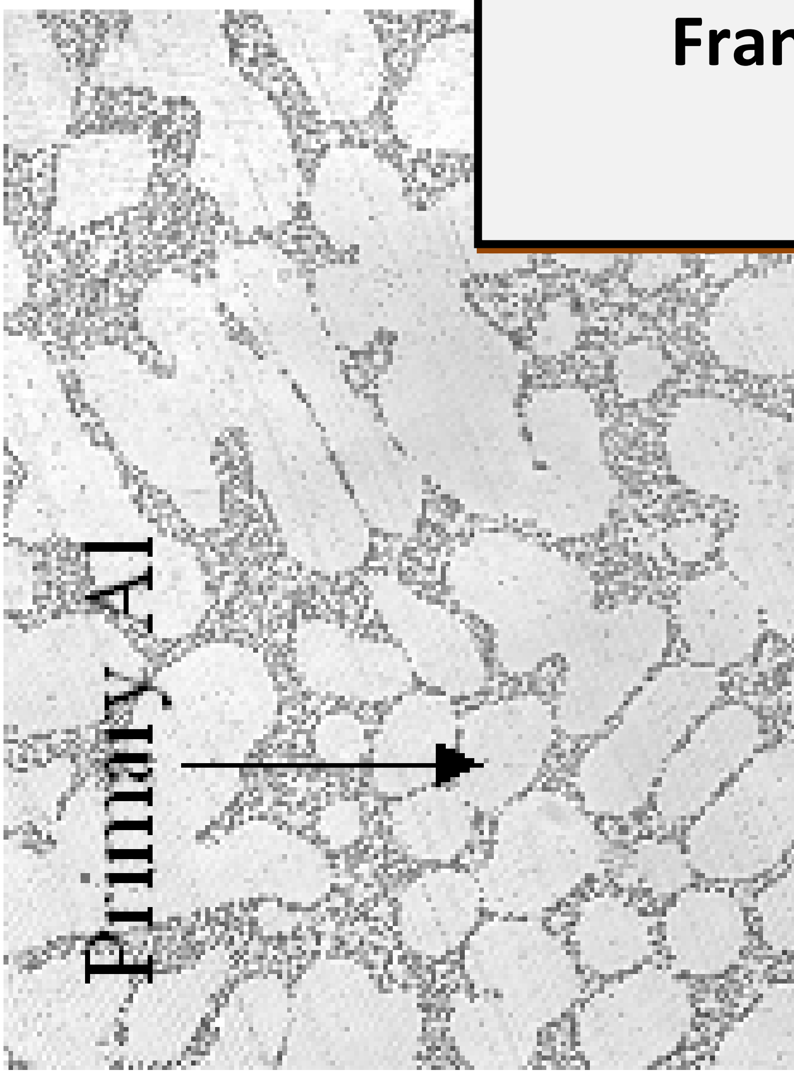
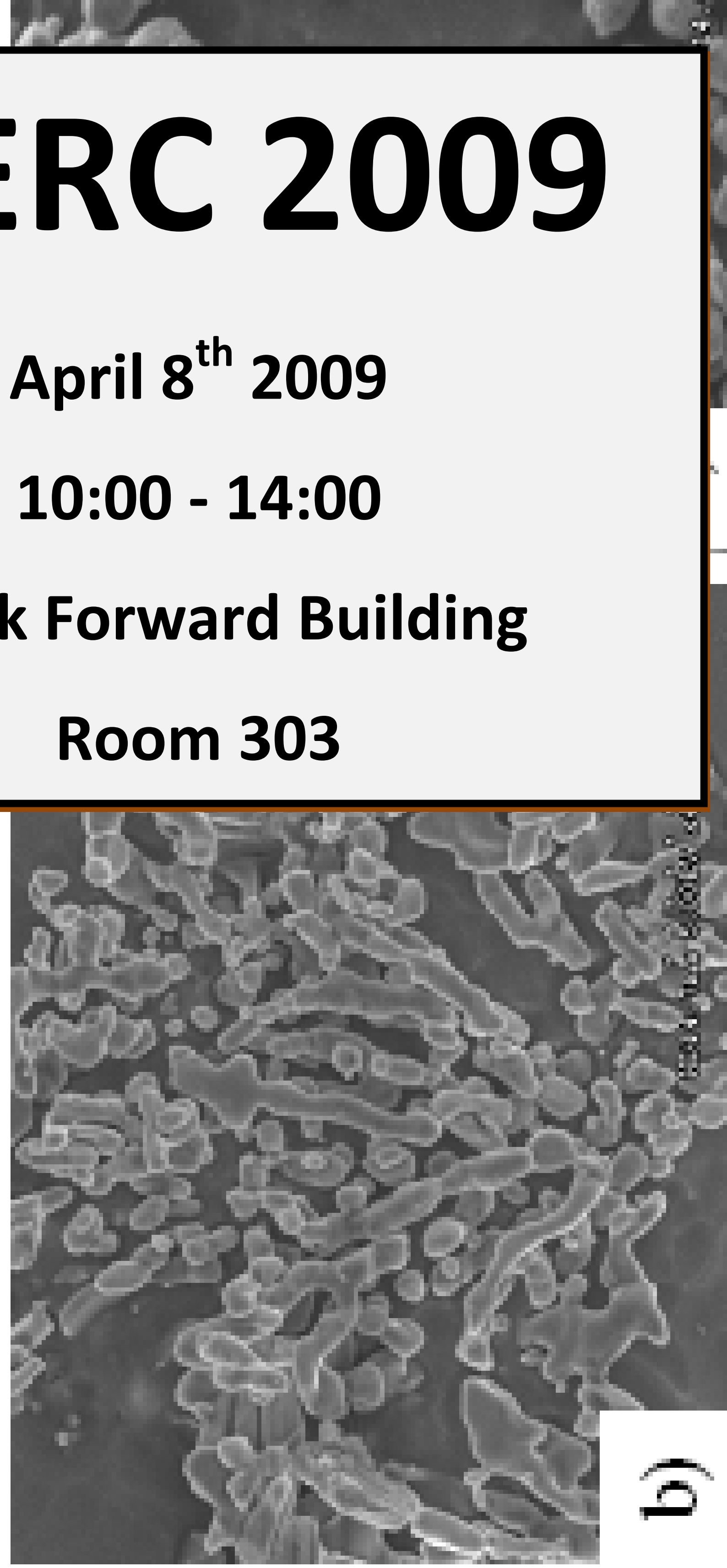




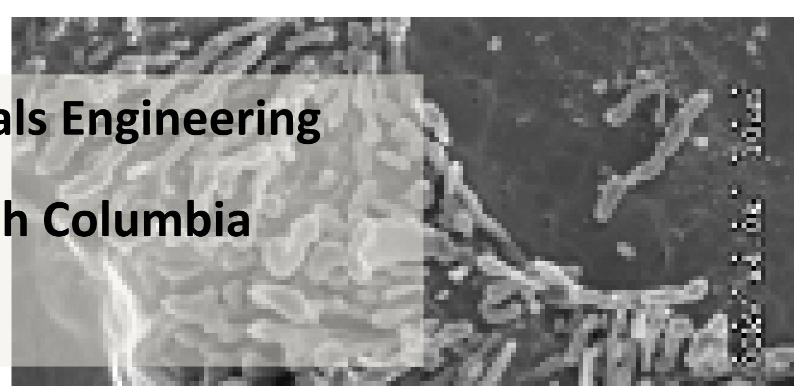
MERC 2009

April 8th 2009

10:00 - 14:00

Frank Forward Building

Room 303



Department of Materials Engineering

The University of British Columbia

Vancouver BC

Materials Engineering Research Colloquium Schedule

Wednesday April 8th, 2009

Presenter	Time	Title
N. Slesinger	10:00	Reducing Uncertainty in Thermal Process Modeling of Thermoset Composite Materials
B. Louis	10:30	Permeability of MTM45-1 / 5HS Carbon Fibre Pre-Preg for Out of Autoclave Manufacturing of Composite Aerospace Structures
H. Sheikh	11:00	Modeling of Degradation of Silicon Nitride due to Migration of Yb3+ ions in an Electric Field
L. Colley	11:30	The Evolution of Microstructure and Yield Strength During Heat Treatment of A356 Alloy
LUNCH	**12:00**	
B. Xue	13:00	Characterization of Secondary Cooling Heat Transfer in Horizontal Direct Chill Continuous Casting of Aluminum Alloy Re-Melt Ingots
J. Lu	13:30	Investigation of Heat Transfer in Properzi Continuous Casting

Reducing Uncertainty in Thermal Process Modeling of Thermoset Composite Materials

Nathan Slesinger and Anoush Poursartip

Research Summary:

The properties of a cured fiber-reinforced thermoset-matrix composite are highly dependant on the thermal cycle experienced by the composite during cure. In the past, cure cycles were designed by iterative trial and error methods, but this approach is neither efficient nor economical as composite parts continue to increase in size and complexity. Thermal simulations can be used to test a cure cycle on a part without the time or expense required for an autoclave cycle.

Many variables are required to accurately simulate the curing process; this work focuses on the heat transfer coefficient (HTC) and the cure kinetics model of the thermosetting matrix. Because the primary method of heat transfer inside an autoclave is via convection, an HTC value is needed to define the thermal boundary condition in the simulation. Methods have been developed to back calculate the HTC using thermocouple data from either a steel rod or a silicone rubber brick in the autoclave. A simple method of validating cure kinetics models using this back-calculated HTC and the COMPRO 2-D finite element package is being developed.

Cure kinetics models are typically generated from differential scanning calorimeter data, but verification of the kinetics model has been limited to simple tests that do not push the limits of the kinetics model. The new validation method uses a thick laminate wrapped around a tube which exotherms at least 10-20°C and this data is compared to a 2-D simulation of the laminate using the measured temperatures and back-calculated HTC from the autoclave run. By reducing the uncertainty of the most important factors in the process model, the engineering importance of cure modeling can be greatly enhanced.

Permeability of MTM45-1 / 5HS Carbon Fibre Pre-Preg for Out of Autoclave Manufacturing of Composite Aerospace Structures

Bryan Louis and Göran Fernlund

Research Summary:
Carbon Fibre Reinforced Polymer (CFRP) composite materials for aerospace applications are typically composed of several lamina sheets stacked together on a mould forming a laminate structure of the desired shape. The evacuation of entrapped gasses during processing is critical to produce low-void content cured composite structures with high mechanical properties. The permeability of a pre-preg laminate is therefore critical in providing a pathway for gas removal prior to the curing process in which the composite structure is hardened to its final shape.
Traditional processing of aerospace composite structures involves the use of an autoclave where-in pressures of up to 100psi is used to produce low-void content parts. A new class of pre-preg materials called Out-Of-Autoclave (OOA) has been developed to produce aerospace quality structures with the absence of the use of an autoclave. The removal of the autoclave in the processing will lead to substantially reduced capital costs, reducing production costs and open up the manufacturing market to smaller manufactures and sub-contractors.
Permeability measurements were made on an OOA pre-preg MTM45-1 / 5HS produced by Advanced Composites Group (ACG) in both the through-thickness and in-plane directions for various lay-up scenarios. The effect of the debulking process, which is commonly used in industry without strict control, was also investigated in relation to the permeability of the pre-preg. Future work includes measuring the dynamically changing permeability of MTM45-1 / 5HS during the cure process temperature ramp and temperature hold stages.

Modeling of Degradation of Silicon Nitride due to Migration of Yb^{3+} ions in an Electric Field

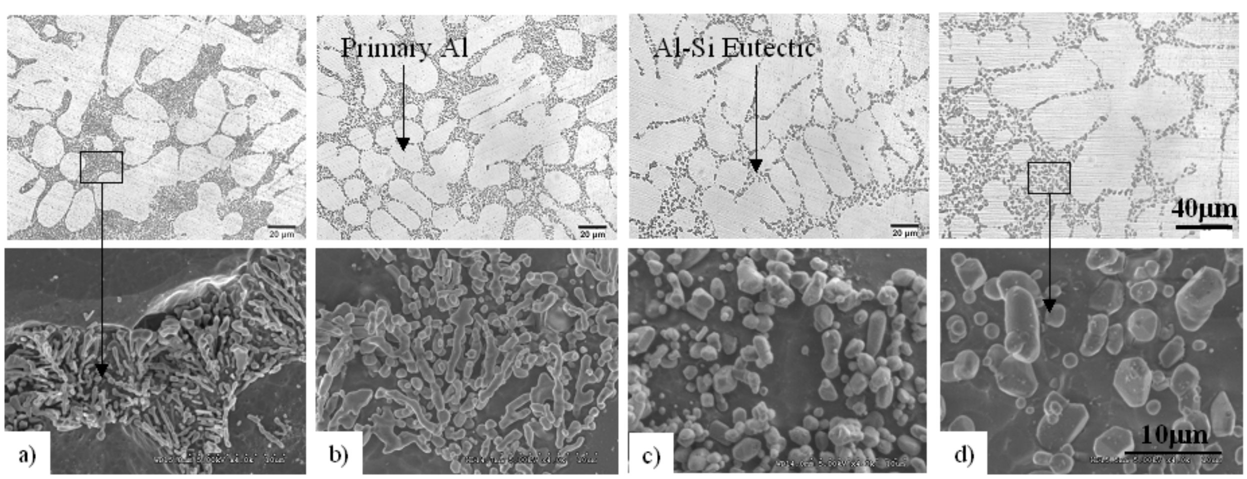
Hamed Sheikh and Tom Troczynski

Research Summary:
The best hot surface ignition systems for natural gas direct injection engines include glow plugs with all-ceramic heating elements based on sintered silicon nitride. In the current work we have demonstrated that such ceramic heaters degrade due to the redistribution of the sintering additives in Si_3N_4/Yb_2O_3 system under an influence of DC electric field and temperatures in excess of 1300C. At these conditions Yb^{3+} ions migrate away from the positive electrodes, continuously changing the composition of the intergranular phase, thus leading to gradual performance degradation and failure. This presentation presents the results of numerical modeling of such electromigration of ytterbium ions in silicon nitride ceramic. A differential equation describing the process is derived, incorporating Poisson, Nernst-Planck and charge continuity equations to predict migration of one mobile ion species (Yb^{3+}) under the influence of an applied electric field. The model is evaluated against corresponding ytterbium migration profiles determined by Energy Dispersive X-ray Spectroscopy (EDS) and Scanning Electron Microscope (SEM). Both the quantitative model and the experimental results show the ionic migration dependence on the experimental parameters, i.e. electric field and temperature.

The Evolution of Microstructure and Yield Strength During Heat Treatment of A356 Alloy

Leo Colley, Warren Poole and Mary Wells

Research Summary:
Many cast aluminum alloys require heat treatment to optimise their structure and properties prior to service. Typically, heat treatment consists of three stages; (1) solution treatment to dissolve non-equilibrium particles and modify insoluble particles, (2) rapid quenching to create a supersaturated solid solution, (3) artificial ageing to precipitate a fine dispersion of strengthening particles. Artificial ageing may be preceded by a delay at room temperature, which can strongly influence the ageing behaviour of the alloy.
A study of the microstructure and mechanical property changes in an A356 aluminum alloy during heat treatment is underway, with the overall purpose of developing predictive models that describe the evolution of microstructure and yield strength for a wide range of heat treatment conditions. The evolution of microstructural features during solution treatment has been quantified using X-ray microprobe analysis, as well as deep etching and image analysis techniques. Microhardness, tensile testing and isothermal calorimetry techniques are being used to examine the behaviour of the alloy during ageing. A description of the models developed to predict behaviour during solution treatment and ageing is also presented.

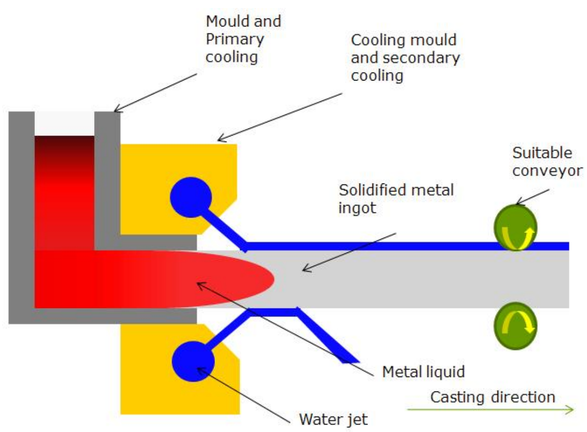


Optical (top) and deep etched (bottom) micrographs illustrating the modification of eutectic silicon particles in the A356 alloy during solution treatment;
a) as-cast, b) 2 minutes at 540ºC, c) 30 minutes at 540ºC, d) 240 minutes at 540ºC

Characterization of Secondary Cooling Heat Transfer in Horizontal Direct Chill Continuous Casting of Aluminum Alloy Re-Melt Ingots

Boran Xue and Daan Maijer

Research Summary:
The horizontal direct chill (HDC) casting is a continuous process used to produce extrusion billet and re-melt ingot. As in vertical DC casting, secondary cooling, where water directly impinges on the cast surface, is an important stage that can affect cast quality and production rates. During HDC casting, secondary cooling is further complicated by horizontal water flow and the orientations of the cast surfaces. Characterizing the heat transfer during the secondary cooling process is necessary for improved understanding of the process and also for developing an accurate process model. In this research, an apparatus has been designed to simulate HDC secondary cooling in a block of aluminum alloy HDC ingot. An inverse heat transfer method is used to estimate the heat flux during cooling based on measured temperatures. The heat flux will be characterized as a function of distance from impingement point and surface orientation. In this way, a heat transfer model will be built for secondary cooling process in HDC casting operation.



Investigation of Heat Transfer in Properzi Continuous Casting

Jung Lun Lu and Daan Maijer

Research Summary:
Properzi continuous casting process has been used to produce high and low alloy content aluminum billets with trapezoid cross-sections which are drawn into wires for mechanical and electrical applications. In order to optimize the Properzi casting process, both an inverse heat transfer code and a 3D finite element heat transfer model are developed and used to gain insight into the air gap formation at the metal/mold interface.