

2009 DOE Hydrogen Program Review

Electron-Charged Hydrogen Storage Materials

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Project ID #
ST051

Overview

Timeline

- Project start: July 1, 2005
- Project end: Sept 30, 2010
- Percent complete: 75%

Budget

- Total project funding
 - DOE share: \$1,562K
 - Contractor share: \$390K
- Funding received in FY09: \$303,010
- Funding for FY10: \$0

Barriers

- Cost: use inexpensive graphite
- Weight and volume: use high density graphite, maximizing capacity
- Efficiency: add electron charge to increase storage rate
- Durability: use electron charge to control cycles
- Refueling Time: use electron charge to increase fueling rate
- Codes and Standards
- System Life-Cycle Assessments

Objectives

Overall	Development of a hydrogen storage material and device for hydrogen quick charge and discharge, high wt% and vol% storage capacities, good durability over many cycles, and safe handling and transport.
2008	<ul style="list-style-type: none">• Combine internal electron-charge (doping) and external charge to increase hydrogen storage capacities• Investigate performance optimization and prototype container systems
2009	<ul style="list-style-type: none">• Reselect the best hydrogen storage materials for charge modifications• Carbon-based materials, such as AX-21 and other high surface carbon using polymer as precursor; metal-modified carbon; and borane-ammonia

Milestone or Go/No-Go Decision

Month/Year	Milestone or Go/No-Go Decision
July 30, 2009	Task 4. Characterize the electron device and the material properties of the carbon based material with CCA/CTA (pore size, density, surface area, etc) Task 5. Prepare samples for independent evaluation. Install framework structure to improve charge distribution Task 6. Scale-up to an 11 liter tank for fueling demonstration to show 50% hydrogen storage increase.
June 30, 2010	Go/No-Go

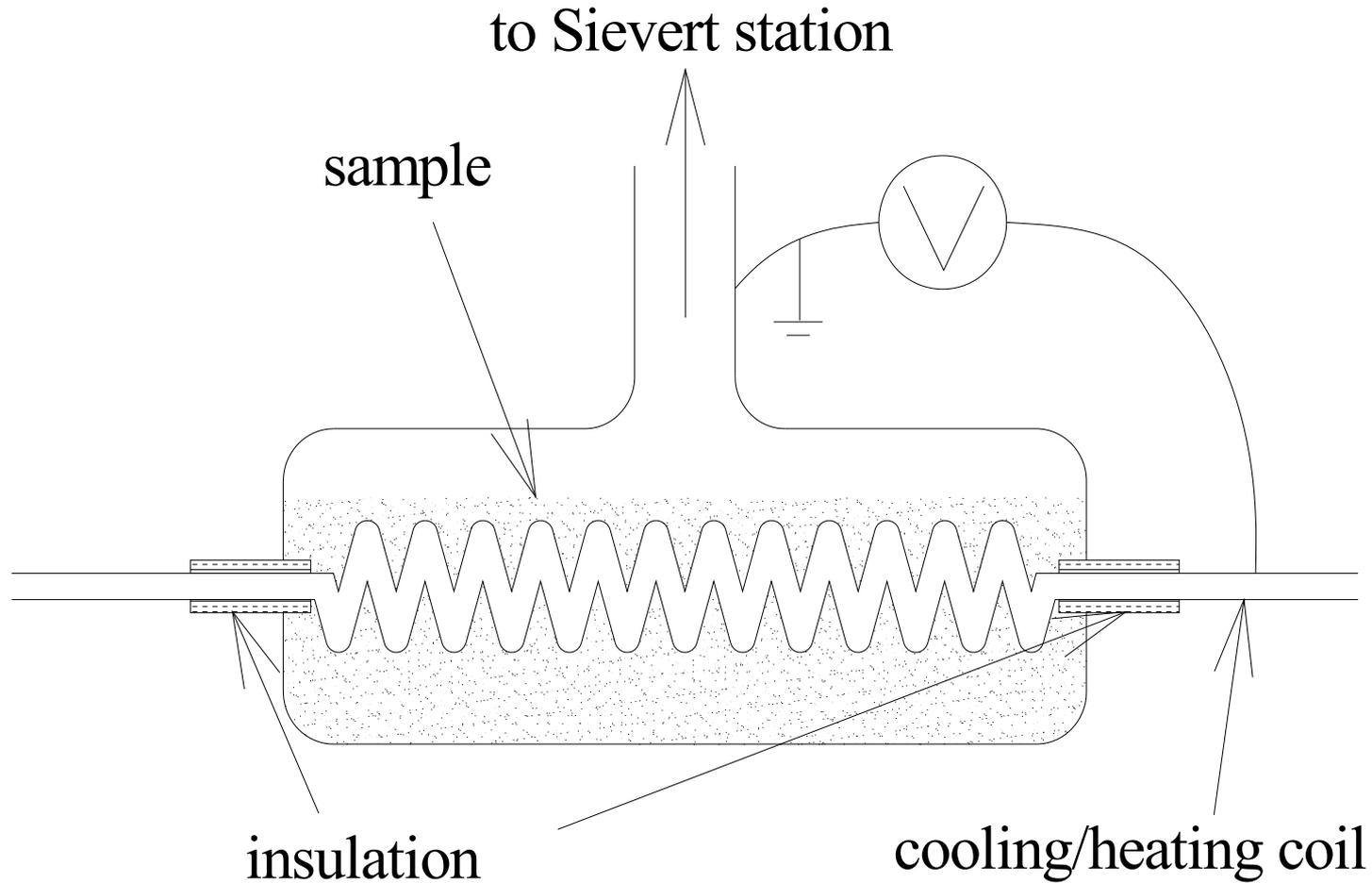
Approach

- Hydrogen storage is based on hydrogen adsorption, which is involved in electron shift (physi-sorption) and electron transfer (chemi-sorption).
- Use external electron charge to increase hydrogen adsorption and alter hydrogen desorption kinetics.
- Use internal electron-rich or -poor material to change carbon-based material surface electron density, which affects hydrogen storage.

Plan and Approach

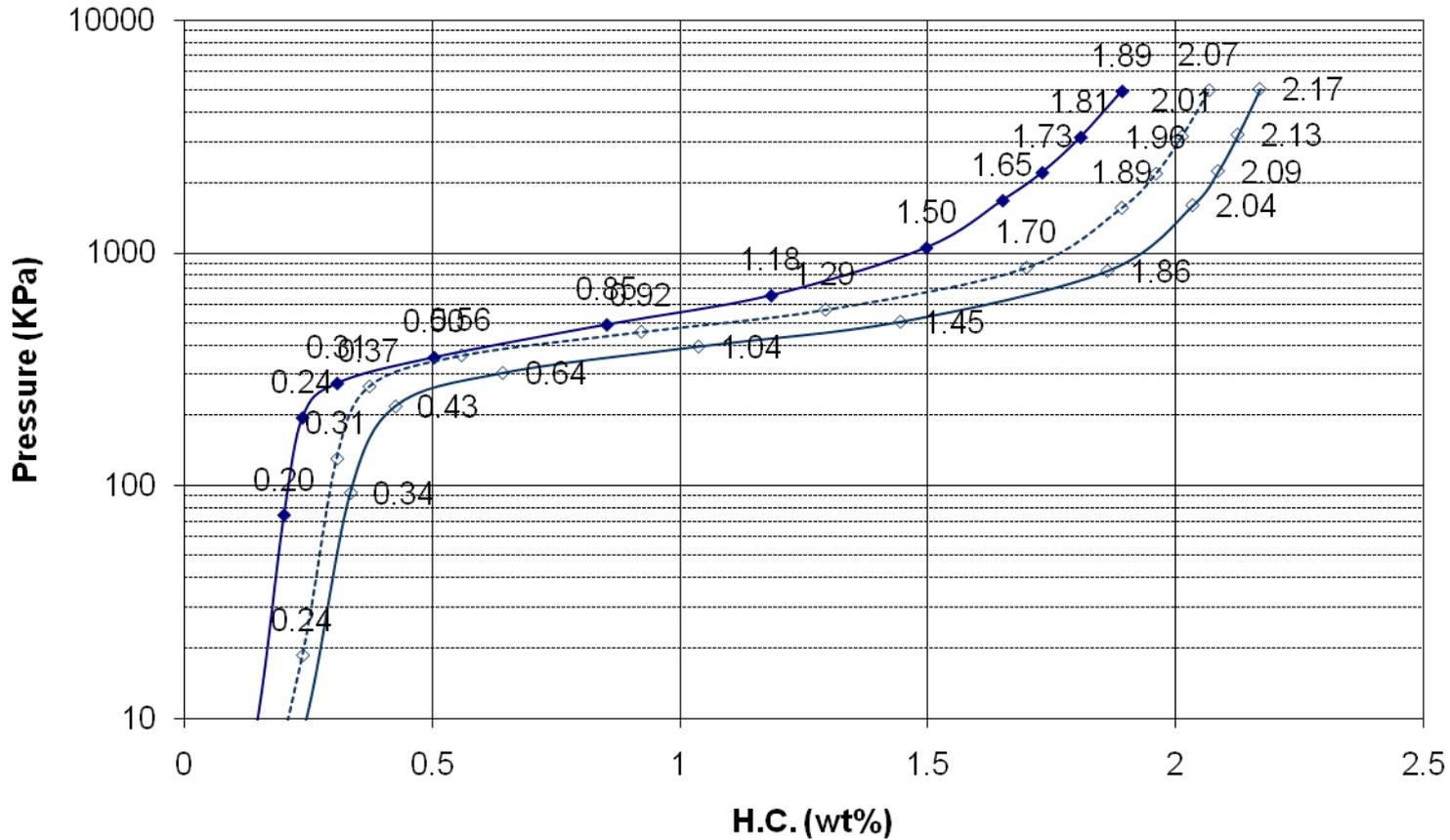
- Select and synthesize carbon-based materials
- Test and evaluate cycles for hydrogen storage
- Test external electron charge effect on hydrogen storage
- Dynamic TGA and Sievert Tests

Approach



Technical Accomplishment and Progress

PCI curve for metal hydride with different current without cooling/heating



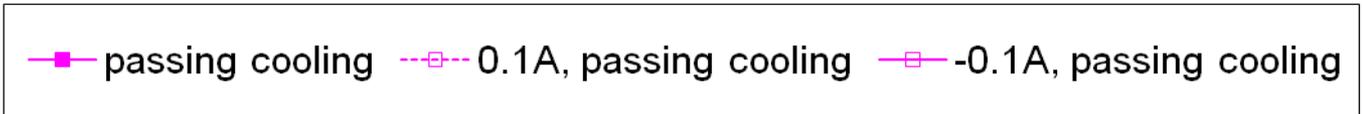
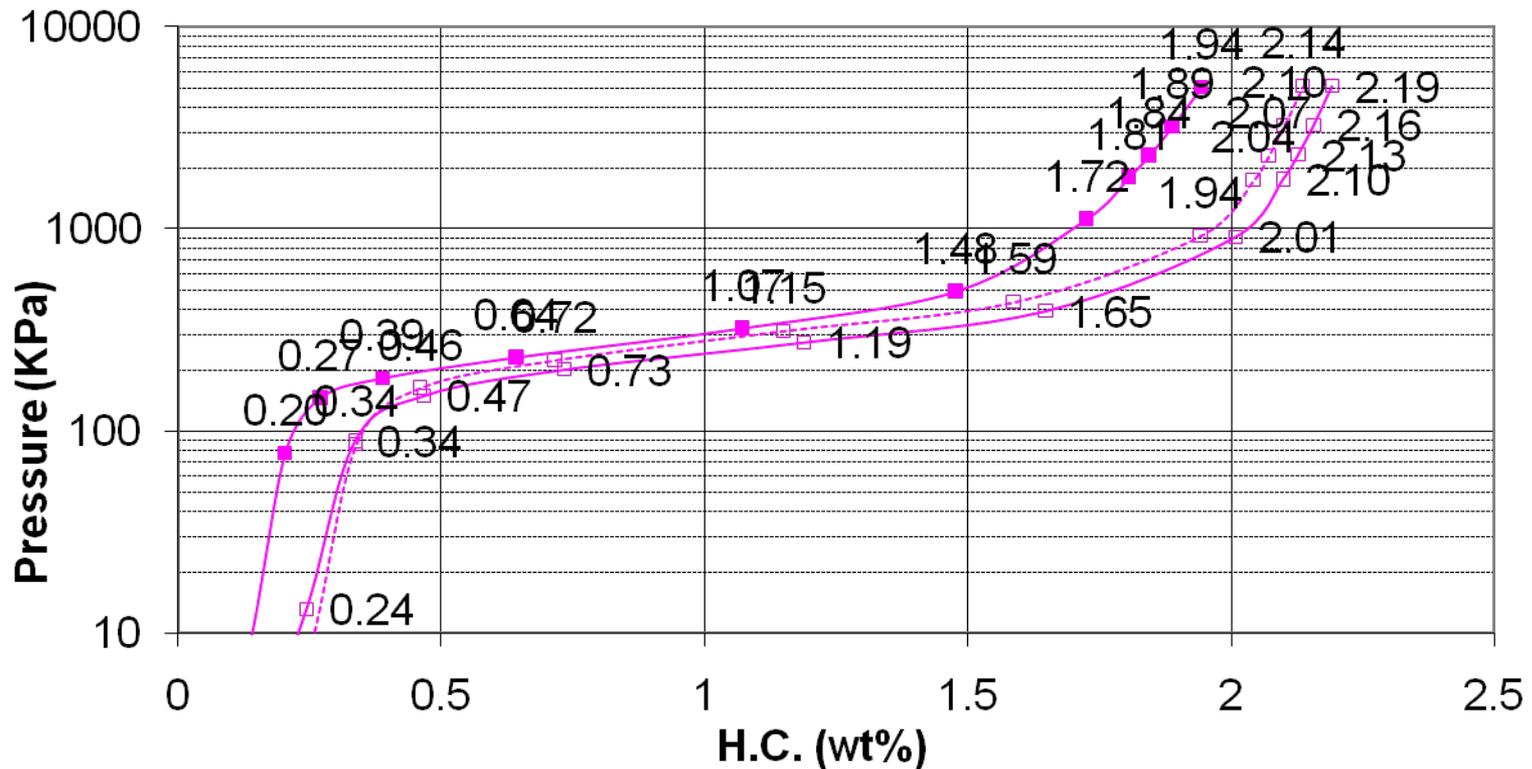
—●— no cooling/heating

- - -◇- - - 0.1A, no cooling/heating

—◇— -0.1A, no cooling/heating

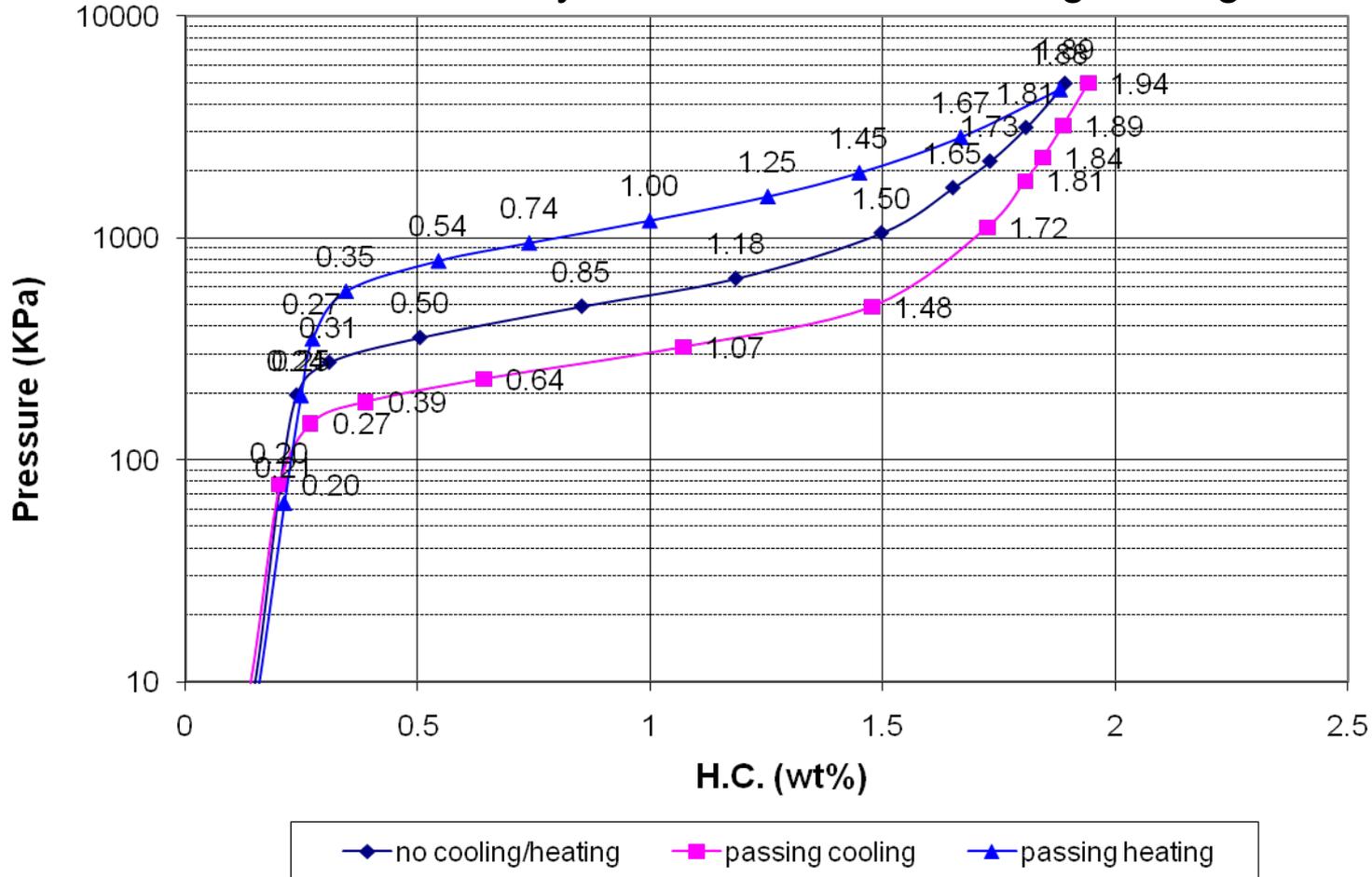
Technical Accomplishment and Progress

PCI curve for metal hydride with different current with cooling



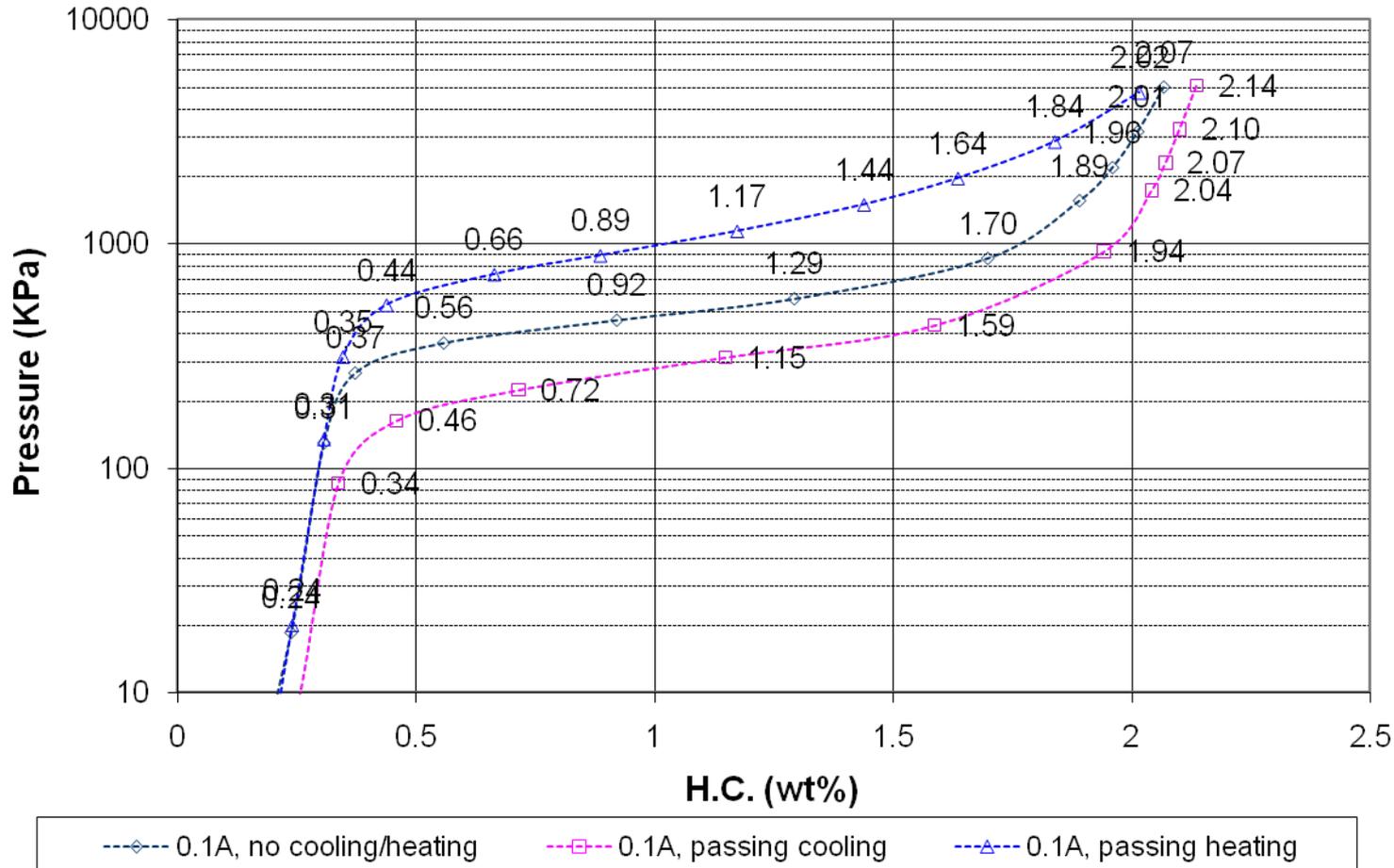
Technical Accomplishment and Progress

PCI curve for metal hydride with/without heating/cooling without current



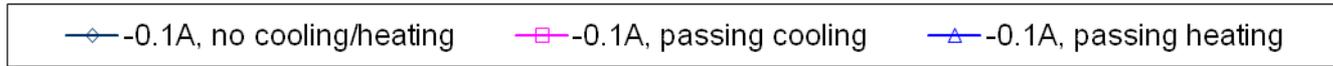
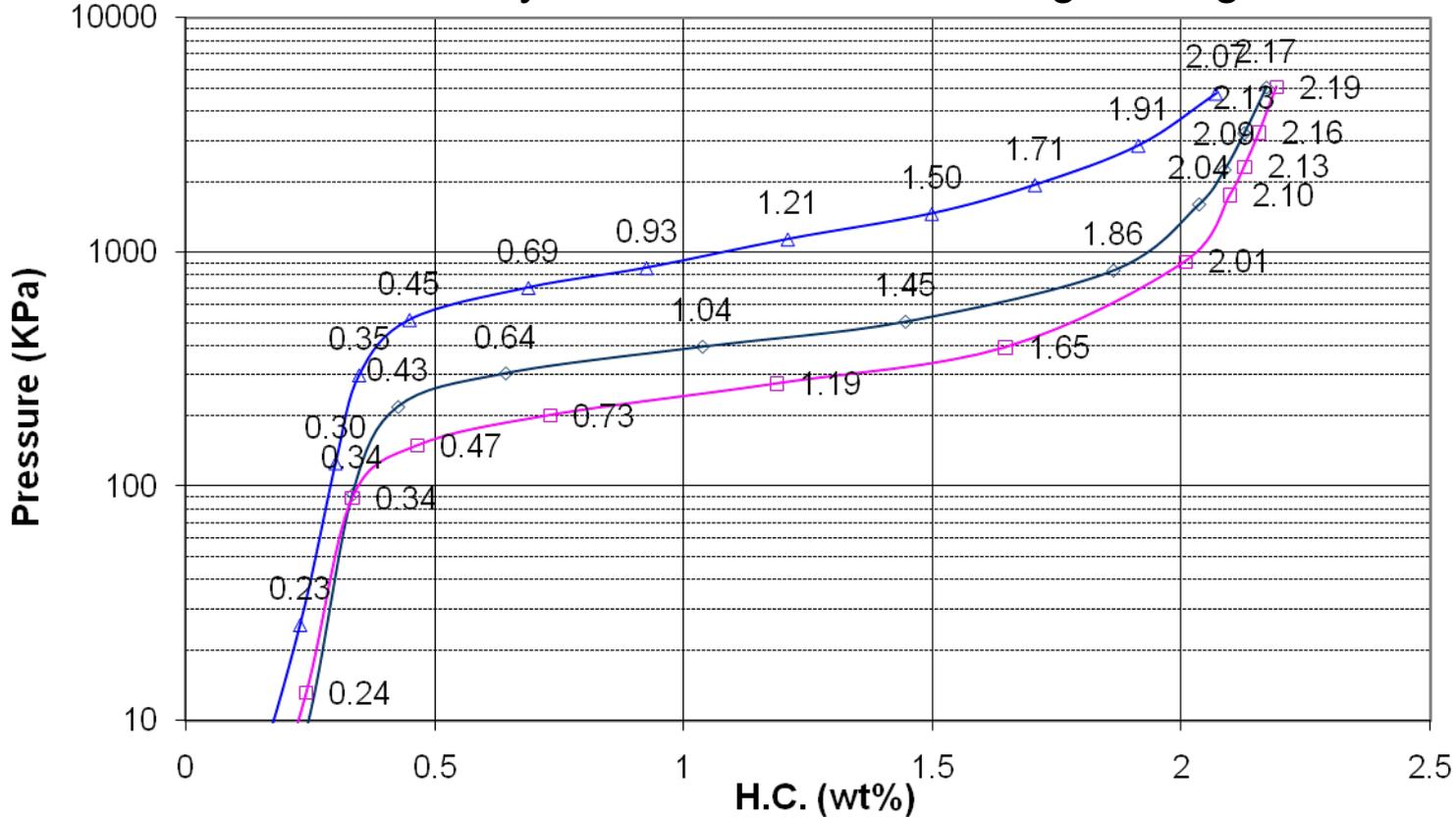
Technical Accomplishment and Progress

PCI curve for metal hydride with/without heating/cooling with 0.1A current



Technical Accomplishment and Progress

PCI curve for metal hydride with/without heating/cooling with -0.1A current



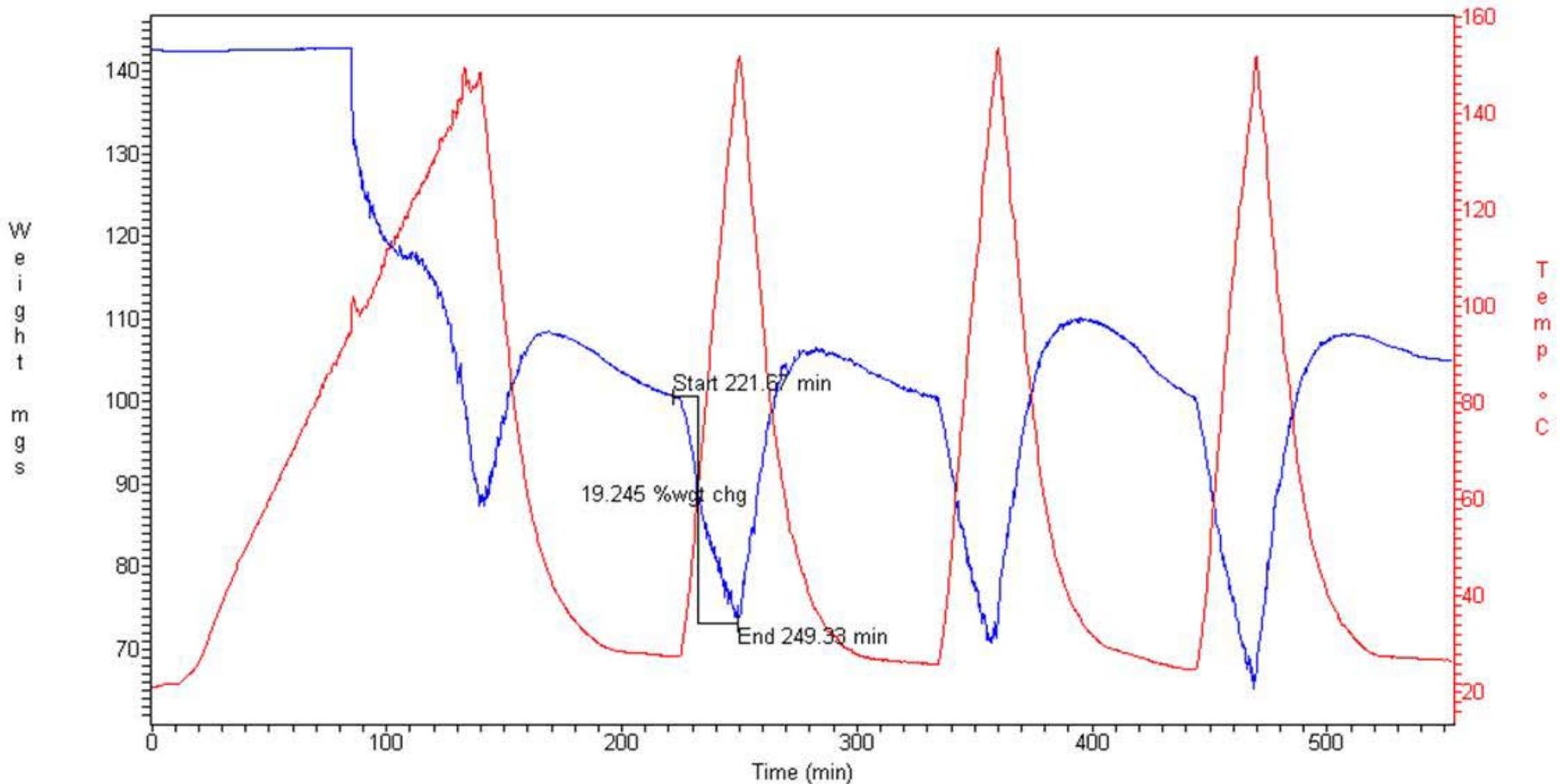
Technical Accomplishment and Progress

borane-ammonia based samples for hydrogen storage in both TGA

Sample content	Weight loss after 150° C (%)
BH ₃ NH ₃ :Ni (1:1)	13.828
BH ₃ NH ₃ :SAPO (1:1)	15.292
BH ₃ NH ₃ :BiPbSnCd (1:1)	10.26
BH ₃ NH ₃ :BZSM5 (1:1)	10.663
BH ₃ NH ₃ :BZSM5 with Rh (1:1)	9.742
BH ₃ NH ₃ :KA (1:1)	13.555
BH ₃ NH ₃ :BiSn (1:1)	9.008
BH ₃ NH ₃ :LaNi ₅ (1:1)	8.583
BH ₃ NH ₃ :FeTiO ₃ :SAPO (2:1:1)	10.92
BH ₃ NH ₃ :Fe _x N:SAPO (2:1:1) _{x=2~4}	12.362
BH ₃ NH ₃ :SiC:Rh (15:11:4)	8.662
BH ₃ NH ₃ :hydroquinone:Rh (15:10:5)	7.773
BH ₃ NH ₃ :Polyaniline emeraldine (1:1)	10.556
BH ₃ NH ₃ :BZSM5:Ag/C (15:10:5)	11.273
BH ₃ NH ₃ :TiC:BZSM5 (2:1:1)	8.826
BH ₃ NH ₃ :Pyrene:PdCl(PPh ₃) ₂ (15:15:2)	8.266
BH ₃ NH ₃ :CoPYY/C:RhCl(PPh ₃) ₃ (15:15:2)	12.546
BH ₃ NH ₃ :CoPYY/C:V:RhCl(PPh ₃) ₃ (15:8:7:2)	12.059

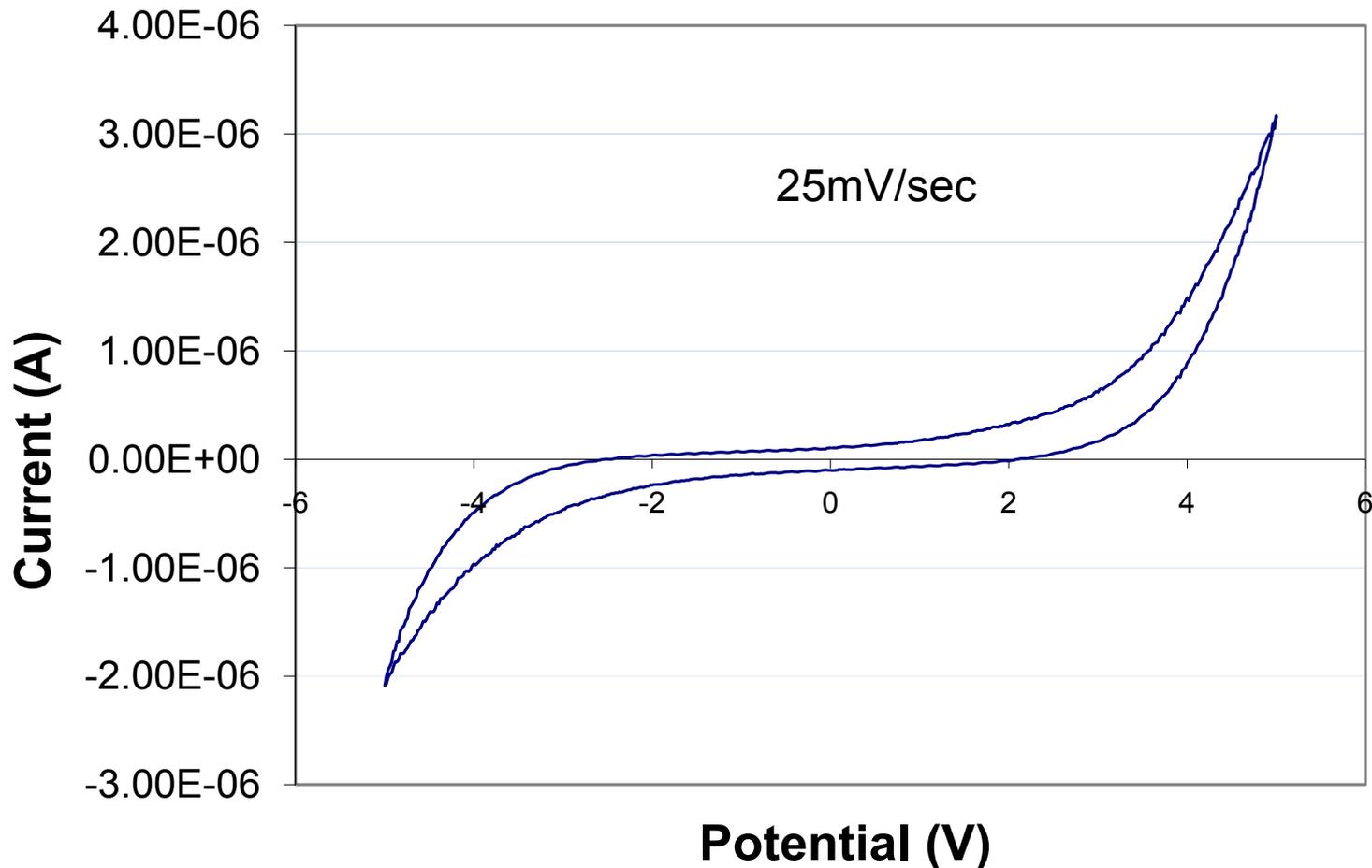
Technical Accomplishment and Progress

One H₂ storage sample subject to heat cycle, results needs to be reproduced



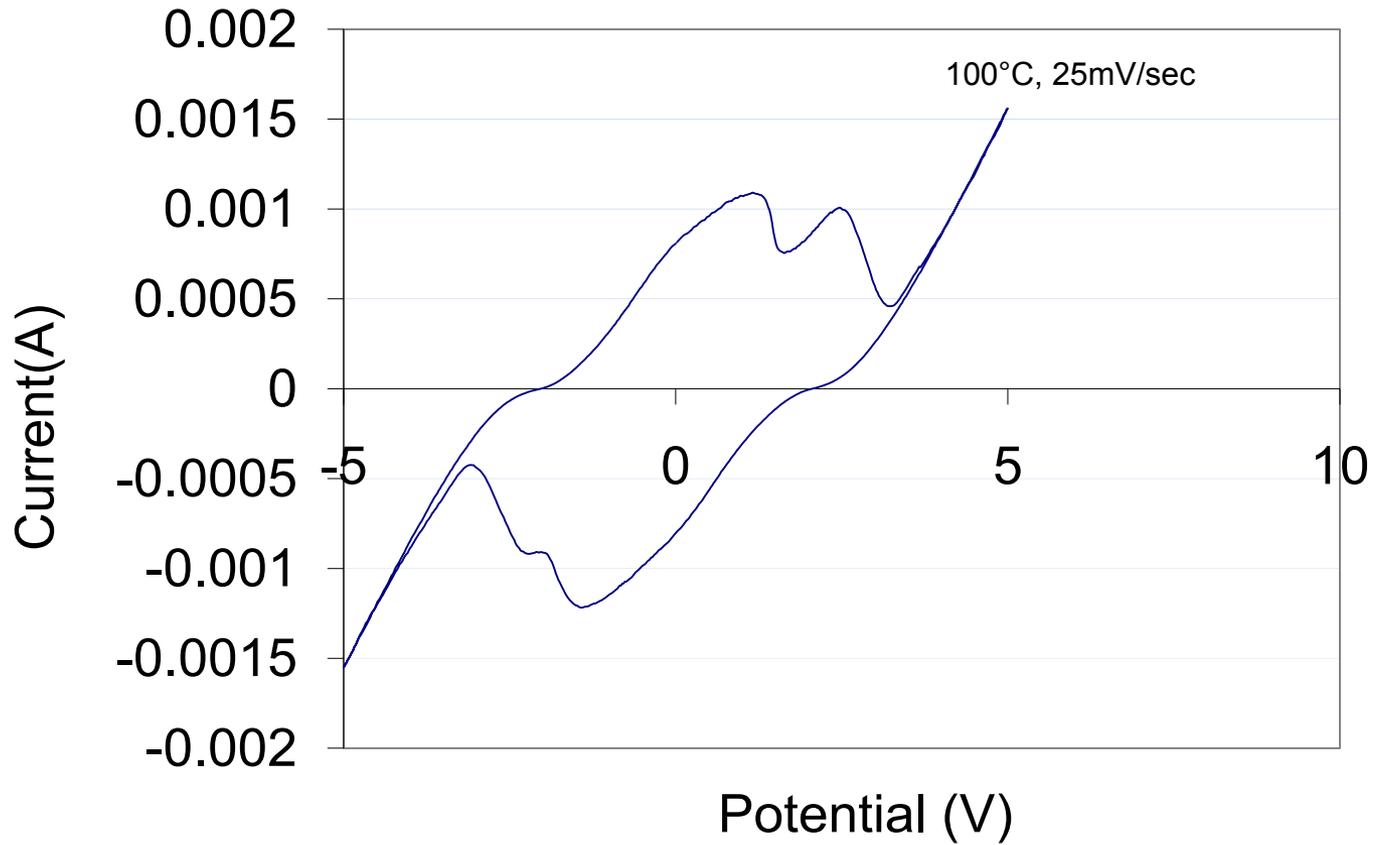
Technical Accomplishment and Progress

Regeneration of BN in diglyme at room temperature



Technical Accomplishment and Progress

Regeneration of BN in Diglyme at 100°C



Technical Accomplishment and Progress

Hydrogen Storage Material Screening without Electrical Charge Summary of SUNY samples at 6300kPa

Sample name	0°C (wt%)	77k (wt%)
APKI-S6	0.58	6.38
APK25-N2	0.463	5.94
Ma015580-2	0	3.45
PZTAPK	0.39	5.47

Proposed Future Work

- Continue boron nitride (hydrogen storage more than 6 wt%) research and external charge bias to increase the hydrogen storage rate. Characterize the external charge effect on material physical and chemical properties (pore size, density, surface area, etc).
- Scale-up to an 11 liter tank for fueling demonstration to show 50% hydrogen storage increase.

Conclusions

- External electron charge does affect the hydrogen storage, however different substrates shows different effects
- Negative charge helps boron nitride dehydrogenation kinetics (4 times faster at 900psi) and increases the reversible hydrogenation
- External charge effect on pure carbon material is limited.

Cooperation

- State University of New York at Syracuse: Prof. Cabasso group
- Japanese CCA Manufacturer
- ATMI
- University of Houston

Acknowledgements

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- ATMI