Fundamental study of the relationship of austenite-ferrite transformation details to austenite retention in carbon steels

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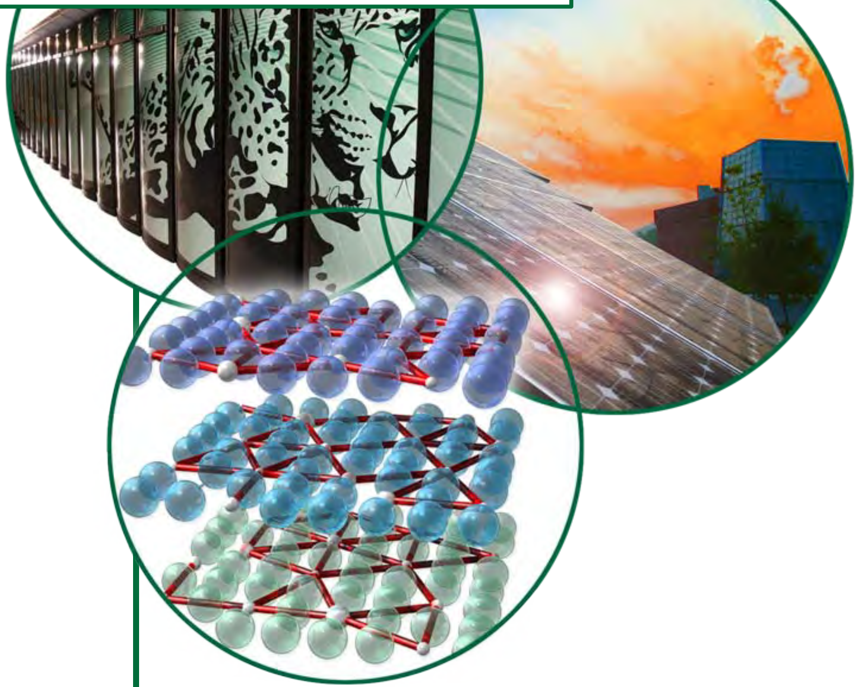

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Overview

Timeline

- Start – November, 2008
- End – June, 2012
- 65% complete as of May 2011

Barriers

- Continuous proposal writing for APS beam time
- Experimentation & data analysis not "canned"
  - Being perfected in parallel with experiments

Budget

- Total funding spent – $300k
- Funding in FY2010
  - $152k
- Funding in FY2011
  - $125k

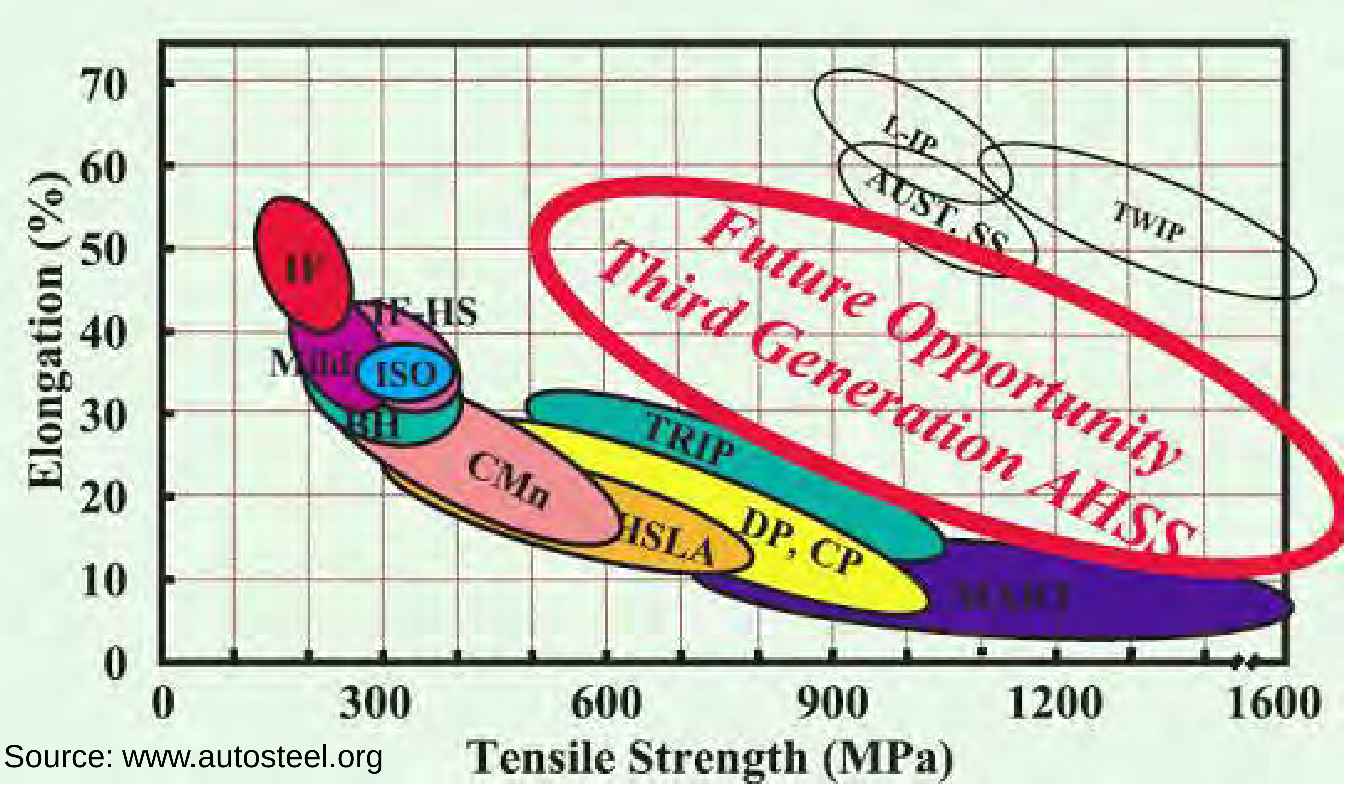
Partners

- None at present time

Relevance: Project Objectives:

- The objective is real-time characterization of austenite-ferrite transformation behavior
  - During T/t conditions representative of processing AHSS
  - Determine conditions that promote retained austenite
    - This will contribute to building the scientific foundation needed for development of Gen III AHSS
- Deliverables:
  - Quantitative description of austenite-ferrite transformation behavior during simulated finishing operations
    - including the effects of carbon, manganese, and silicon
  - Quantitative description of alloying element partitioning between austenite and ferrite
  - Assessment of how retained austenite can be maximized within constraints of normal sheet processing infrastructure

Relevance: Develop high strength-high ductility steel at current pricing



Controlling costs will require:

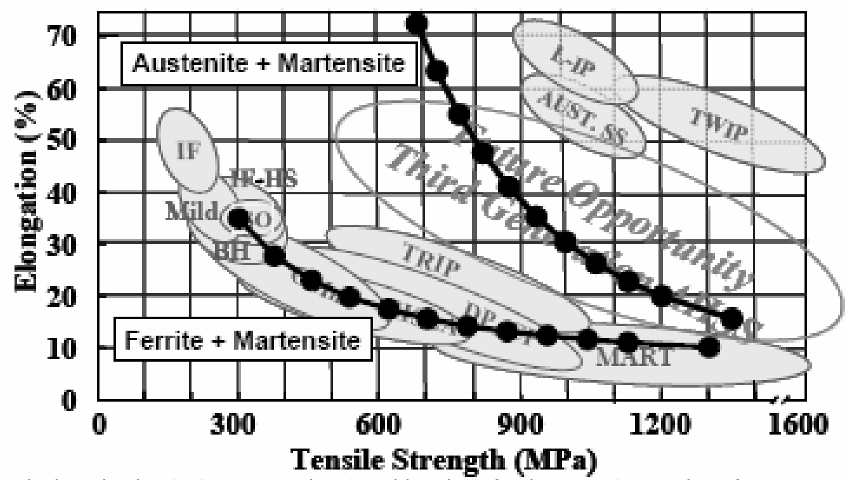
- Gen III AHSS be no more than modestly alloyed compared to Gen I steels
- Capability of being produced within existing steel-mill infrastructures
- Forming and welding characteristics consistent with existing steels

Relevance: Possible path to Gen III includes:

1. Alloying, but with content near those of Gen I steels
   - Only modest additional alloying tolerated
2. Modified/novel processing & heat treatments
   - Must produce desired bcc + fcc microstructures

Predictions suggest high strength + high ductility may be possible with microstructures of:

- Austenite + martensite, bainite, ferrite
- Ferrite + larger amounts of metastable austenite
  - Larger TRIP effect



David K. Matlock and John G. Speer, "Design Considerations for the Next Generation of Advanced High Strength Sheet Steels," The 3rd International Conference on Advanced Structural Steels Gyeongju, Korea, 2006

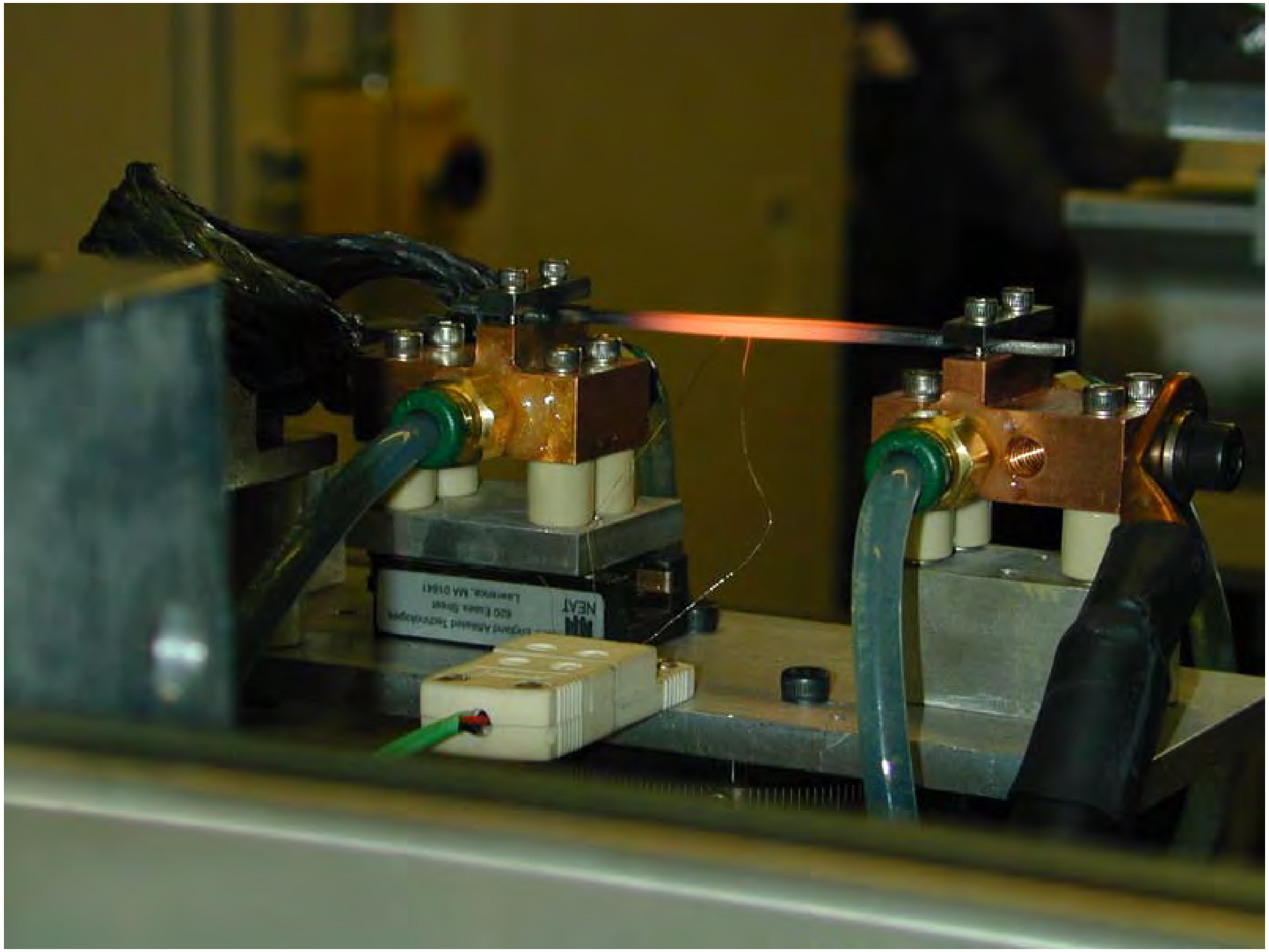
Relevance: Milestones

1. Experimental and data analysis procedures will be reexamined to determine possible sources of errors, and an approach for minimizing the effects of surface reactions will be established. October 2010
2. Experimental alloys will be formulated and analyzed for the possibility of increasing retained austenite over commercial steel grades which generally contain around 10%. October 2011

Approach:

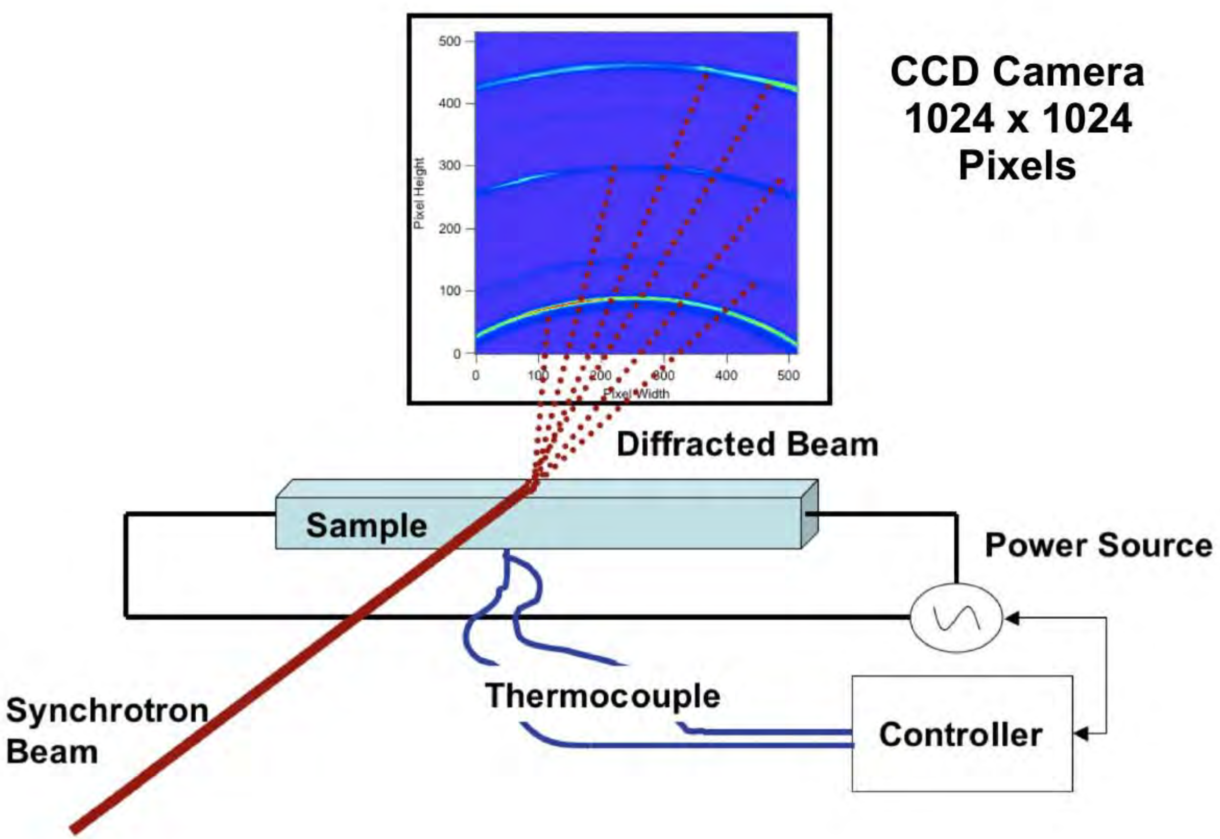
- High-speed diffraction experiments was conducted at the Advanced Photon Source
  - The austenite-ferrite phase transformation behavior was characterized *in-situ* under the rapid heating/cooling conditions

Approach: Specimens are heated by resistance in vacuum



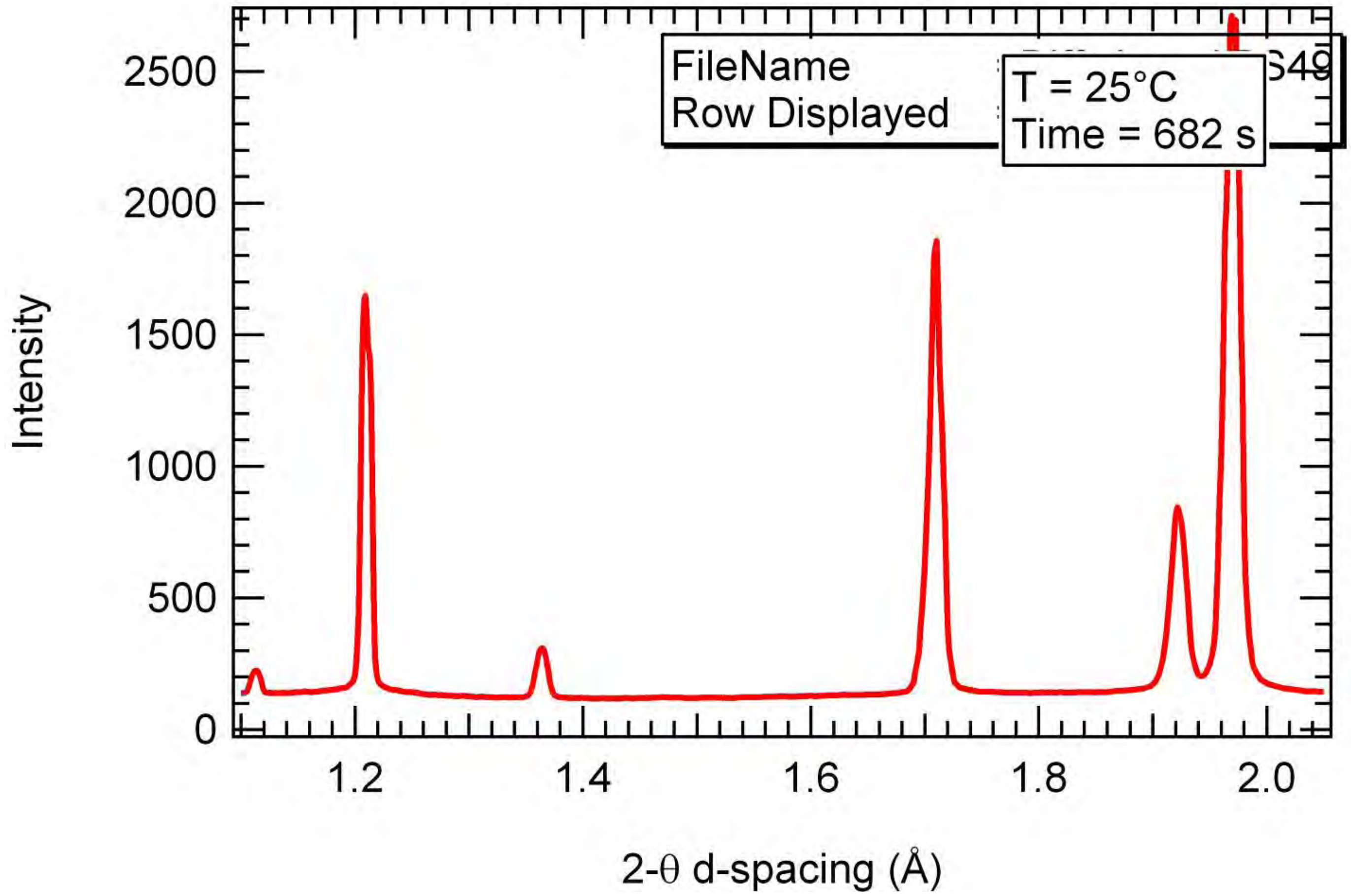
- Thermocouple feedback is used for temperature control
- Specimen grip is spring-loaded to maintain positioning

Approach: APS synchrotron permits diffraction patterns at ~ 1 s intervals



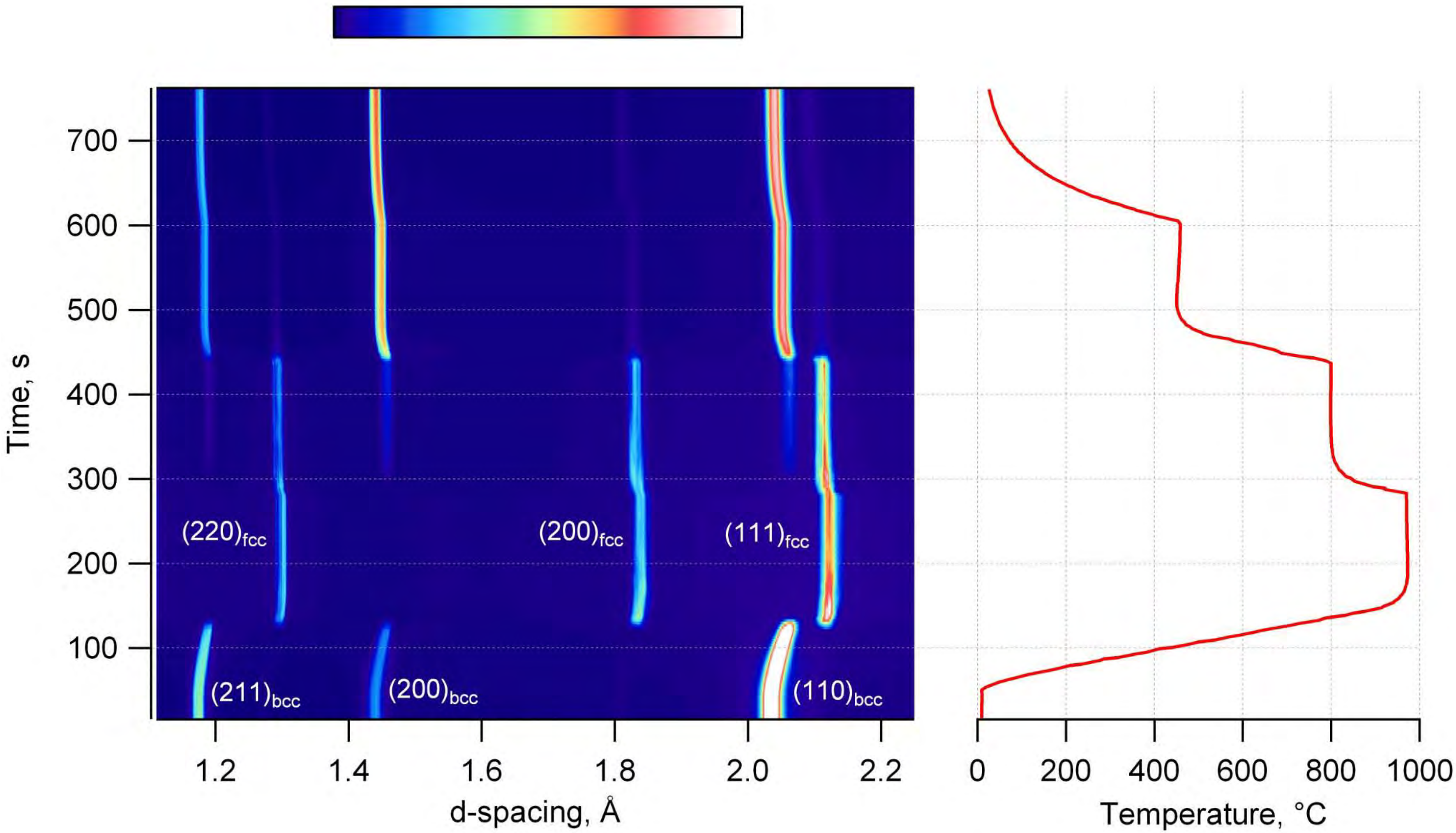
- Calibrated Debye arcs are converted into plots of Intensity-vs-(d-spacing)

Approach: Direct comparison method is used to determine phase fractions



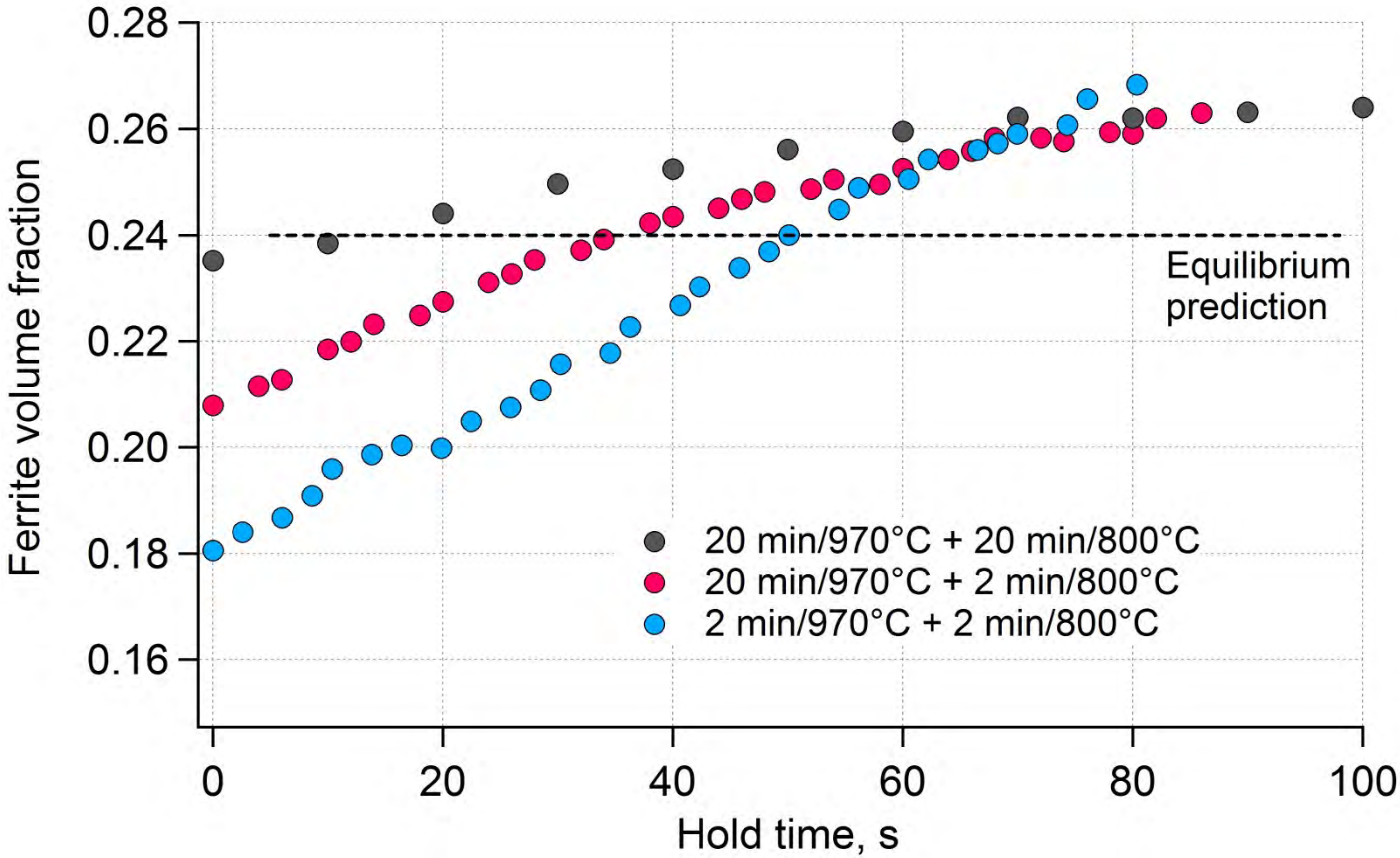
- Peak areas are corrected for polarization, temperature
- Integrated intensities are corrected for texture

FY2010 Accomplishments: Example of overall transformation behavior



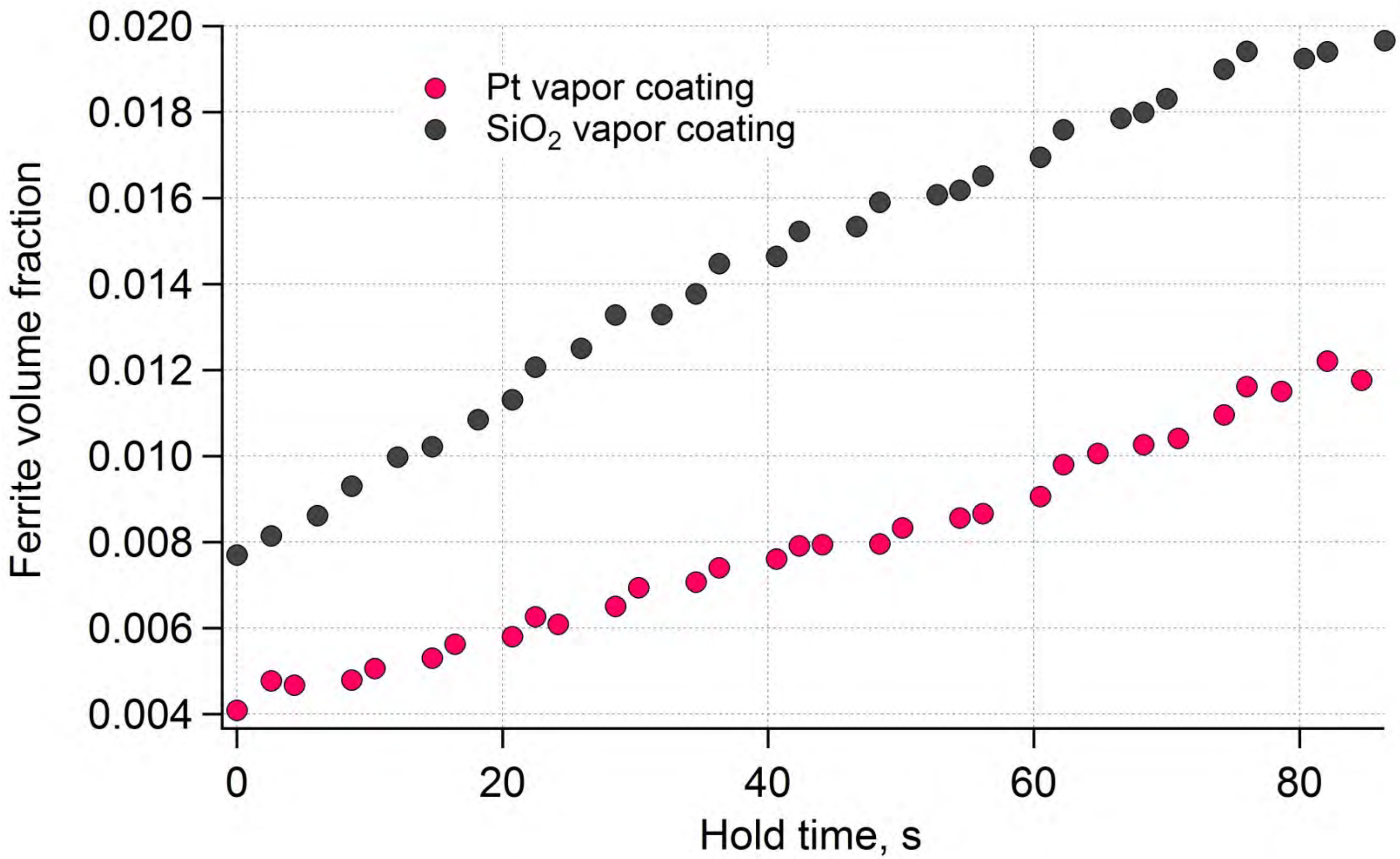
- Time-temperature approximates normal steel processing during cooling

FY2010 Accomplishments: Effects of process conditions on transformation during intercritical hold



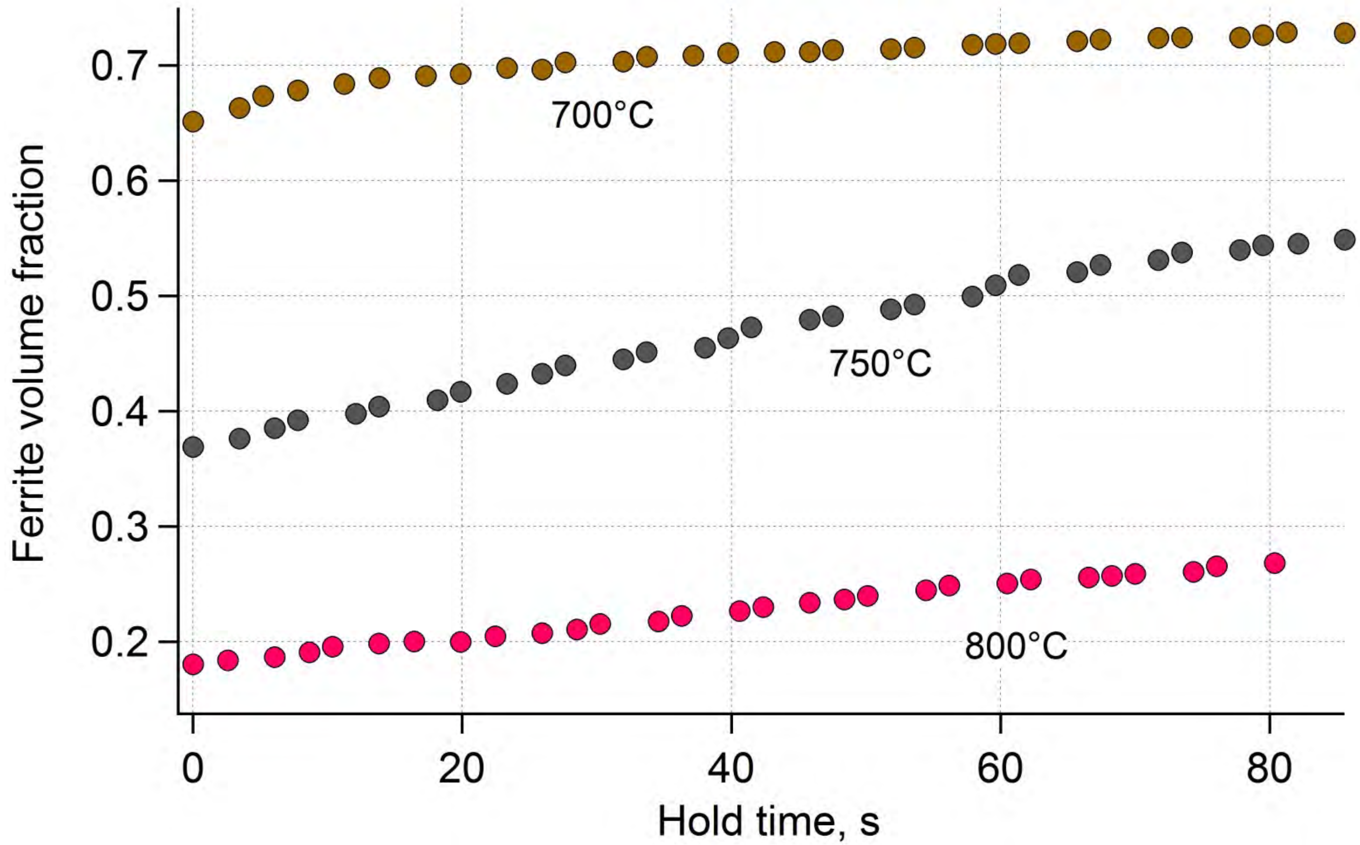
- Ferrite should but did not stabilize at a fixed amount near equilibrium value

FY2010 Accomplishments: Effects of coatings on characterization



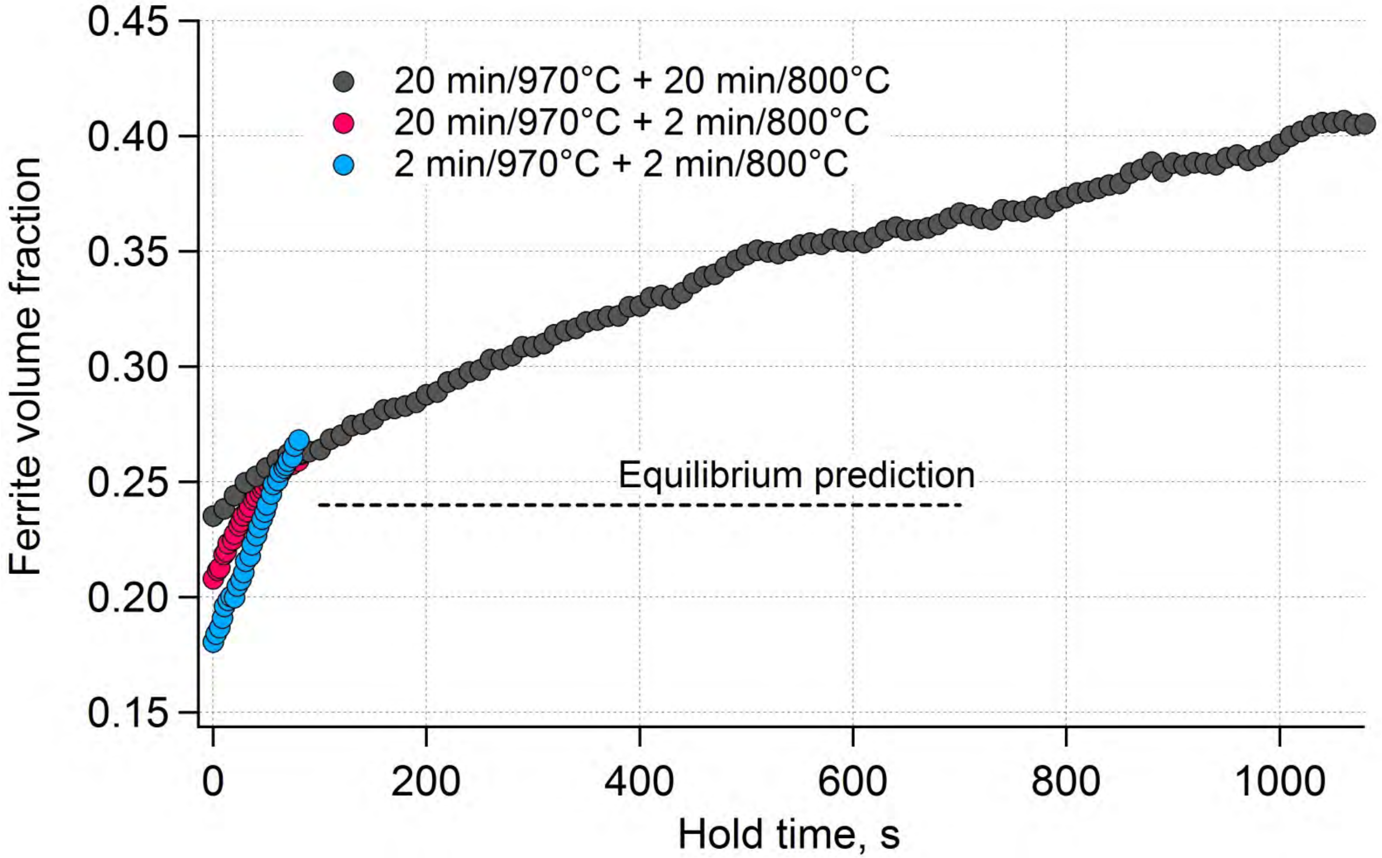
- Coatings caused unacceptable preferential attenuation of ferrite
- Coatings did not prevent increase with time of ferrite amount

FY2010 Accomplishments: Effect of temperature on transformation during intercritical hold



- Drift of ferrite/austenite fractions was found over a range of intercritical temperatures

FY2010 Accomplishments: Effect of time on transformation during intercritical hold



- A possible explanation of increasing ferrite at diffracting surface is carbon loss

Collaborations/Coordination

- Activities were summarized at AS/P-organized workshops for projects funded through NSF to develop 3rd generation steels
- Experimental techniques need improved before productive collaborations could be established

Proposed Future Work

- Conventional diffraction facilities at the APS/synchrotron do not appear suitable for characterizing ferrite-austenite transformation behavior
  – Other facilities such as for transmission diffraction may be more appropriate
  – Use of neutron diffraction is also being considered
- Both processing and alloying approaches will be evaluated during remainder of project

Summary

- Data collection at APS/synchrotron is fast enough to characterize transformations during carbon steel processing
  - Critical transformation temperatures can be determined
  - Measurements of lattice parameters are possible
- To date, ferrite-austenite phase fractions cannot be accurately determined by conventional diffraction
  - Experimentation and data analysis needs further developments to accurately represent transformation behavior

