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NEXT GENERATION ANODES FOR LITHIUM-ION BATTERIES: THERMODYNAMIC UNDERSTANDING AND ABUSE PERFORMANCE

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2016 U.S. DOE HYDROGEN and FUEL CELLS PROGRAM and
VEHICLE TECHNOLOGIES OFFICE ANNUAL MERIT REVIEW
AND PEER EVALUATION MEETING

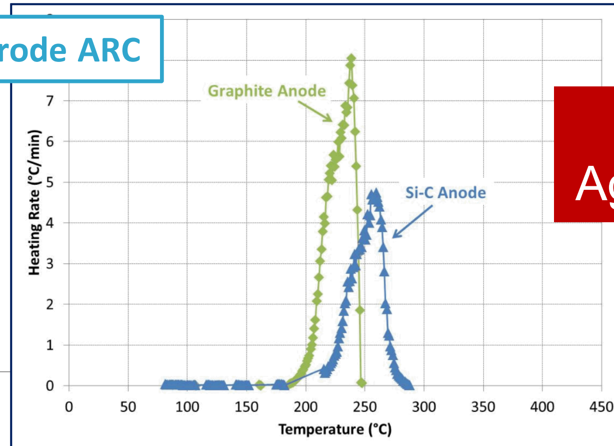
ABUSE RESPONSE OF SILICON ANODES

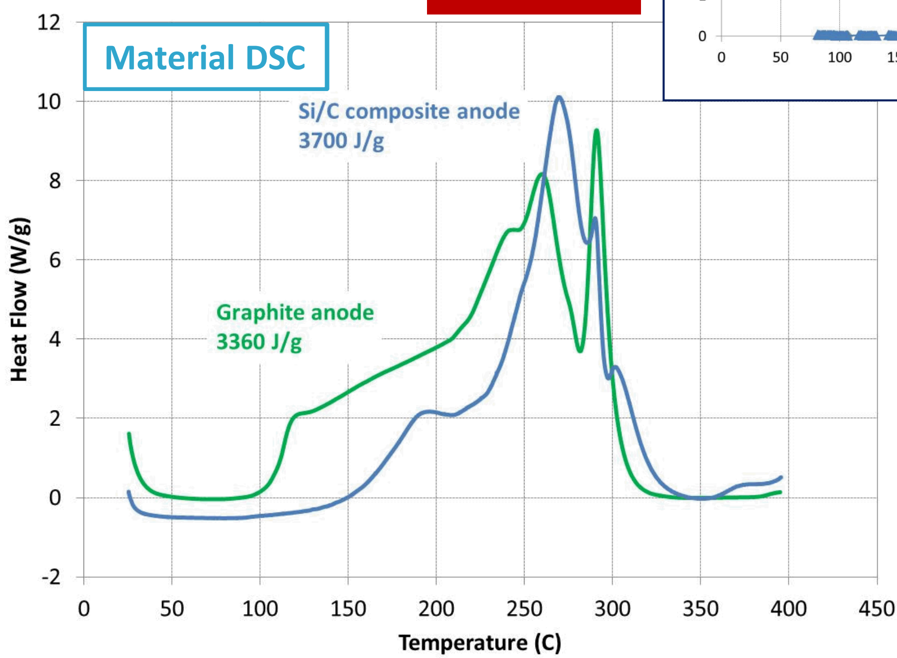
XG Sciences Material – Previous Evaluations

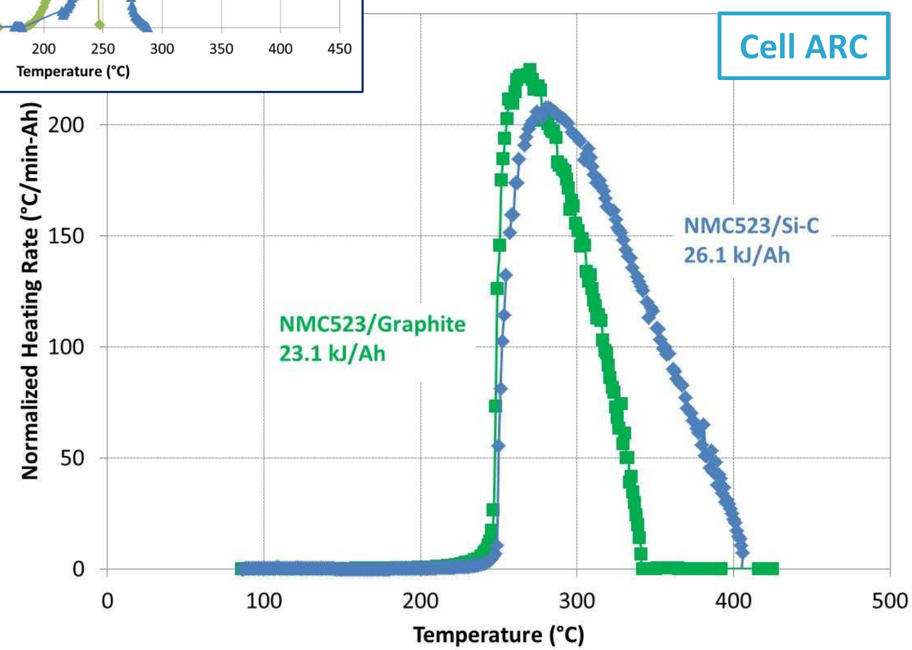
ES036
2014 AMR

XG Si/C
~5% Si

ARC and DSC
Agree on Si/C differences







Thermal runaway enthalpy of NMC/Si-C cells is ~10% greater than NMC/Graphite cells

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NREL National Renewable Energy Laboratory
Berkeley Lab
Argonne National Laboratory

ABUSE RESPONSE OF SILICON ANODES

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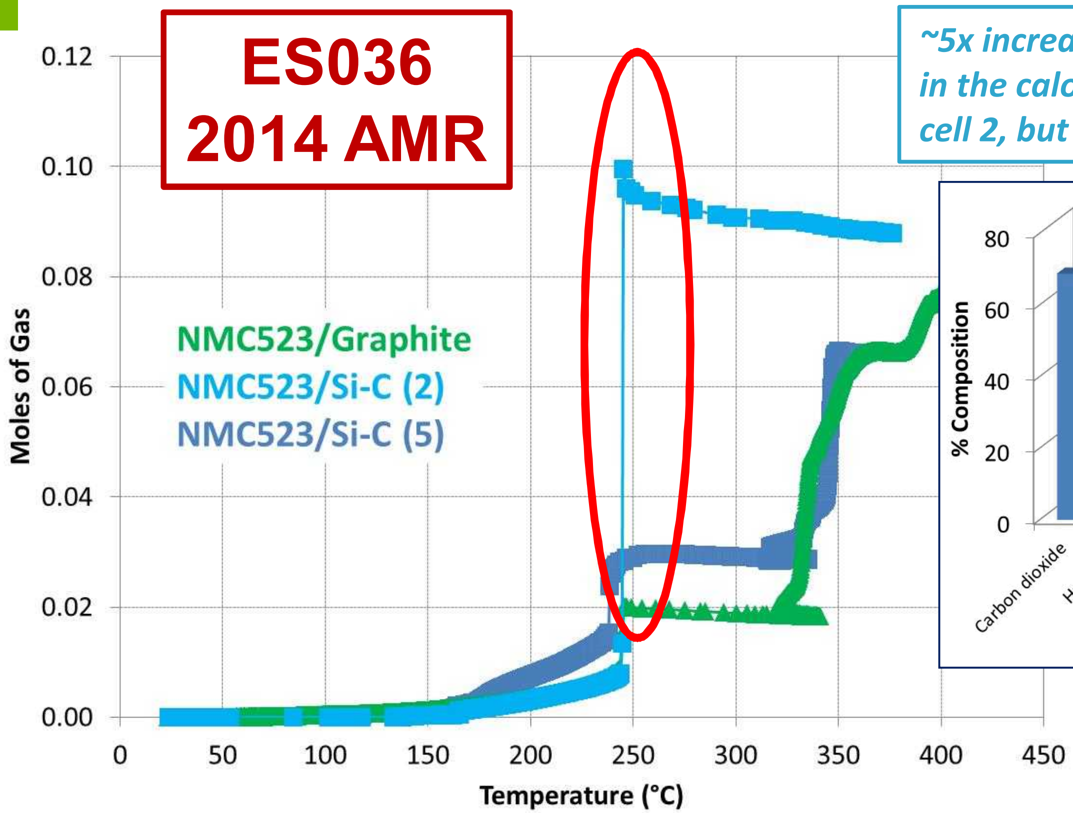
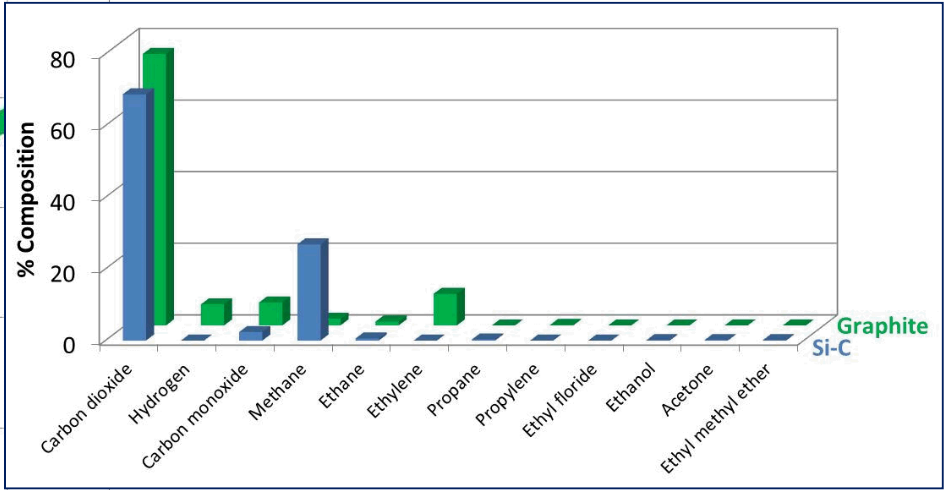


~5x increase in the amount of gas generated in the calorimeter during thermal runaway of cell 2, but comparable gas generation for cell 5



Difference in gas generation attributed to the differences in surface reactivity and surface products generated at the anode/electrolyte interface

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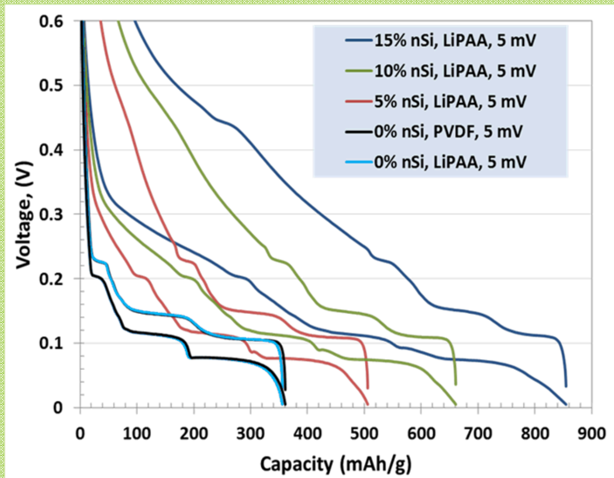
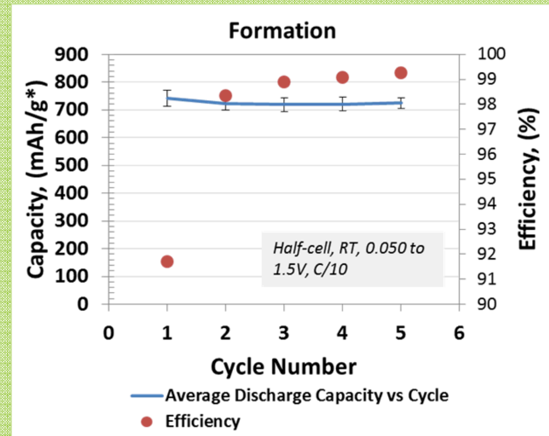
NANOAMOR MATERIAL EVALUATION

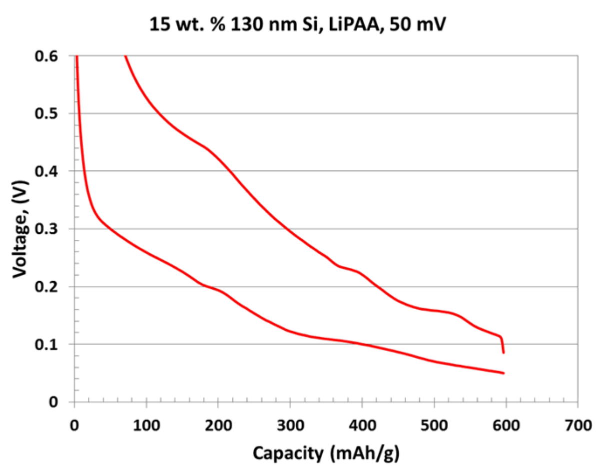
Electrode comparison and baseline

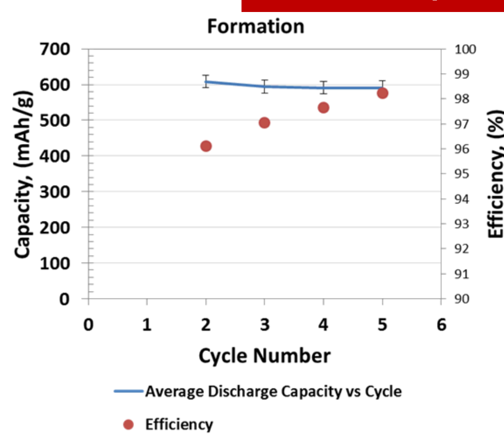




- Data from ANL using 50-70 nm NanoAmor silicon with 10 % FEC in electrolyte
- Charge / discharge profiles to 5mV
- Observed specific capacity upon discharge to 50 mV

Comparison with baseline CAMP cells comparable performance for SNL





- Electrodes prepared at SNL using 130 nm NanoAmor silicon, all other aspects prepared in accordance with ANL processes, **no FEC**
- Only 15 wt. % nSi tested thus far
  - Areal Loading ~ 4.75 mg/cm^2 active material (Gr + Si)
  - Areal capacity ~ 1.6 mAh/cm^2
- Lower specific capacity and CE

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NANOAMOR MATERIAL EVALUATION

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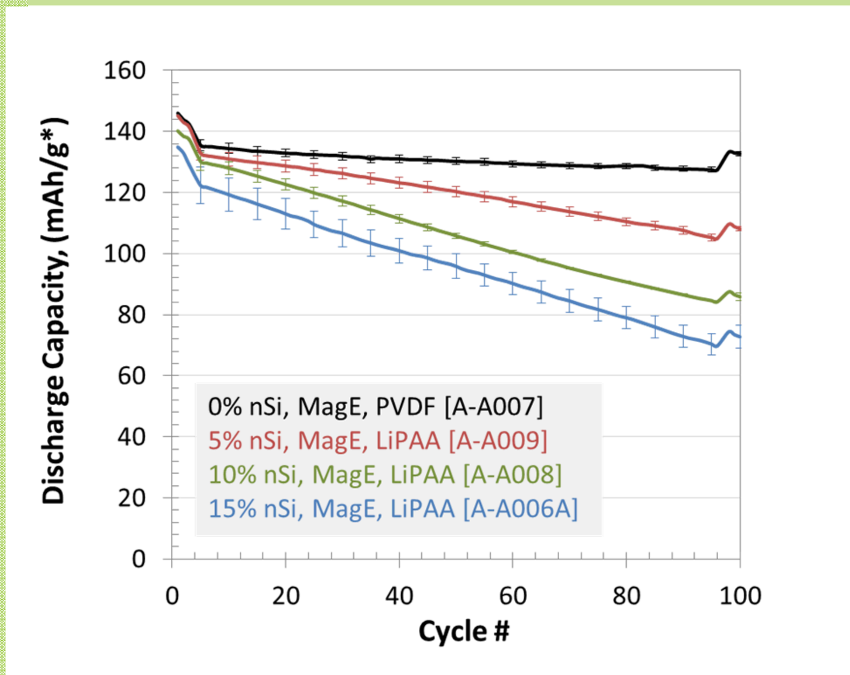
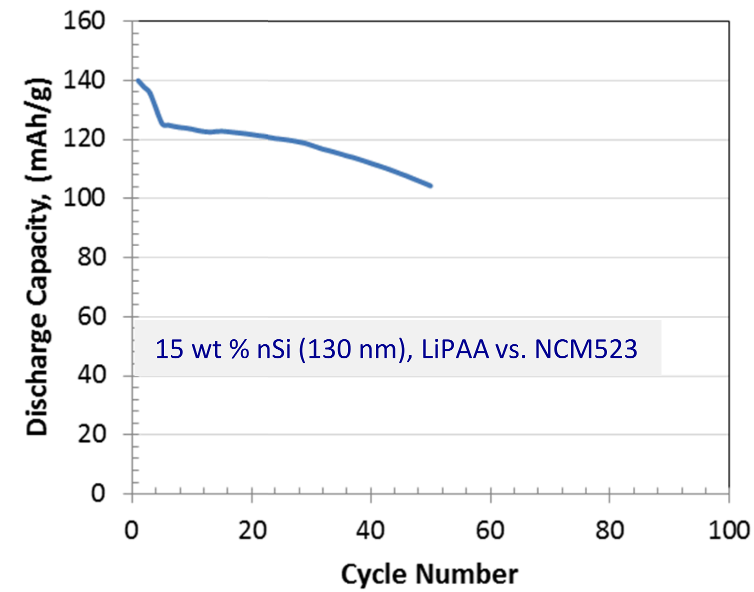


- Data from ANL using 50-70 nm NanoAmor silicon with 10 % FEC in electrolyte
- Voltage window of 4.1 – 3.0 V

Good agreement between electrodes – baseline electrochemical evaluations, thermodynamic evaluations ongoing



- Electrodes prepared at SNL using 130 nm NanoAmor silicon, all other aspects prepared in accordance with ANL processes using NCM cathodes from ANL, **no FEC**
- Voltage window of 4.1 – 3.0 V
- N/P = 1.13
- Shows slightly higher capacity than ANL data to 50 cycles

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FUTURE WORK

Understanding link between materials properties and abuse response of silicon materials

- **Materials Characterization – Determination of influence on overall thermal runaway enthalpy and/or electrode reactivity**
  - % Si Loading (starting with baseline)
  - Electrolyte effects (FEC, VC, etc.)
  - Particle Size Effects
  - Coating Efficacy (Collaboration with NREL)
  - Binder Effects – Polysiloxane based, Ion-conductive binders, etc.
- **Abuse Testing and Decomposition Product Analysis**
  - ANL baseline Si electrodes
  - Candidate materials from materials characterization and CAMP
- **Post Abuse Tear Down Evaluations**
  - Program electrodes (Collaboration with Post Test Facility)
- **SiO and Si_xSn_y Alloys – Potential for future PYs**

DSC

Determine correlation between material level and full cell level

ARC