate by bottom jet impingement has been analysed.

The Recycling of Sodium Metaborate to Sodium Borohydride: Properties of Alkaline Aqueous Sodium Metaborate Solutions

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Research Summary:

The transtition to a “hydrogen economy” is hindered by the lack of a practical storage method and concerns associated with its safe handling. Chemical hydrides have the potential to address these concerns. Sodium borohydride (sodium tetrahydroborate, NaBH4), is the most attractive chemical hydride for H2 generation and storage in automotive fuel cell applications, however recycling from sodium metaborate (NaBO2) is difficult and costly. An electrochemical regeneration process could represent an economically feasible and environmentally friendly solution.

We studied the physicochemical properties of NaBO2 solutions that are necessary for the development of electrochemical recycling methods in aqueous media. The solubility, pH, density, conductivity and viscosity of aqueous NaBO2 solutions containing varying weight percentages (0, 1, 2, 3, 5, 7.5, 10) of hydroxides (NaOH, KOH and LiOH) were evaluated at 25oC. The precipitates formed in the supersaturated 10 wt% alkaline aqueous NaBO2 solutions were characterized by X-Ray Diffraction and Scanning Electron Microscopy. The effects of temperature (50, 75oC) and of the addition of glycine on the solution properties are currently being investigated.

The use of KOH as the electrolyte was found to be more advantageous for the NaBH4 H2 storage and generation system based on NaBO2 solubility, solution half-life and viscosity. However, the addition of NaOH led to the highest ionic conductivity, and its use seems more suitable for the electroreduction of NaBO2. Further investigations on the impact of KOH and NaOH on the electroreduction of NaBO2 in aqueous media have the potential to enhance the commercial viability of this fuel.

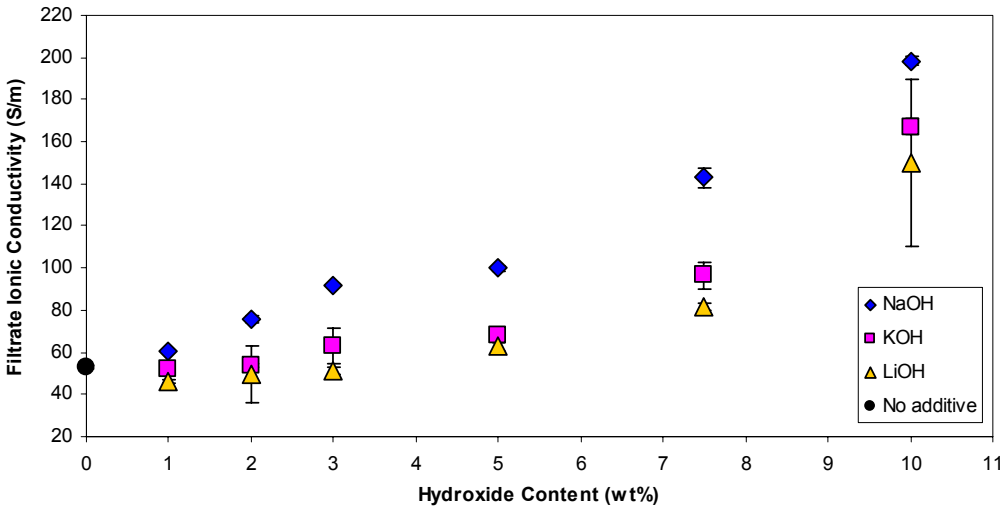

Fig. 1: NaBO2 Ionic Conductivity in the Filtrate as a Function of Hydroxide Content at 25oC.