Advanced Batteries: Enabling Technology for the Drivetrains of the Future

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acknowledgments

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UM AMSL Support

General Motors (Mr. Jim Queen, Mr. Bob Kruse)
U.S. Department of Energy
(BATT Program)
National Science Foundation
Army Research Office
Air Force Office of Scientific Research
Ford Motor Company
Sun Microsystems

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OUTLINE

- Drivers and Technology
- Educational Efforts
- Research Efforts
- Commercialization Efforts
- Markets, Policy and Next Steps

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Why vehicle electrification?

Reduce CO2
Footprint

Reduce Oil
Dependence

Create
Green Jobs

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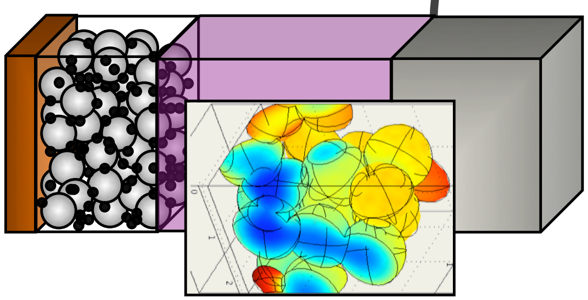
Why batteries?

plug-in
technologies:
Auto to Grid

design of Li batteries:
advanced computation



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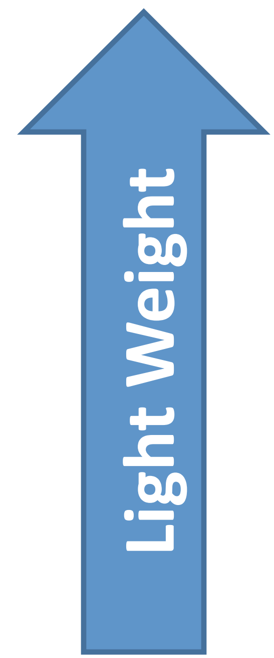
a few elements are very important

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				



Designing and building a knowledge ecosystem

Universities, National Labs, Financiers, Raw Materials Suppliers, Cell-makers, Pack-makers, Testers, and OEM's are all a part of the solution.

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timeline…

December, 2006 - March, 2007 - Discussions with key faculty on research and teaching interests

May, 2007 - Unanimous approval by Faculty for program formation

September, 2007 - Official program launch, per Regents' approval

March, 2008 - May, 2008 - Recruitment and launch of two concurrent intern programs with strategic partners GM and DTE

January, 2009 - GM acceptance of program into TEP, with enrollment of 50 engineers in ESE

May, 2009 – GROWTH of intern programs at GM and DTE, summer offering of ESE505

September, 2009 – ESE >170 students! 50 additional GM engineers.

ESE concentrations

civil power supplies:

- Developing and developed worlds have vastly different infrastructures, demands and opportunities.
- Economies, geographies, and natural resources play major roles in technology implementation.
- Knowledge base that includes both social and technical aspects of the challenges, is required.

automotive power supplies:

- Internal combustion engine has set the standard for energy and power density.
- Advances in fuel technologies, including clean diesel, biofuels and high compression combustion ignition, require parallel fluency in vehicle technologies.

microelectronic and portable power:

- Wireless electronics have become ubiquitous in modern life, and the costs will become a significant contributor to the demand on grid power.
- Major scientific challenges remain in realization of compact and robust systems, and life-cycle analysis of compact power supplies, including considerations of disposal and/or recyclability.

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greater electrification changes the demands placed on batteries from power to energy

HEV	PHEV	EREV
2 kWh	5 kWh	16 kWh
		
Light hybrids.	Medium hybrids, but mechanically coupled drivetrains.	Paradigm change: electrified drivetrain, Li batteries. Uses 8kWh or a 16kWh system. We need to carry around less unused capacity.

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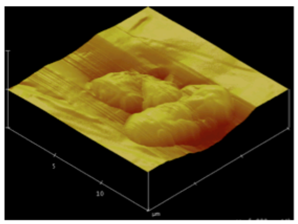
at the smallest scales…

in-situ AFM

(a)



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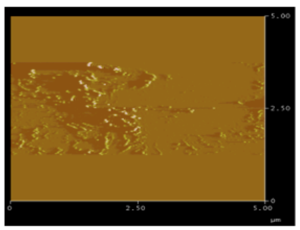
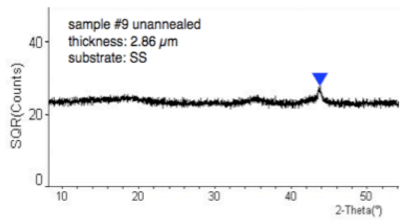


- (a): $LiMn_2O_4$ particles on Au foil
- 3D morphology
- (b): MWNT composite
- mapping of electrical resistance

XRD

(a)



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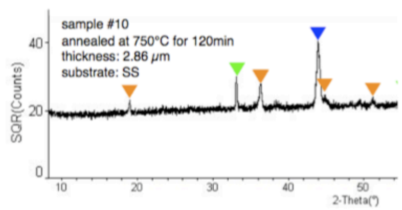
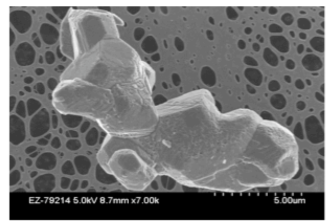


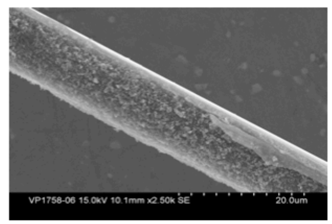
- (a) $LiMn_2O_4$ before annealing
- (b) $LiMn_2O_4$ after annealing
- annealing induce crystalline structure
- signature of crystal structure (spinel)

SEM

(a)



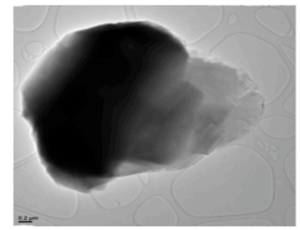
(b)



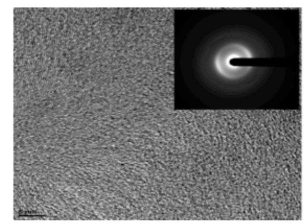
- (a): $LiMn_2O_4$ particle
- surface morphology (GB)
- (b): carbon fiber (XN-15)
- surface morphology (SEI layer)

TEM

(a)



(b)



- (a): $LiMn_2O_4$ particle
- atomic scale microstructure (GB)
- (b): carbon fiber (XN-15)
- crystalline structure (trubostratic)

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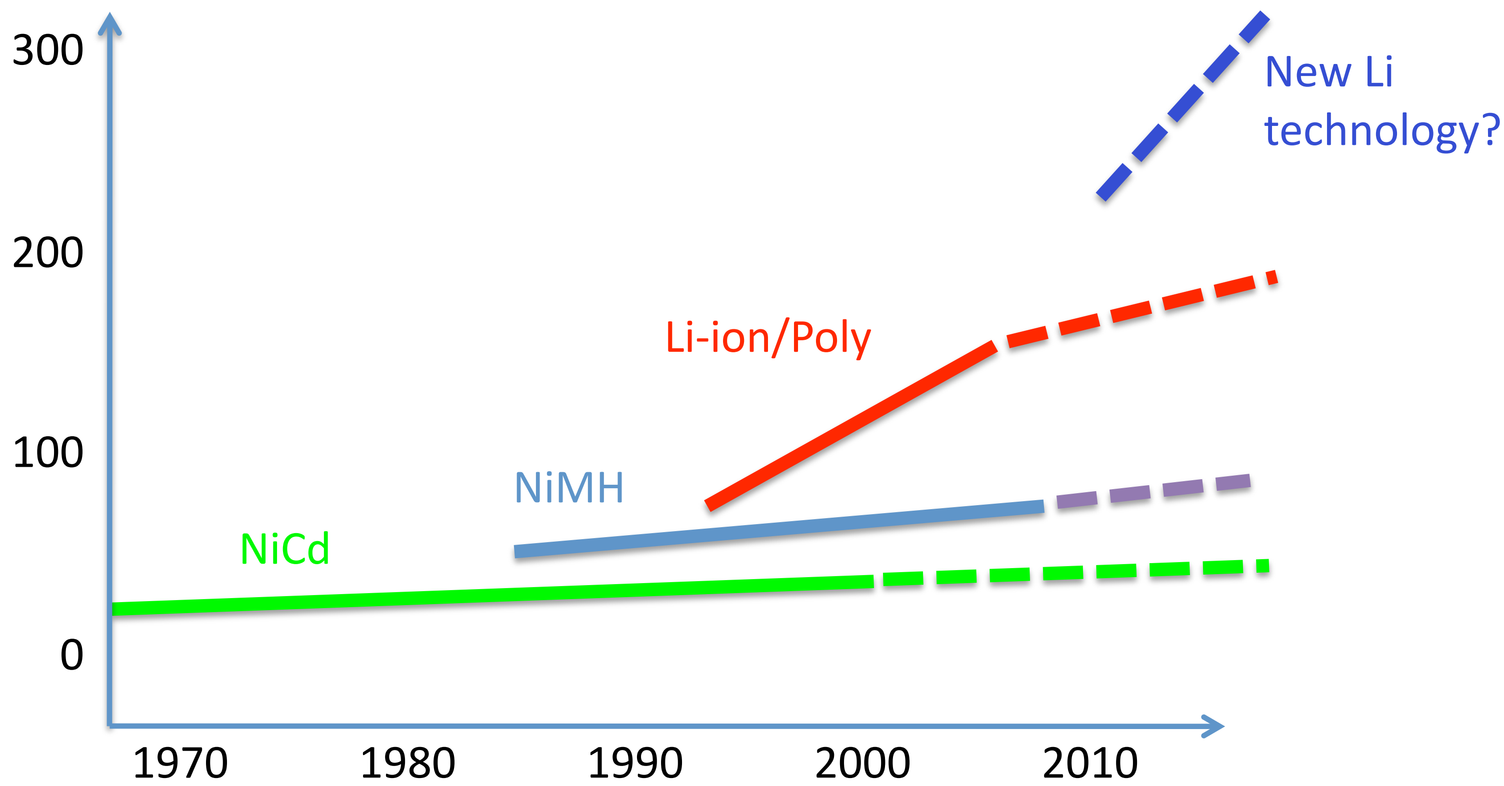
Asia has locked up a competitive advantage with this generation of Li-ion, but the future home of second gen is still wide open



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commercialization

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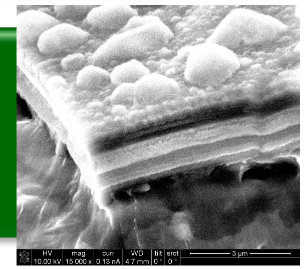
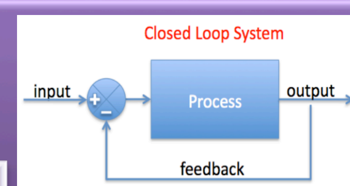
Commercialization at Sakti3

Computational Models (Physics)

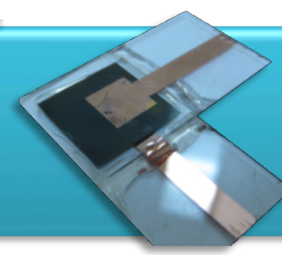
Materials Development



Optimization of Cells



Fabrication of Cells



recycling of batteries is possible: Prof. Lastoskie, UM

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public opinion matters in policymaking

Beijing, China, before and after: getting ready to improve air quality for the Olympics

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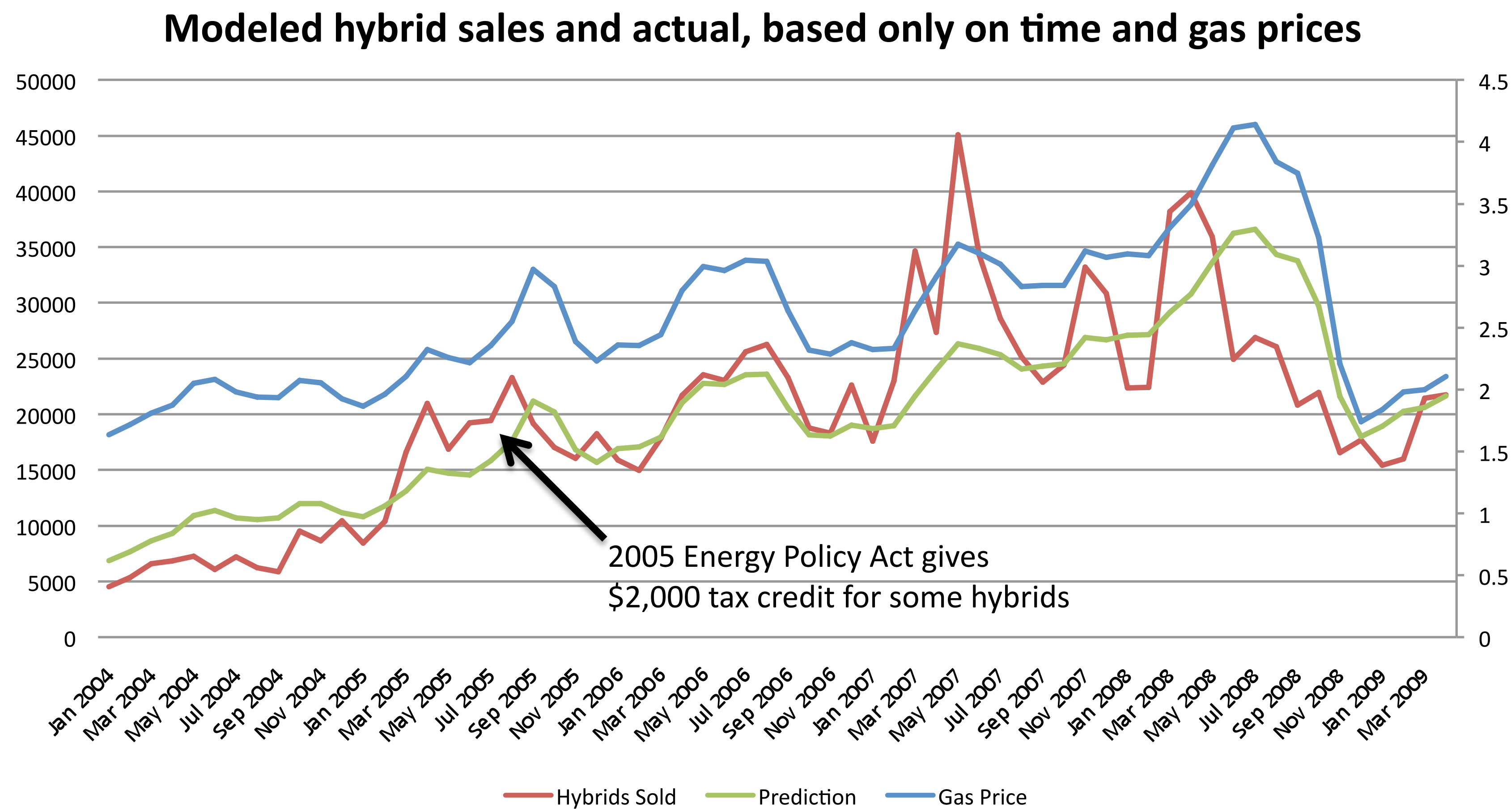
yes, gas price matters, really.



Simple regression: Number of hybrids sold = 8124(gas price in dollars) + 174(months after introduction of hybrids); P < 0.05; R-squared = 0.65)

Sources: EIA, GreencarCongress

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Great technical accomplishments are made possible with the right model

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questions