An Overview

CHTE

Center for Heat Treating Excellence

At Worcester Polytechnic Institute

WPI

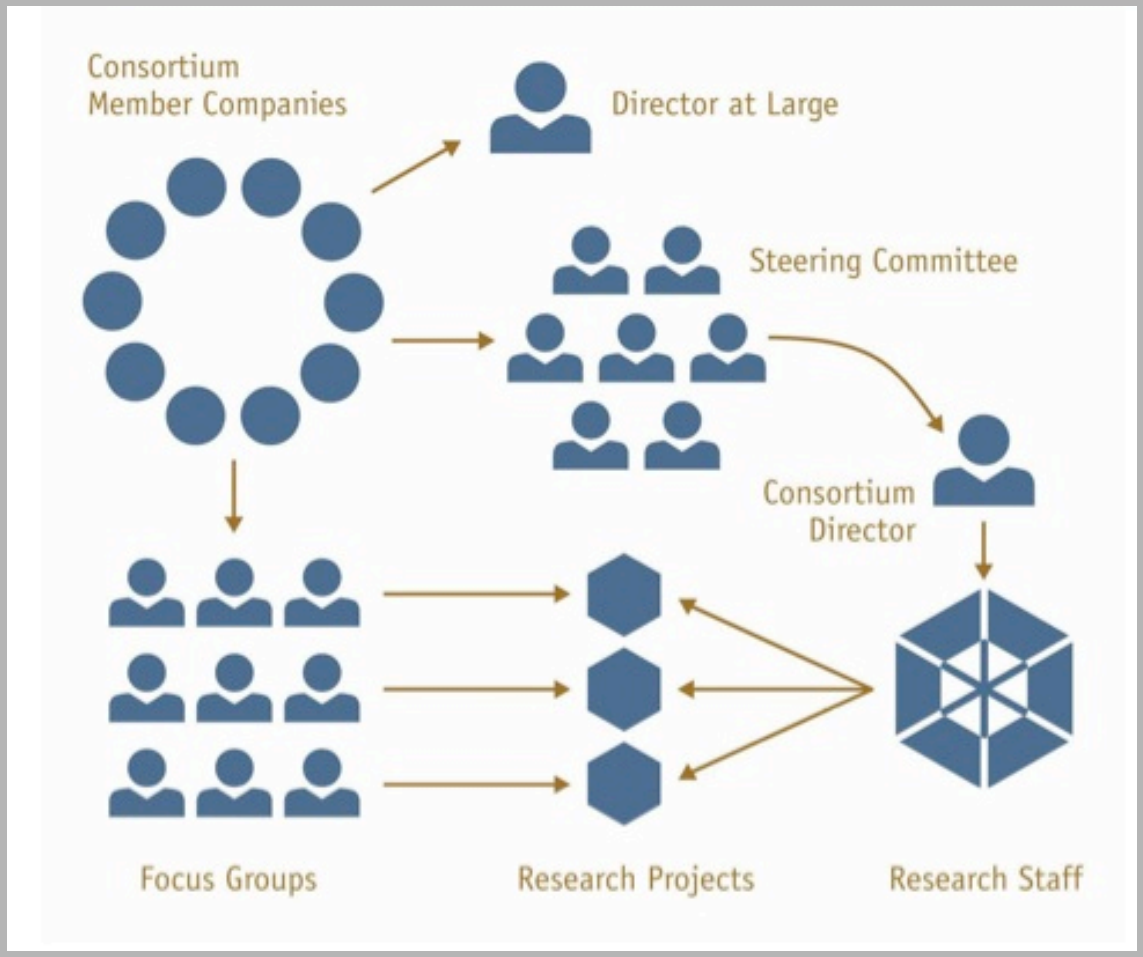
Management Team

Diran Apelian	*Executive Director*
Richard Sisson	*CHTE Director*
Mike Pershing	*Chair, Board of Directors*
Roger Fabian	*Director-at-Large*

CHTE Mission

To be the premiere industry-university alliance serving the thermal processing industry by serving consortium members' needs, by establishing the needed knowledge base, and by educating future leaders of the industry.

Industry-University Alliance in Action



Our Industrial Partners and Sponsors

Air Liquide • Air Products • ALD Vacuum Technologies • ASM Heat Treating Society • Bluewater Thermal Solutions • Caterpillar • Chrysler • Cummins Fuel Systems • John Deere • Harley-Davidson Motor Company • Houghton • Pratt & Whitney – Sikorsky • Praxair • Scientific Forming Technologies Corporation • Seco/Warwick • The Sousa Corporation • Spirol • Surface Combustion • Thermatool • The Timken Company

Fundamental Reseach

BUT…

Context / Applications are well defined

BY WHOM?

The Marketplace – the Industry

Research Programs

- ***Pre-Competitive*** *Fundamental Research funded by the members*

- ***Large-Scale*** *Projects funded by the Federal Government or foundations leveraging the research agenda of the centers*

- *Specific and* ***Proprietary Research*** *conducted for collaborative members*

Major Impact

- ***Commercialization of Ideas***
- ***Innovation***
- ***Competitiveness of Our Industrial Members***
- ***"Theory and Practice".....Practiced!!***

"In theory, there is no difference between theory and practice. In practice, there is."

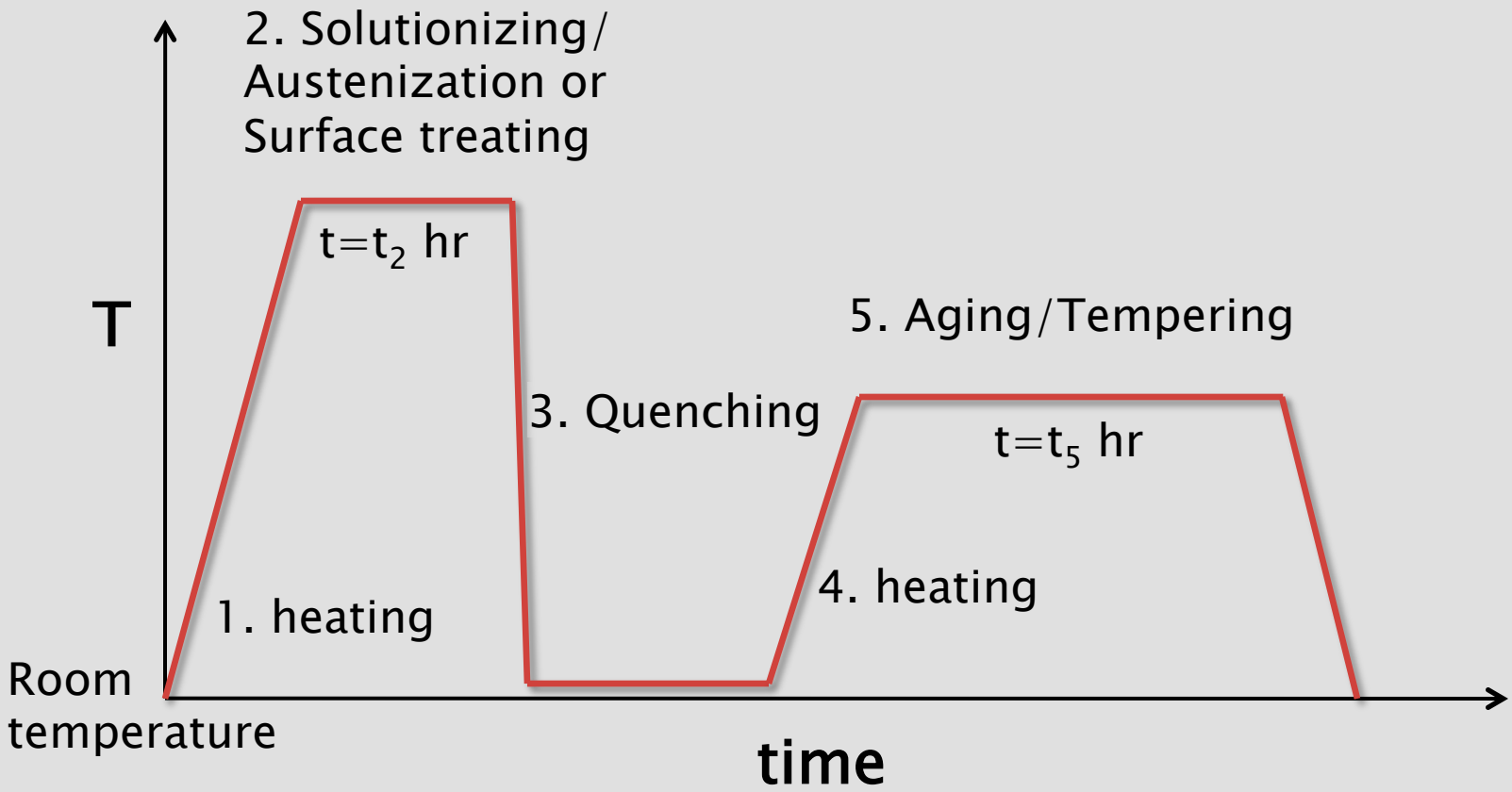
Yogi Berra

Inter-disciplinary Approach

- Materials Engineering
- Mechanical Engineering
- Electrical Engineering
- Chemical Engineering
- Management/Marketing
- Other Universities
- Government Laboratories

CHTE Portfolio

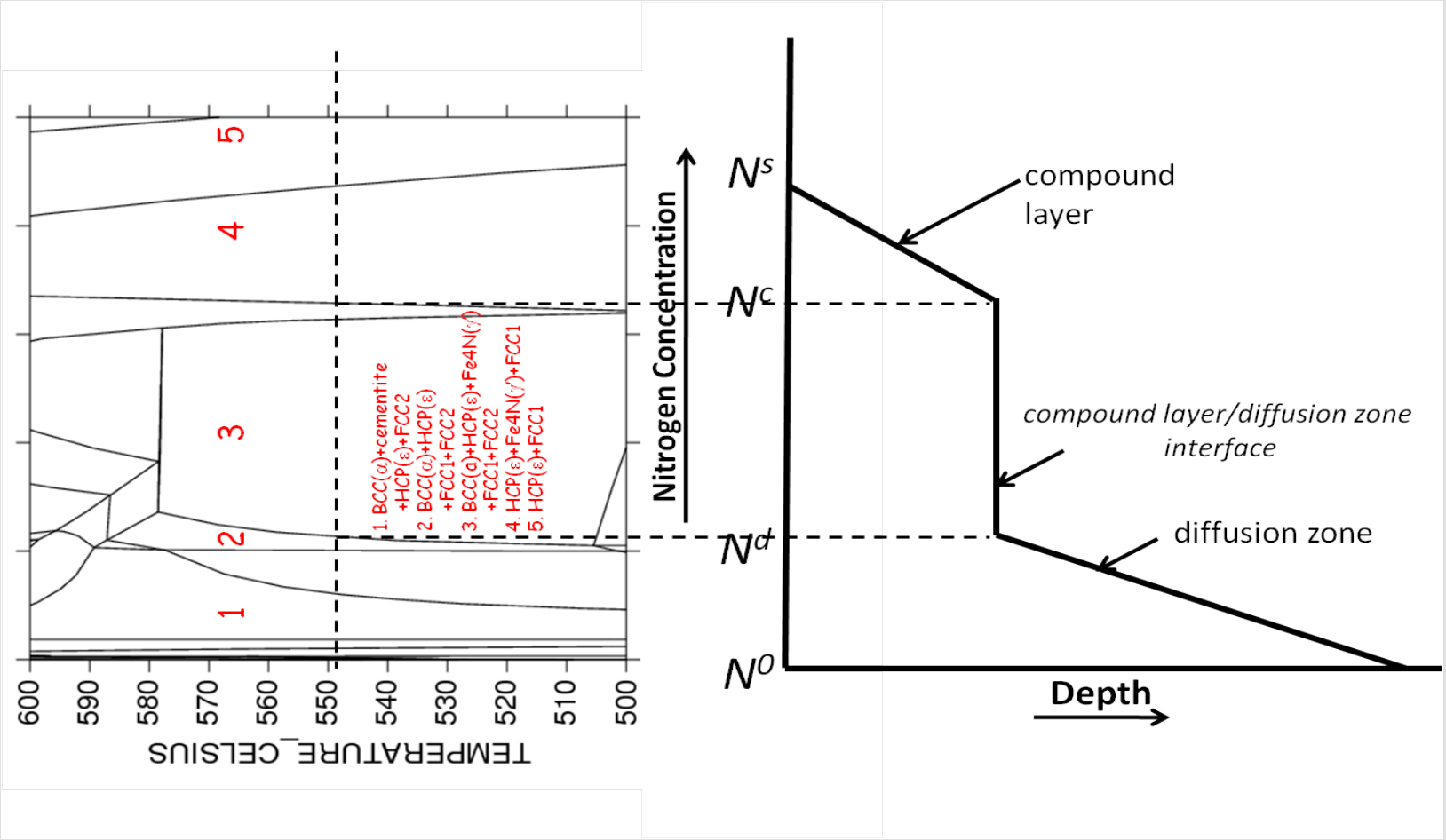
Heat Treatment Processes



Ferritic Nitrocarburizing

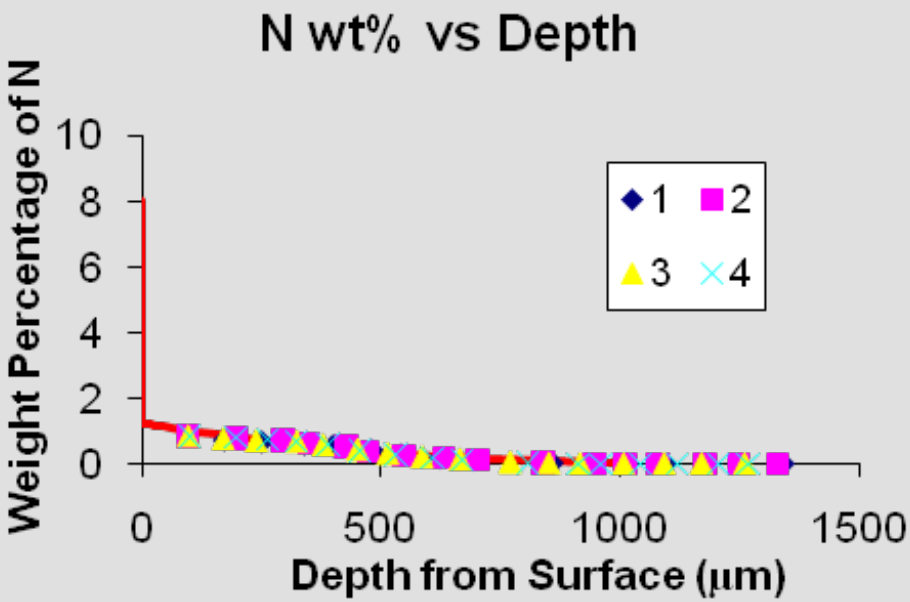
- *Alloy specific Lehrer diagrams developed for the first time and verified experimentally*
- *Alloy specific isopleths - phase diagrams developed*
- *Kinetic model framework developed using the Lehrer diagrams and isopleths – software to be ready for testing in the fall 2011*
- *NitrideTool ©*
- *Need experimental verification – testing at CAT*
- *CHTE member testing*
- *Model completion 6/2012*

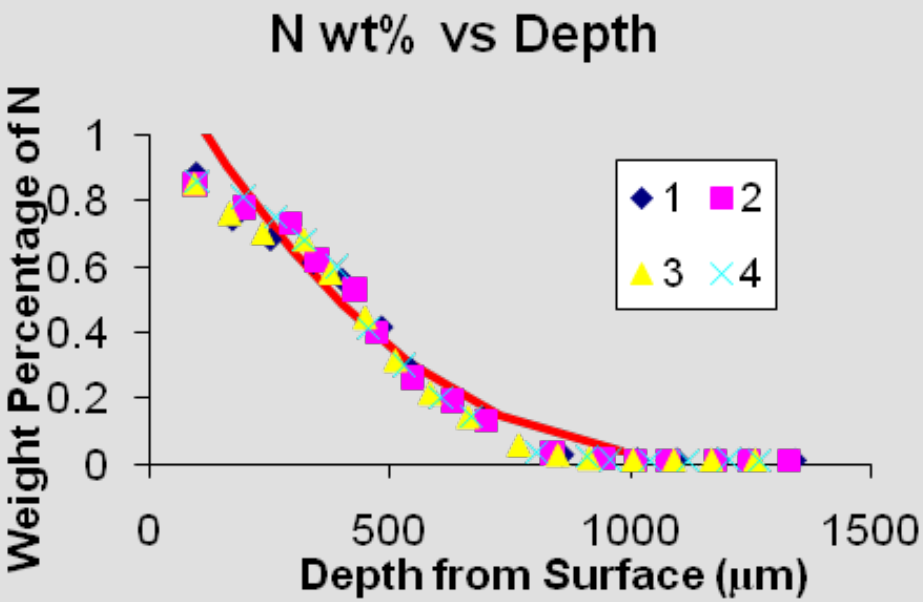
Isopleth vs. Nitrogen Concentration Profile



Preliminary Simulation Results for AISI 4140

- *Diffusion Coefficients*
  - *Inverse method used to fit the OES results*
    D^d=9x10^{-7}cm^2/s, close to 7.3x10^{-7}cm^2/s (diffusivity of N in α) [1]
  - *Should be determined experimentally*





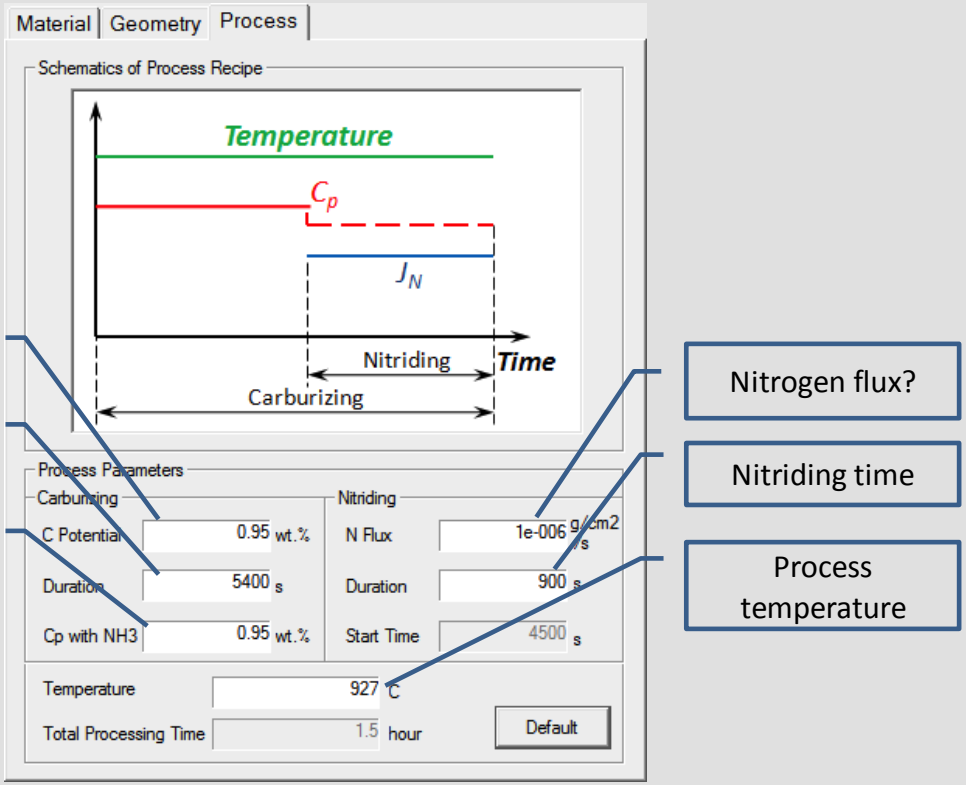
[1] Przylecki, Z. and L. Maldzinski, Poznan/Kolobrzeg, Poznan, Poland, 1987: p. 153-162

Carbonitriding

- *CarbTool© has been modified for carbon and nitrogen absorption – **CarboNitrideTool** ©*
- *Database needs for diffusivities of N and C*
- *Database needs for mass transfer coefficients and fluxes*
- *Experimental verification ongoing*
- *Simulation ready for testing in January 2013*
- *Model completion 12/2011*

CarboNitrideTool ©

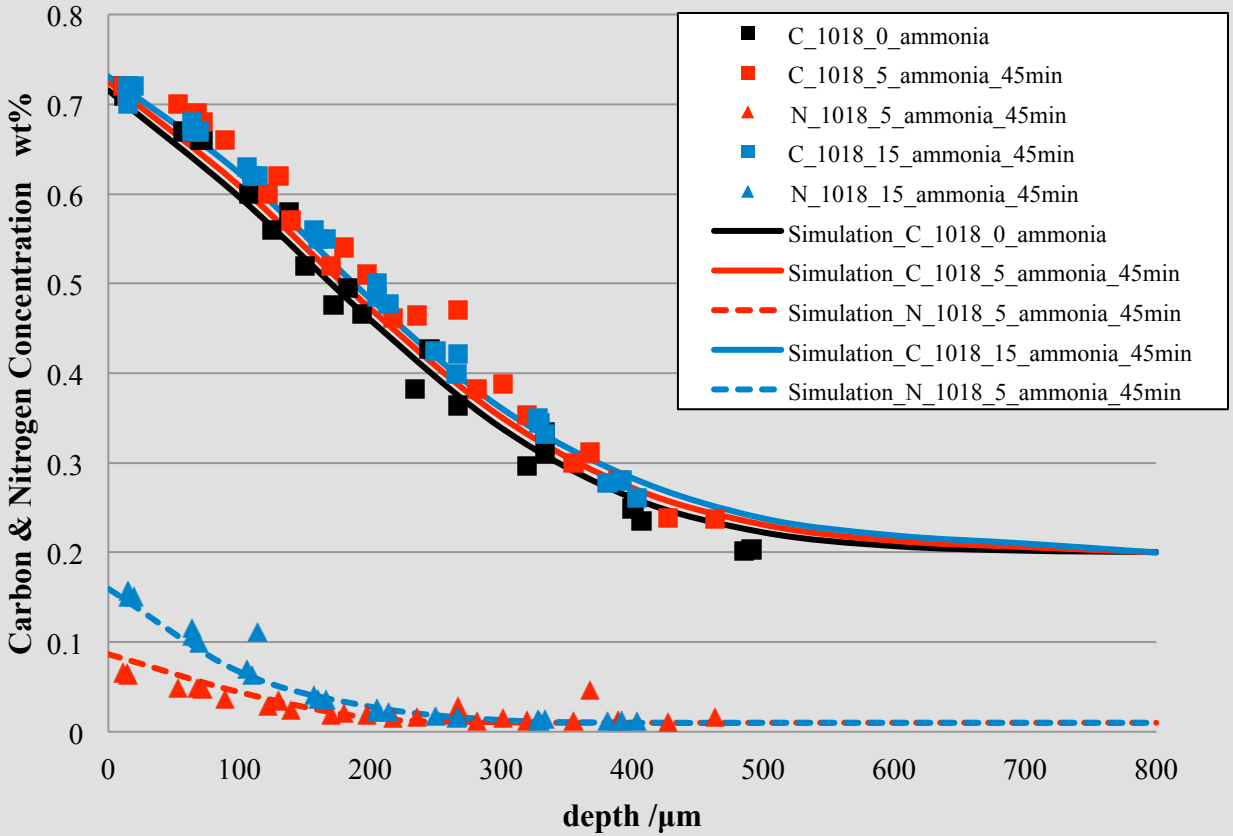
- *Carbon potential*
  - *The initial Cp without NH3 addition.*
- *Carburizing time*
  - *The time that only carburizing is operated.*
- *Cp variation with NH3 addition*
  - *When NH3 is added into the furnace, Cp may be affected and drop a little which must be taken into account.*
- *Process temperature*



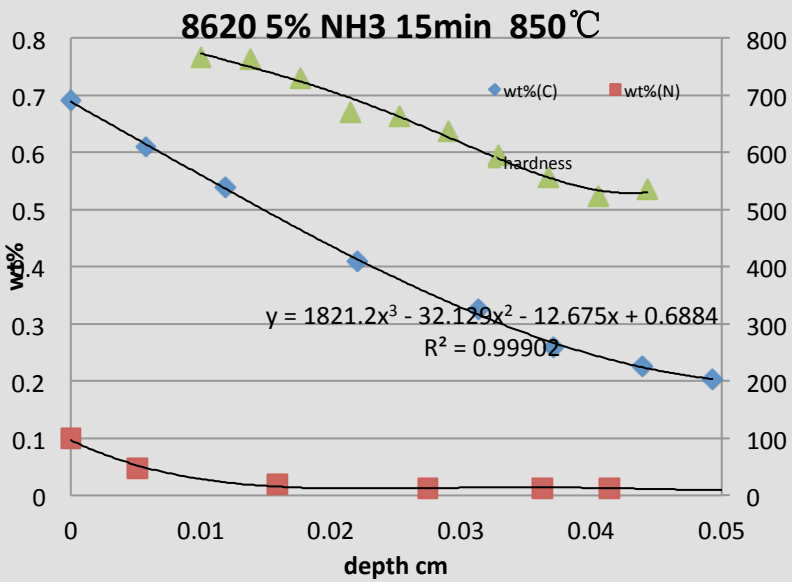
- *Nitrogen flux.*
  - *Nitrogen flux as a constant or a function of time calculated by weight gain method.*
- *Nitriding time*
  - *The time with NH3 addition.*

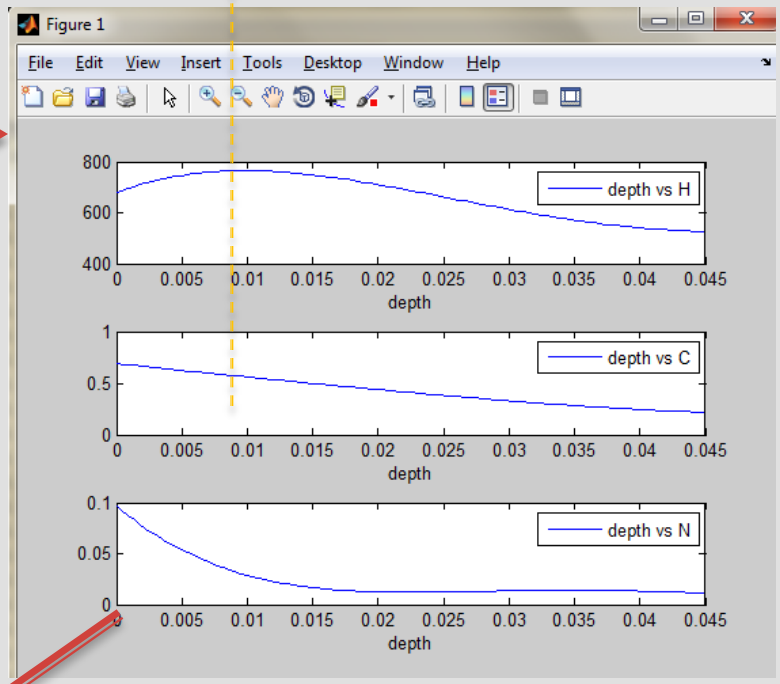
Simulation Results

- AISI 1018 850°C



Simulation Results



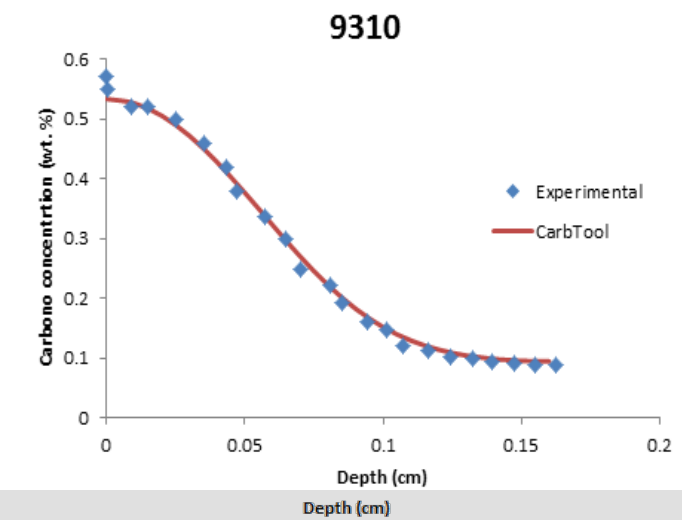


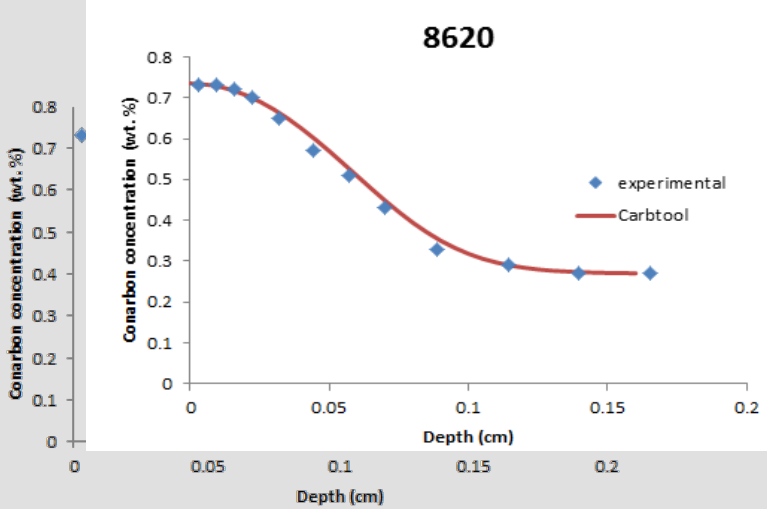
Distance (cm)	c%	N%	Hardness
5.00E-03	7.22E-01	4.95E-02	6.88E+02
....	....	....	....

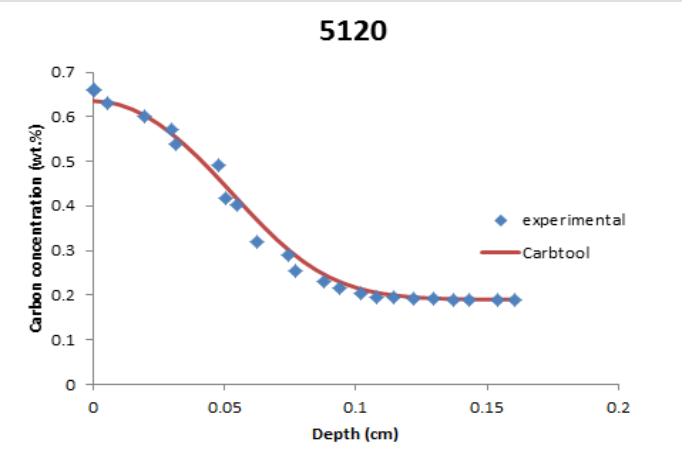
Atmosphere vs. Vacuum Carburizing

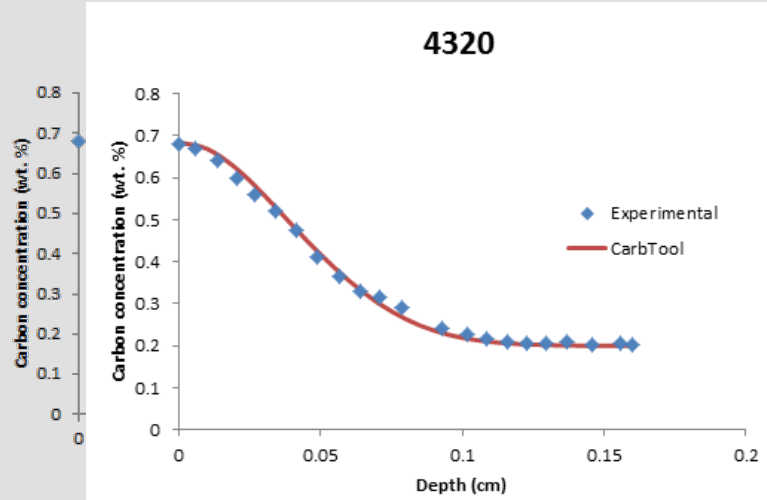
- Continuing to work with Surface Combustion and SECO/ WARWICK to develop recipes (process parameters) and carburize the steels.
- Demonstrated the capability of matching the Carbon Concentration profiles for gas and vacuum carburizing
- Project continuing – modeling with DEFORM for quenching effects
    - Residue Stress, retained Austenite, microstructure

Vacuum Carburizing Process – Experimental & Simulation Results





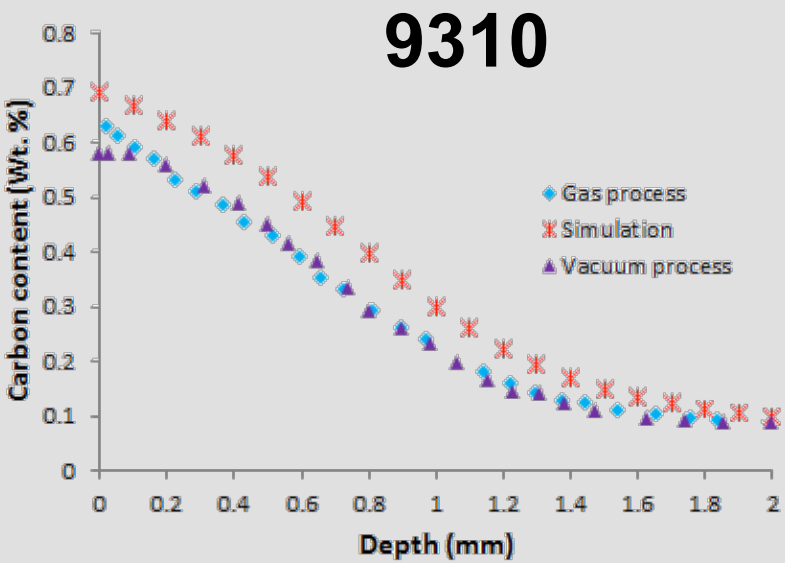


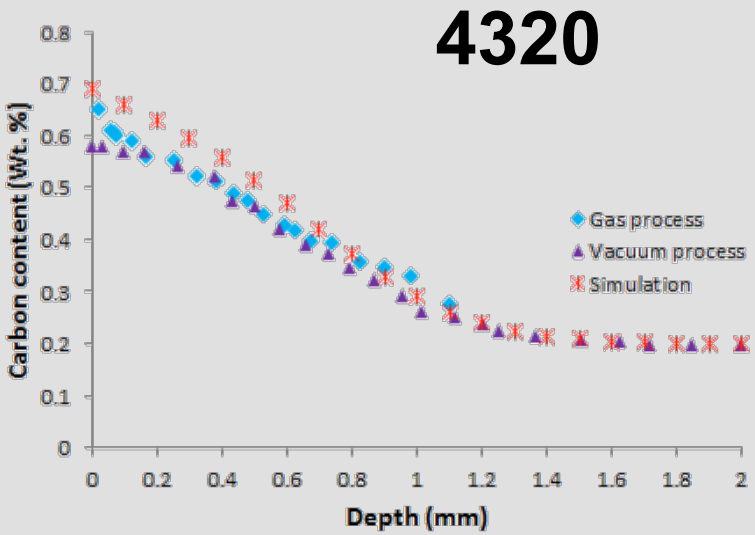


$$J(x) = \frac{d}{dt}\int_{C'}^{C_0} x\,dC$$

$$J = \frac{Area\ under\ the\ curve\ \times\ Density}{total\ effective\ carburizing\ time}\ \left[\frac{g}{cm^2 s}\right]$$

Comparison of Two Processes





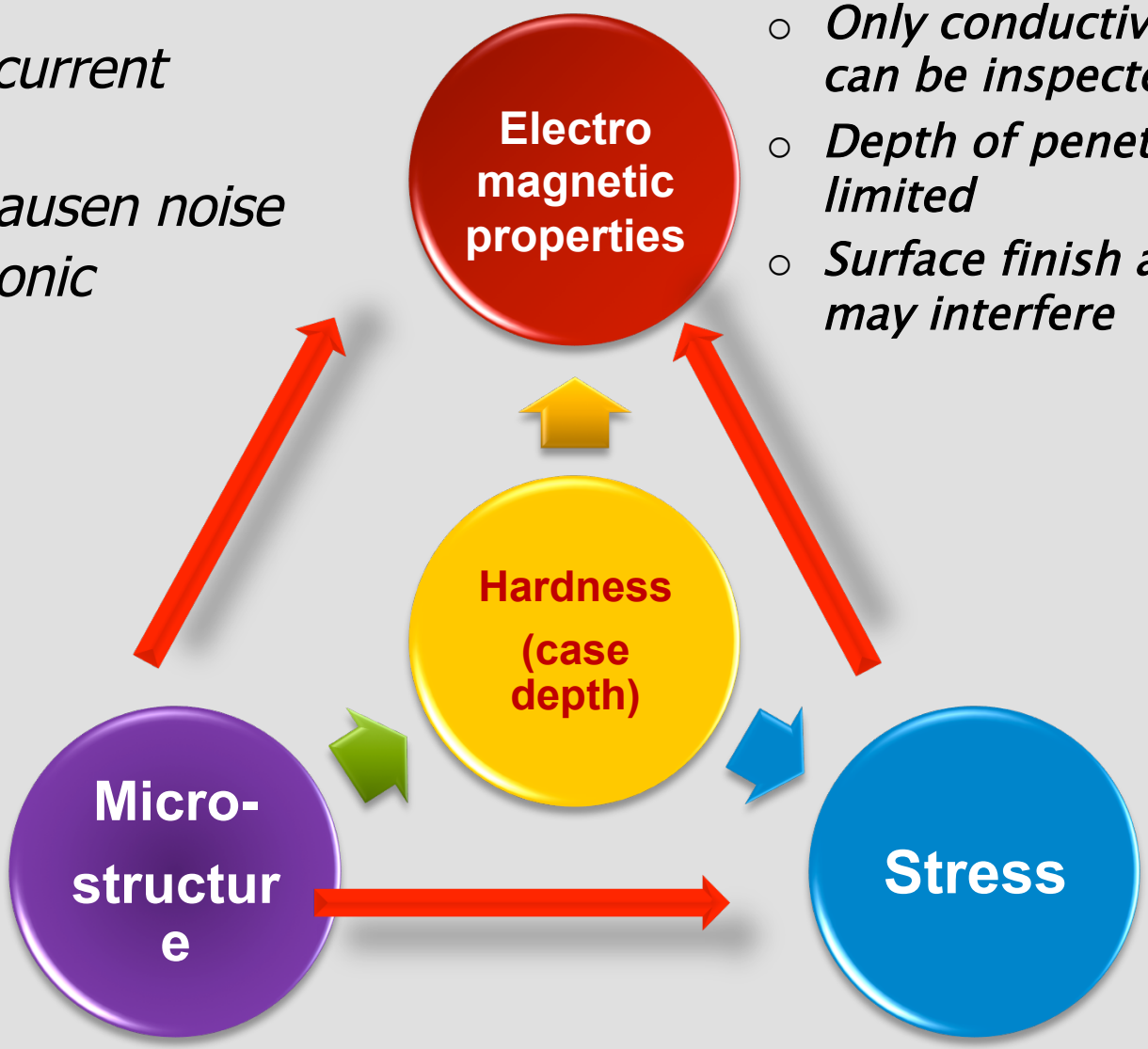
		9310	4320	8620	5120
Surface Carbon (wt.%)	Target	0.7±0.05		0.8±0.05	
	Gas	0.63	0.65	0.80	0.82
	Vacuum	0.58	0.58	0.70	0.77
Effective Case Depth (mm)	Target	0.89±0.05			
	Gas	0.67	0.87	0.82	0.84
	Vacuum	0.71	0.78	0.80	0.80

Nondestructive Testing for Hardness and Case Depth Measurements

- *Project planning completed*
  - *Design and fabrication of standard test samples will be the key to a successful project*
- *Literature review ongoing*
- *Standard Test Sample Design*
  - *DEFORM*
  - *Microstructure & Residual Stress*
- *Equipment identified*
  - *MWM and Barkhausen Noise Equipment secured!*
- *Preliminary Testing in Spring semester*
- *Estimated Completion 6/2013*

Review of NDT Technologies

- *Eddy current*
- *MWM*
- *Barkhausen noise*
- *Ultrasonic*
- *ACPD*



- *Only conductive materials can be inspected*
- *Depth of penetration is limited*
- *Surface finish and roughness may interfere*

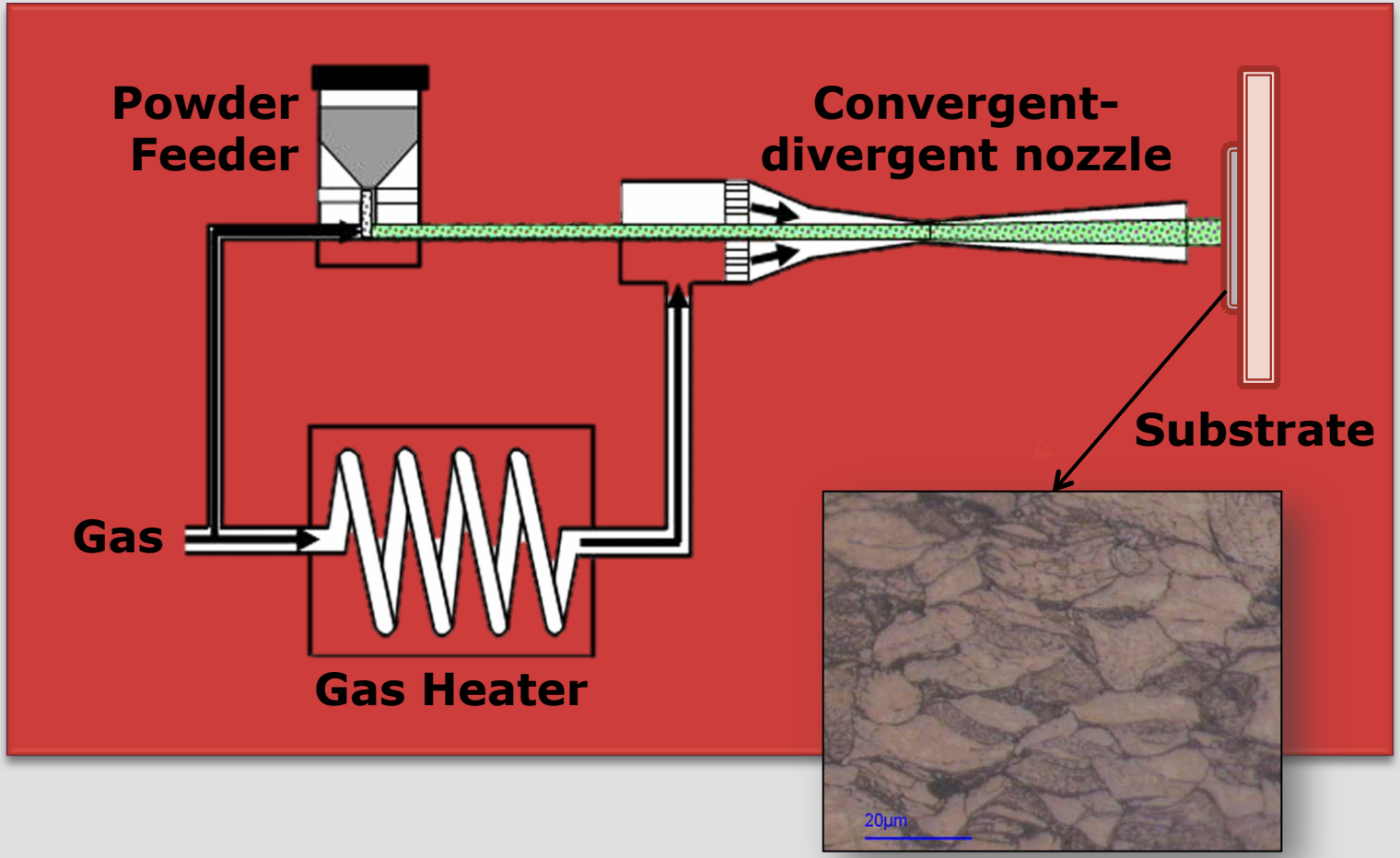
Thermomechanical Processing of Light Alloys by Design

- ***Faculty: Rick Sisson, Diran Apelian, Makhlouf Makhlouf, Jianyu Liang, Nikolaos Gatsonis***

- ***Research Assistants: Mei Yang, Luke Bassett, Danielle Belsito, Aaron Gatz, Baillie McNally, and Rose Roy***

Background

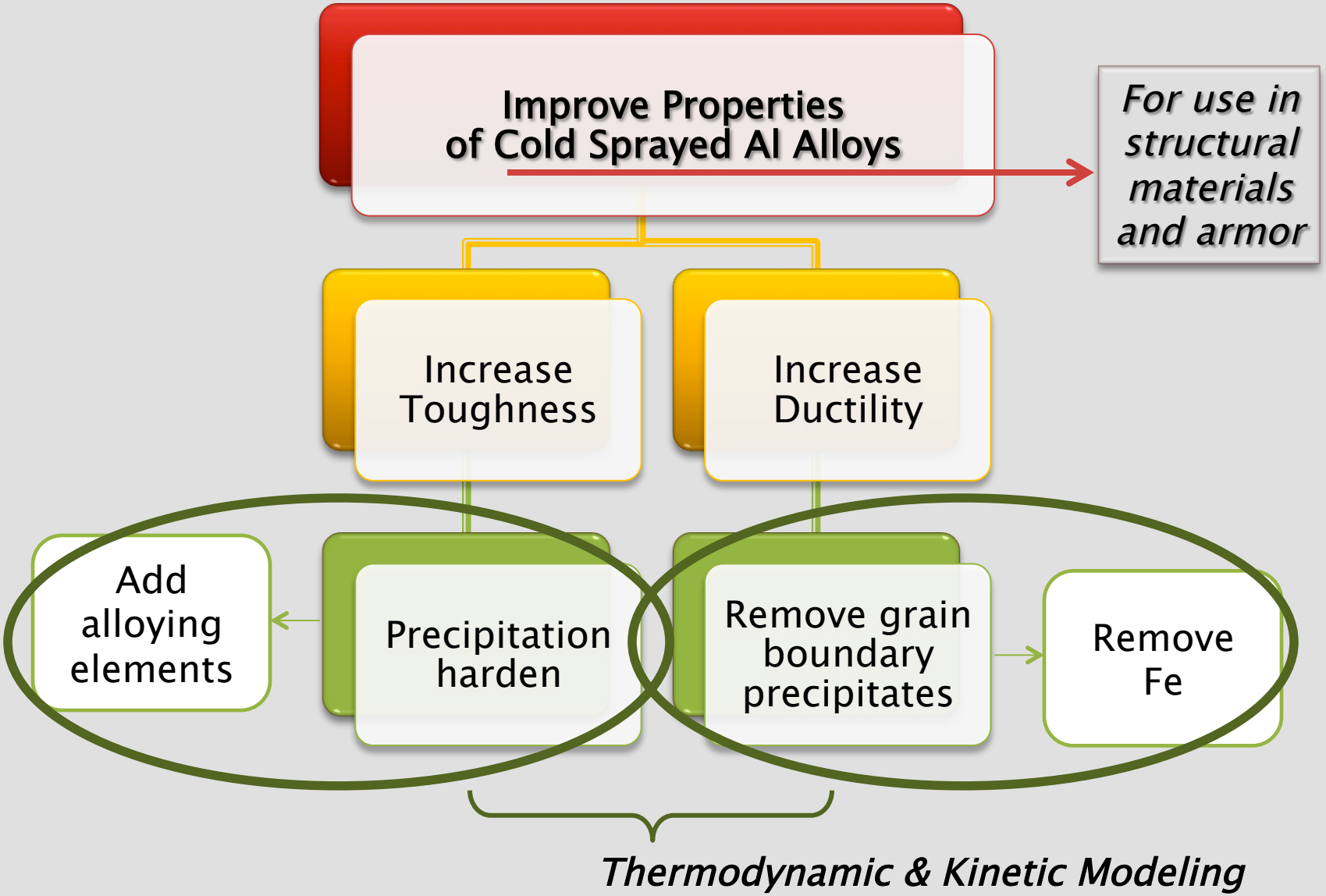
- ***Cold Spray Process***



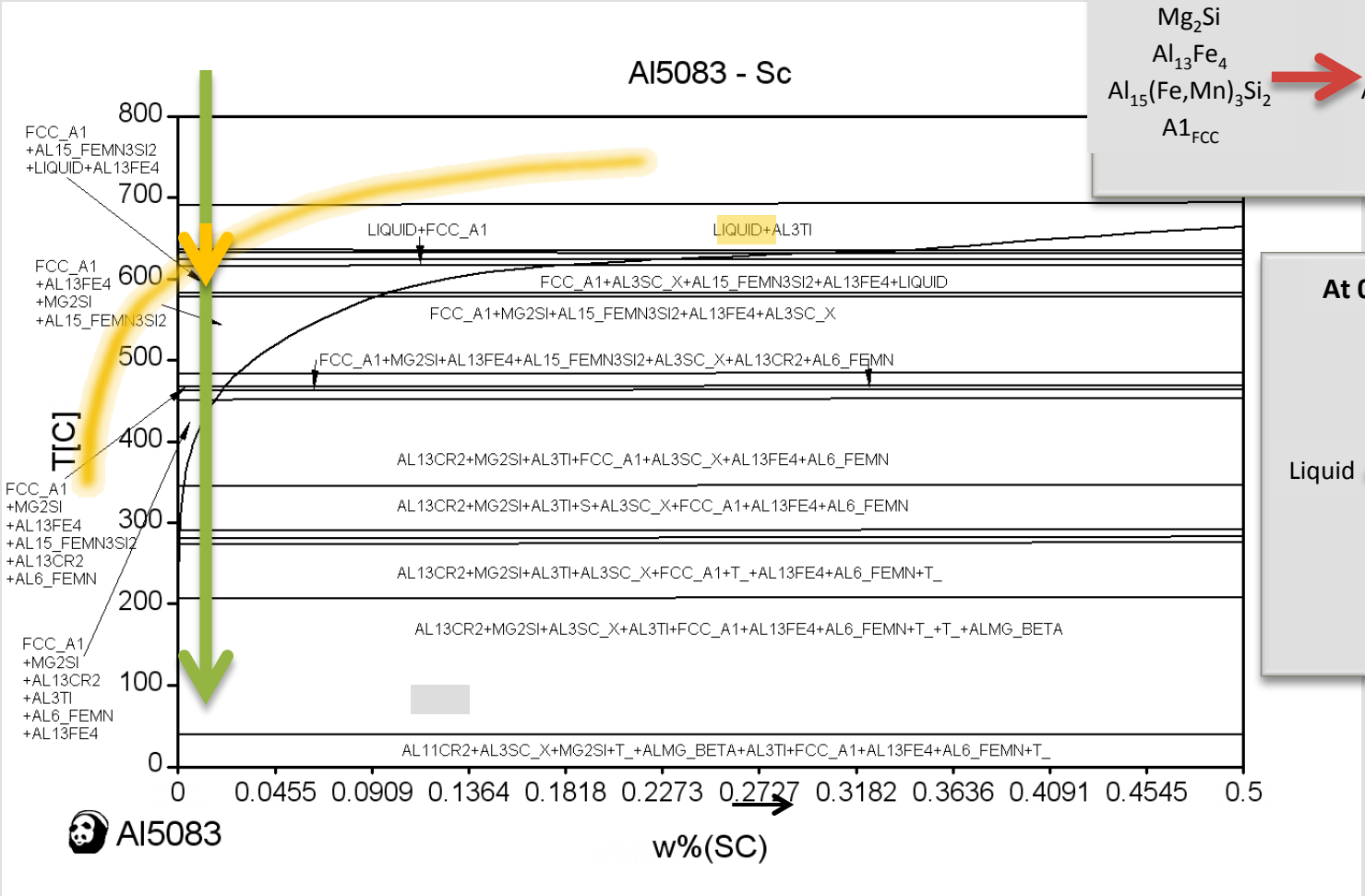
Cu coating sprayed on an Al substrate

Tobias, S., & et.al. (2009). From Particle Acceleration to Impact and Bonding in Cold Spraying. *Journal of Thermal Spray Technology*

Research Objectives



Alloying Element: Sc



At 0.05 wt% Sc

Mg_2Si	Mg_2Si
$Al_{13}Fe_4$	$Al_{13}Fe_4$
$Al_{15}(Fe,Mn)_3Si_2$	$Al_{15}(Fe,Mn)_3Si_2$
$A1_{FCC}$	$A1_{FCC}$
	Al_3Sc

At 0.05 wt% Sc

Liquid →

$Al_{11}Cr_2$
Mg_2Si
T_, T_
AlMg-β
Al_3Ti
$A1_{FCC}$
$Al_{13}Fe_4$
Al_6FeMn
Al_3Sc

Al_3Sc forms strong solid solution and does not cause much embrittlement

Precipitation Simulations

- *Currently testing TC-PRISMA with ThermoCalc for precipitation kinetics predictions*
  - ***TC-PRISMA** is a new software package which can treat concurrent nucleation, growth and coarsening under isothermal conditions in multi-component and multi-phase systems by using Langer-Schwartz theory and Kampmann-Wagner numerical approach. Jointly developed by Thermo-Calc Software AB and QuesTek Innovations LLC, the software extends the functionality currently available through Thermo-Calc and DICTRA.*

Benefits and Membership

- ***Intellectual Capital***
  - *Collaborative members guide and select research projects*
  - *Proprietary property developed is available to member companies (royalty free)*
  - *Member-driven research programs on diverse and practical projects*

- ***Human Capital***
  - *Access to faculty, students, industrial interns, and future employees*
  - *Educate young adults for future careers and leadership positions*
  - *Provides human capital and intellect for the 21st Century*
  - *Industrial Internships*

Benefits and Membership

- ***Valuable Source of R & D Data***
  - *Asset to the Metals Industry for more than twenty years*
  - *Research Project Reports – two reports per year*
  - *Participation and discussion through focus groups and steering committees at two annual meetings (June and December)*
  - *Cost Effective – Facilities and human capital are shared by other MPI centers*

Benefits and Membership

- ***Meetings***
  - *Two Annual Meetings – typically, June and December*
  - *Workshops and Seminars on topical themes*
- ***Cost***
  - *Annual Dues: $25,000 per membership year (flexible payment options available)*
- ***How to Join***
  - *Email Prof. Diran Apelian – dapelian@wpi.edu*
  - *See Website: http://www.wpi.edu/academics/Research/MPI/*

Contact Information

Diran Apelian

Director

dapelian@wpi.edu

508-831-5992

508-380-1203 (Mobile)

http://www.wpi.edu/academics/Research/CHTE/

http://wp.wpi.edu/mpinews/

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