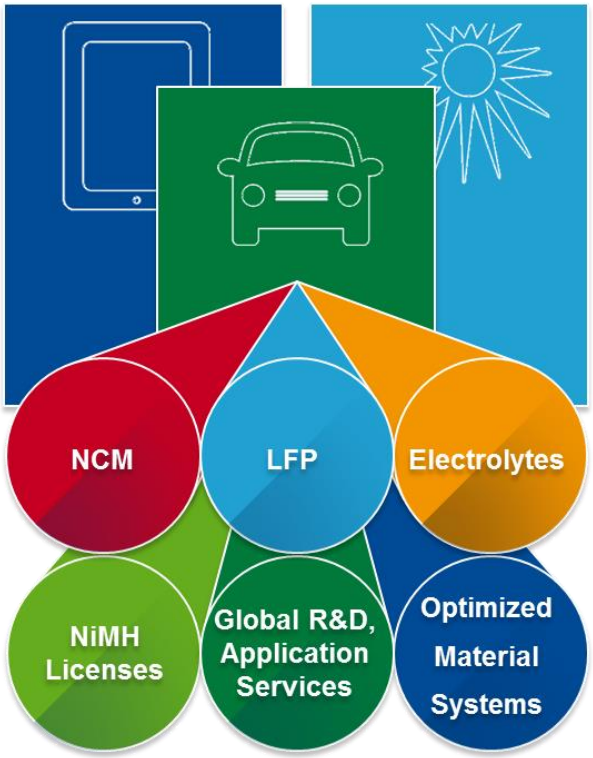
BASF - ANL Collaboration on NCM Cathode Materials



Michael Fetcenko

Commission to Review the Effectivenes of the National Energy Laboratories

November 4, 2014

BASF
The Chemical Company

BASF – The Chemical Company

We Create Chemistry for a Sustainable Future

- **We combine economic success, social responsibility and environmental protection**
- **Sales 2013: €73,973 million**
- **EBIT 2013: €7,273 million**
- **Employees (as of December 31, 2013): 112,206**
- **6 Verbund sites and 376 other production sites**
- **Our chemistry is used in almost all industries – Sales into automotive industry around 15% of total sales**

Chemistry-based innovations @ BASF

BASF
The Chemical Company

Global needs

Resources, Environment & Climate

Food & Nutrition

Quality of Life

Key customer industries

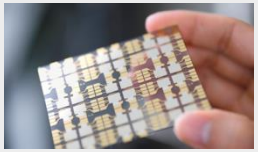

Transportation


Agriculture


Construction


Energy & Resources


Consumer Goods


Electronics


Health & Nutrition

Growth fields

- Batteries for Mobility
- Enzymes
- E-Power Management
- Functional Crop Care
- Heat Management for Construction
- Lightweight Composites
- Organic Electronics
- Plant Biotechnology
- Water Solutions
- Wind Energy
- ...

Technology fields

Materials, Systems & Nanotechnology

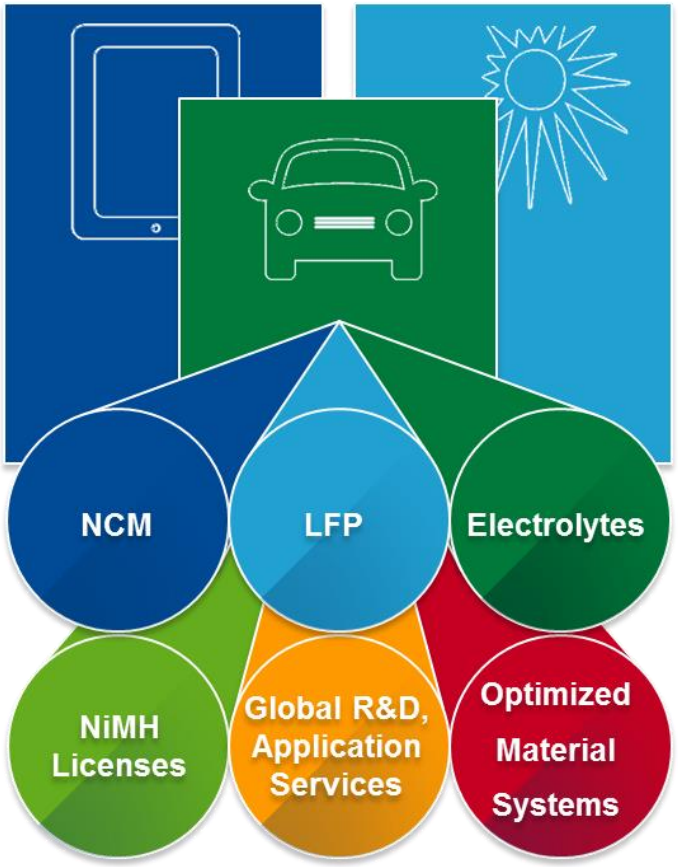
Raw Material Change

White Biotechnology

BASF – The Chemical Company

BASF's Comprehensive Battery Materials Portfolio

- Global business unit established 2012
- Significant expansion of the scope of its battery materials technologies over the last two years
  - Start-up of own production sites
  - Licensing agreements
  - Multiple acquisitions
  - Investment into companies
- In-house R&D and strategic partnerships



Argonne National Laboratory

ANL and Inventors – Strong Reputation

BASF
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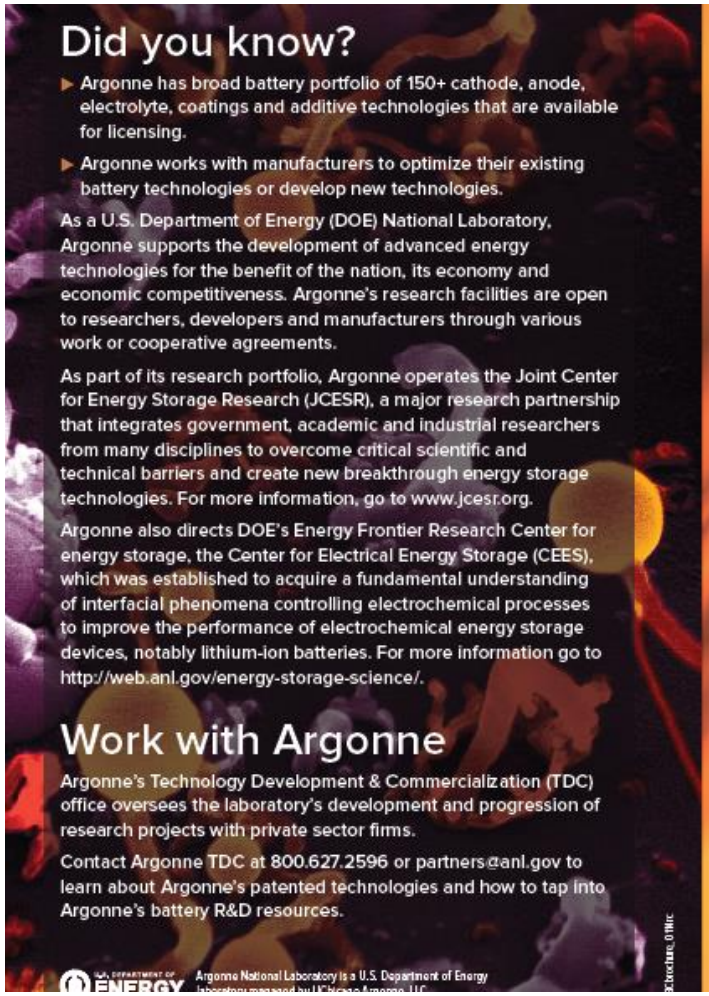


Argonne NATIONAL LABORATORY

"Argonne's strength is that its battery research initiatives cover the broad space of discovery science through to technological implementation."
– Michael Thackeray, Li-ion battery research pioneer

DOE's investment in Argonne's advanced battery research supports Obama administration goals to reduce American reliance on oil, decrease greenhouse gas emissions and create jobs, in this case through the development of a growing industry.

Argonne employs several of the field's top scientists and is home to some of the worlds most sophisticated and unique scientific research facilities, including the Advanced Photon Source, the Advanced Leadership Computing Facility and the Materials Engineering Research Facility. These facilities allow scientists to gain not only an in-depth understanding of a battery material's structure, but also to develop, bench test and scale-up innovative new materials for industrial investigation and potential commercialization.

Argonne is DOE's primary National Laboratory for battery research. The Laboratory has a portfolio of more than 150 battery patents and inventions that are available for licensing. Argonne also operates DOE's energy storage hub, the Joint Center for Energy Storage Research (JCESR), which is developing next generation batteries and other energy storage technologies that go beyond lithium-ion systems.

Argonne National Laboratory seeks solutions to pressing national problems in science and technology. The nation's first national laboratory, Argonne conducts leading-edge basic and applied scientific research in virtually every scientific discipline. Argonne researches work closely with researchers from hundreds of companies, universities, and federal, state and municipal agencies to help them solve their specific problems, advance America's scientific leadership and prepare the nation for a better future. With employees from more than 60 nations, Argonne is managed by UChicago Argonne, LLC for the U.S. Department of Energy's Office of Science.

BASF collaboration with ANL on patent protection and commercialization of ANL Technology.

Argonne Battery Technology

Patent Confirmed by U.S. Patent Office

(12) **EX PARTE REEXAMINATION CERTIFICATE** (9760th)
United States Patent
Thackeray et al.

(10) **Number:** **US 6,677,082 C1**
(45) **Certificate Issued:** **Jul. 19, 2013**

(54) **LITHIUM METAL OXIDE ELECTRODES FOR LITHIUM CELLS AND BATTERIES**

(75) Inventors: **Michael M. Thackeray**, Naperville, IL (US); **Christopher S. Johnson**, Naperville, IL (US); **Khalil Amine**, Downers Grove, IL (US); **Jaekook Kim**, Naperville, IL (US)

(73) Assignee: **U Chicago Argonne LLC**, Chicago, IL (US)

Reexamination Request:
No. 90/012,243, Apr. 12, 2012

Reexamination Certificate for:
Patent No.: 6,677,082
Issued: Jan. 13, 2004
Appl. No.: 09/887,842
Filed: Jun. 21, 2001

Certificate of Correction issued Jul. 6, 2004

Related U.S. Application Data

(60) Provisional application No. 60/213,618, filed on Jun. 22, 2000.

(51) **Int. Cl.**
H01M 4/50 (2010.01)
C01G 45/00 (2006.01)
C01G 45/02 (2006.01)
C01G 53/04 (2006.01)

(52) U.S. Cl.
USPC **429/224**; 429/223; 429/231.1; 429/231.6; 429/231.3; 425/595; 423/594.3

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/012,243, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

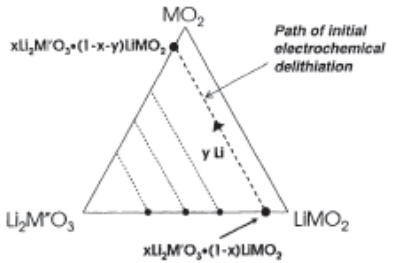
Primary Examiner — Timothy Speer

(57) **ABSTRACT**

A lithium metal oxide positive electrode for a non-aqueous lithium cell is disclosed. The cell is prepared in its initial discharged state and has a general formula $xLi_2M'O_3 \cdot (1-x)Li_yMO_2$ (in which $0<x<1$, and where M is one or more trivalent ion with at least one ion being Mn or Ni, and where M' is one or more tetravalent ion. Complete cells or batteries are disclosed with anode, cathode and electrolyte as are batteries of several cells connected in parallel or series or both.

January 29, 2014

The U.S. Department of Energy's (DOE) Argonne National Laboratory is pleased to announce that after a careful reexamination of the relevant prior patents and publications, the U.S. Patent and Trademark Office (USPTO) has confirmed the novelty of U.S. Patent 6,677,082.



(M'= e.g., Mn, Ti, Zr) (M= e.g., Mn, Ni)

NMC cathode technology as described in this patent can be found in commercial consumer and vehicle lithium-ion batteries.

See more at:
http://www.anl.gov/technology

U.S. DEPARTMENT OF ENERGY

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AABCpatenthandout_0114rc

NCM Product Overview

Broad range of available compositions

1 State-of-the-art

NCM 111: $Li_{1+x}(Ni_{0.33}Co_{0.33}Mn_{0.33})_{1-x}O_2$
Discharge Capacity: 154 Ah/kg @ 0.1C

NCM 523: $Li_{1+x}(Ni_{0.5}Co_{0.2}Mn_{0.3})_{1-x}O_2$
Discharge Capacity: 164 Ah/kg @ 0.1C

NCM 424: $Li_{1+x}(Ni_{0.4}Co_{0.2}Mn_{0.4})_{1-x}O_2$
Discharge Capacity: 155 Ah/kg @ 0.1C

2 Hi Nickel

NCM 622
Discharge Capacity: 178 Ah/kg @ 0.1C

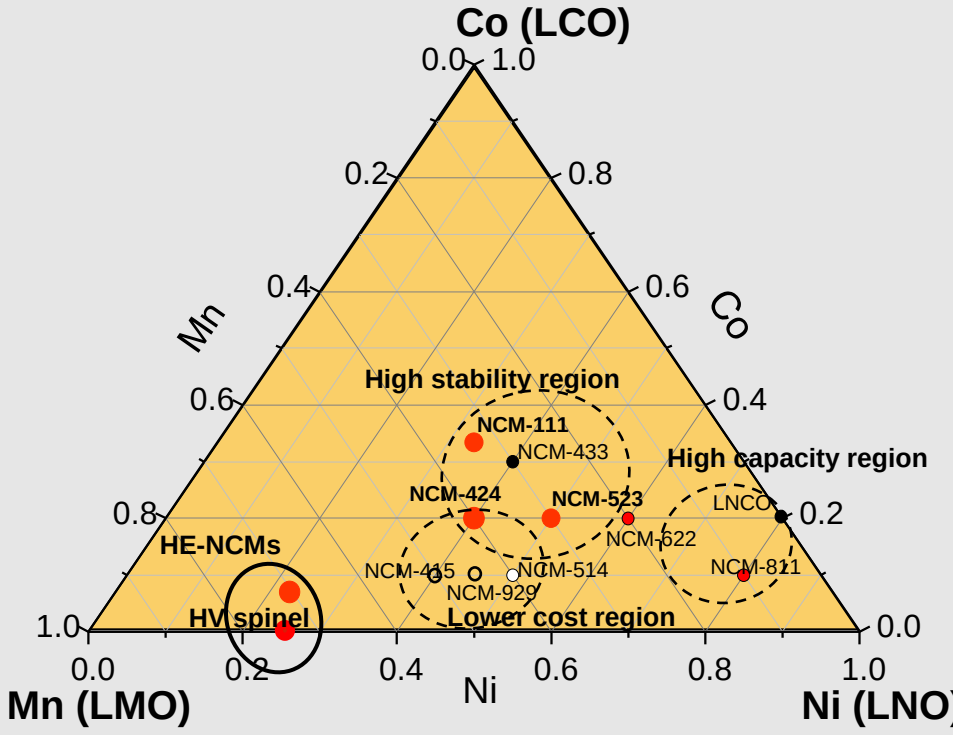
NCM 811 and others
Discharge Capacity: >185 Ah/kg @ 0.1C

3 Mn rich

HE-NCM:
Discharge Capacity: 260 Ah/kg @ 0.1C

HV-Spinel:
Discharge Capacity: 140 Ah/kg @ 1C

NCM COMPOSITION DIAGRAM



BASF Battery Materials - Manufacturing

NCM plant – Elyria, Ohio

Electrolytes - Zachary, Louisiana and Suzhou, China

NCM & LFP Cathode Materials

- Fully operational production plants
- Suitable for NCM materials as well as for next generation high energy NCM

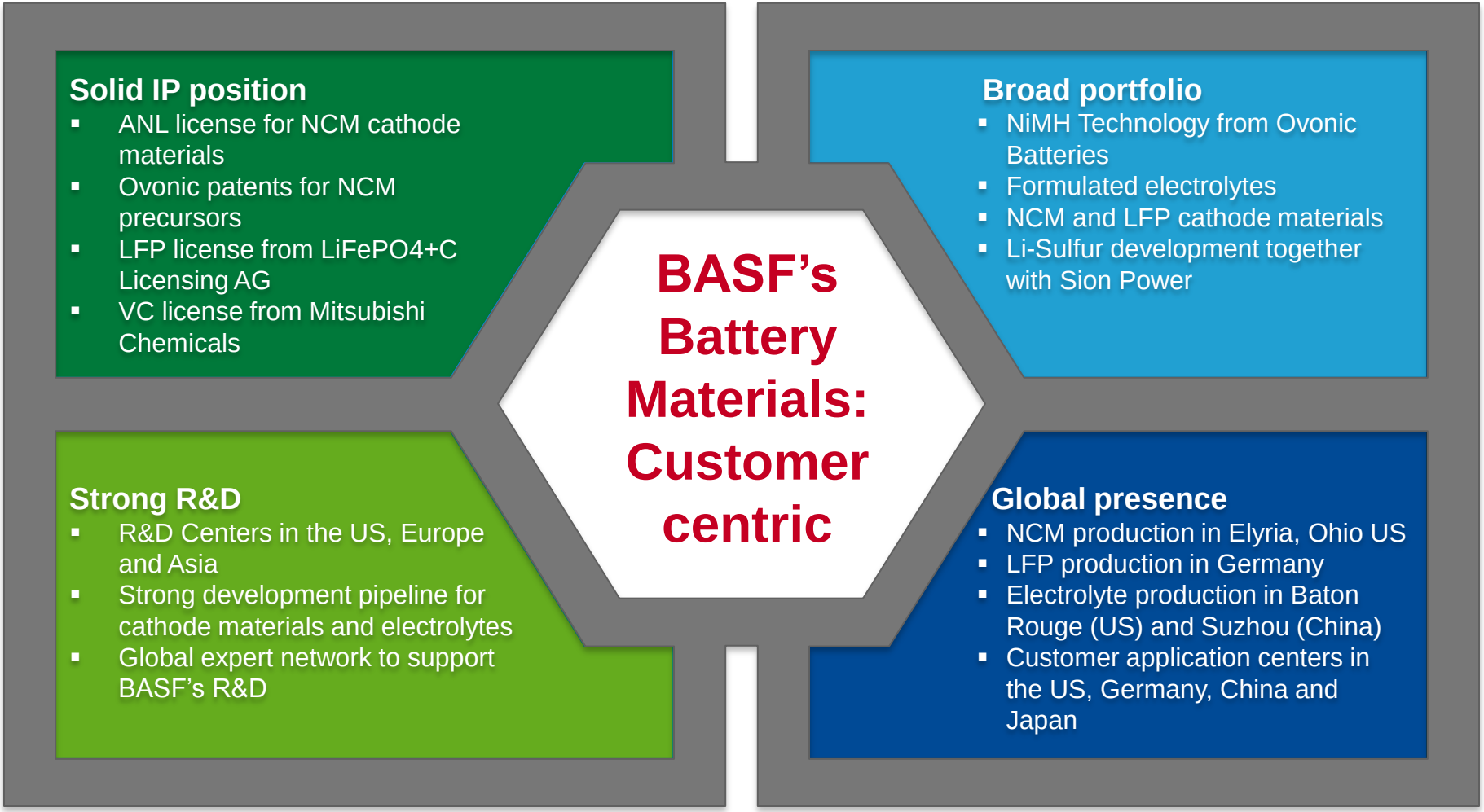
Electrolytes

- State-of-the-art manufacturing technology
- Global presence: North America and China

BASF Global Presence – includes R&D and Pilot Production in Ludwigshafen, Germany

BASF's battery materials portfolio:

Driving Your Success



High Energy Cathode Materials

Overview about next generation cathode materials

HE NCM

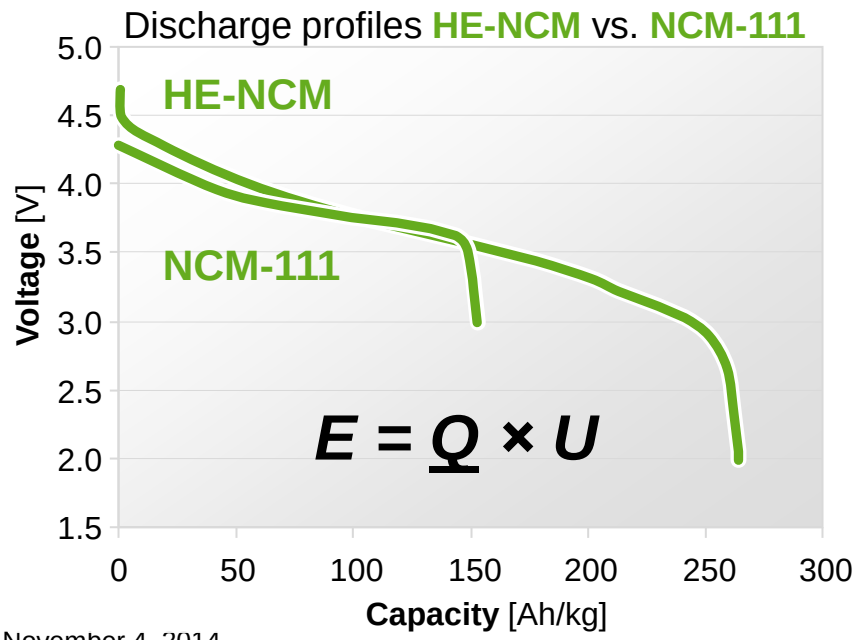
Marked capacity increase at slightly lower voltage “High Energy”

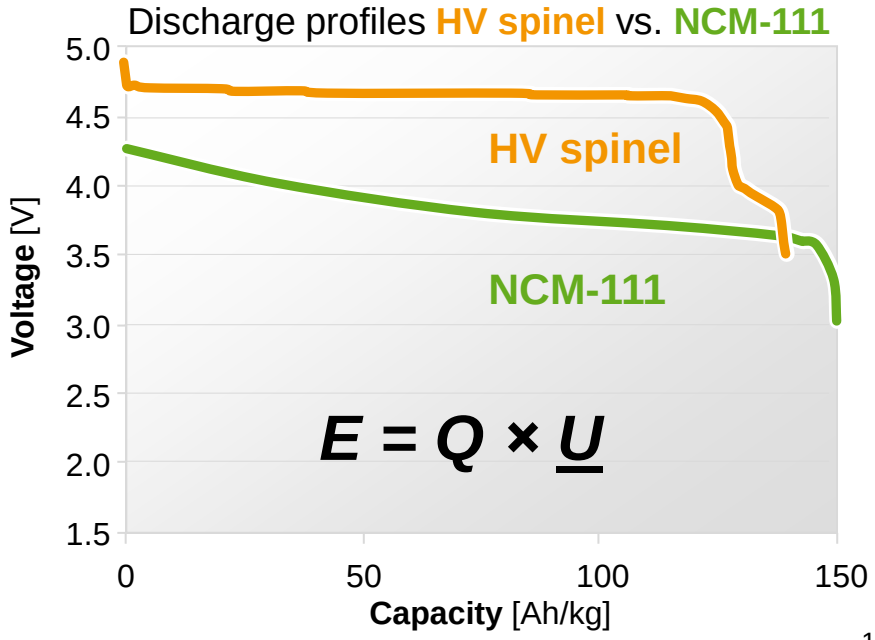
Performance benefit calculated in a model cell

	Gravimetric energy density [Wh/kg]	Volumetric energy density [Wh/l]
NCM-111	**219**	**606**
HE-NCM	**+15%**	**+5%**
HV spinel	**+8%**	**+8%**

HV Spinel

Marked voltage increase at slightly lower capacity “High Voltage”

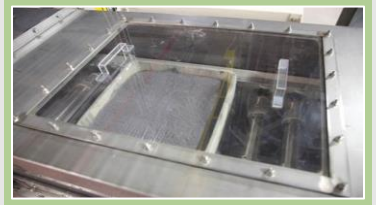




BASF Battery Materials

Global footprint

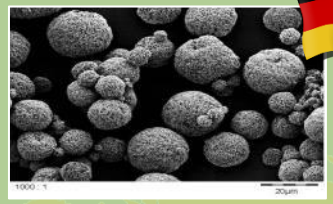
NCM production



NCM production plant in Elyria, US (2.4 kt)

LFP production

LFP production in Ludwigshafen and Weimar, Germany (3.0 kt)



Application labs, research centers

Amagasaki, Japan.
Further application labs in the US, China and Germany
Research centers in the US and Germany

Electrolyte production

Production capacity in *Suzhou, China*.
Further capacity in Louisiana

BASF Collaboration with ANL

Multiple Fields including Battery and Agricultural

BASF
The Chemical Company

- **BASF is proud licensee of ANL NCM Cathode Technology**
- **Active development of next generation NCM Materials**
- **Capital Investment for Commercialization**
  - Elyria, Ohio factory for NCM Calcination
  - Acquisition of Ovonic Precursor
- **Patent Collaboration**

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Thank you

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