UNITED STATES ADVANCED BATTERY CONSORTIUM LLC

DEVELOPMENT OF ADVANCED HIGH-PERFORMANCE ELECTROLYTES FOR LITHIUM ION BATTERIES USED IN VEHICLE APPLICATIONS

REQUEST FOR PROPOSAL INFORMATION (RFPI)

ELECTROLYTES FOR AUTOMOTIVE APPLICATIONS

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USABC DEVELOPMENT OF ADVANCED HIGH-PERFORMANCE ELECTROLYTES FOR AUTOMOTIVE APPLICATIONS

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1.0 Statement of Purpose/Objectives

The United States Advanced Battery Consortium LLC (USABC), an organization whose members are Chrysler Group LLC, Ford Motor Company and General Motors defines and conducts pre-competitive, vehicle-related research and development (R&D) in advanced battery technology. USABC has carried out a number of battery development programs, focusing on low-cost, long-life, high-energy, high-power technologies, including several programs in which the development of improved electrolytes was critical to the successful outcome of the program. The USABC, in recognition of the importance of the electrolyte to advanced battery systems, intends to further extend development of this critical component.

The purpose of this RFPI is to identify developers having electrolyte technologies which have the capability of meeting or approaching the USABC long-term criteria, as listed in the attached Appendix, when employed in an appropriate battery cell. The USABC is currently working under a cooperative agreement with the United States Department of Energy (USDOE) for the development of high performance batteries. The USABC has concluded that it is now appropriate to solicit additional proposals from developers who have the potential to meet or approach the criteria noted in the Appendix.

The USABC intends to capitalize on the knowledge it has gained through the HEV, PHEV, and EV research and development activities it has been engaged in. We expect developers to bring past experiences and lessons learned from their high power and/or high-energy work to bear on developing energy storage technologies for this application.

2.0 Business Objectives

This USABC RFPI represents a unique opportunity for developers to leverage their resources in combination with those of the automotive industry and the federal government. For the automakers, this type of pre-competitive cooperation minimizes both duplication of effort and risk of failure, and maximizes the benefits to the public of the government funds.

Beyond the efficient and timely usage of resources, the auto makers recognize that successful commercialization of these technologies will only be completed when a supplier base has been established for the selected components and subsystems. It is, therefore, a major business objective of USABC to enhance a supplier base as the development progresses. All developers submitting proposals will be required to demonstrate that they have the potential to develop a commercially viable business, which can produce sufficient volumes to meet automotive requirements, and provide engineering and testing support to meet automotive implementation

requirements. Research organizations with current, direct affiliations with businesses that derive a majority of their income from related product sales, will also be considered. At the time of submittal, all developers will be required to have demonstration hardware and test results available for USABC inspection. Testing performed in accordance with the USABC battery test procedures is preferred, however not mandatory. Inspection and testing of samples by the USABC may be included in the selection process. Developers who do not have test results available for examination by USABC at the time of submittal need not respond.

3.0 Developmental Timing

The proposals must be accompanied by a development time chart specifying the following:

1. Length of time the technology has been under development by the developer;
2. Length of time remaining to full scale availability; and
3. Time line for commercialization, including any preproduction phases that may be planned.

4.0 Business Case

The submittal must be accompanied by a business case, divided into two sections. The first section shall state the cost assumptions used that will lead to the cost targets listed in the Appendices. These assumptions should be in general terms, broken down by major components, including material cost, processing cost and other costs. These costs should be presented in sufficient detail such that they can be used by the USABC to build confidence that its cost targets can be met by the proposed technology.

The second portion of the business case should address the anticipated capital investment required to support this initial program investment, including anticipated non-EV markets for the technology, sources of capital, etc. A copy of the USABC cost model, which is a multi-stage spreadsheet, is available on the USABC website:
http://www.uscar.org/guest/article_view.php?articles_id=143.
Please note that USABC will not provide funding for capital expenses.

5.0 Technical Challenges

Proposals must be accompanied by a clear description of the remaining technical challenges that the developer still needs to meet in order to commercialize the proposed technology and meet USABC's long-term criteria. A narration of the technical challenges that have already been met in order to reach the present state of development will also be useful. Any testing, by USABC, of pre-contract demonstration hardware will be done in accordance with the USABC battery test procedures. These procedures can be found on the USABC website:
http://www.uscar.org/guest/article_view.php?articles_id=86.

6.0 Information Requested

The information USABC is requesting from interested parties is specified in the following subsections. It includes: (1) a brief description of your company(s) background; (2) a description of the advanced electrolyte technology being proposed; (3) the development plan for the technology; (4) the proposed program deliverables, timing, and cost-share; and (5) any formal or informal teaming arrangements planned, and (6) acknowledgement of export control compliance. Note that the ultimate testing and technology demonstration of the advanced electrolyte technology must occur in cell formats and sizes of automotive interest (12 V, 48 V, PHEV or EV). Note also that the 18650 cell format is acceptable, but not preferred, throughout the development program. Relevant information regarding USABC performance targets can be found on the USCAR website, at
http://www.uscar.org/guest/teams/12/U-S-Advanced-Battery-Consortium-LLC .
Therefore, a partnership between the electrolyte developer and a cell fabricator with a proven track record (of the developer's choice) is a necessary condition for electrolyte program approval.

USABC does not expect to award contracts on the sole basis of responses to this RFPI. All responses will be considered by representatives of the partners and other participants and will be ranked according to their merit. The submitters of the most promising proposals will be contacted by USABC to enter into negotiations that may lead to firm contractual arrangements. If the government and other funding become available, as now expected, USABC intends to award one or more development contracts. However, nothing herein should be interpreted as a commitment to award a contract.

The information requested below should be answered as thoroughly as possible within a maximum of twenty-five pages, in total, for the response to the RFPI. Your submission package should be sent via electronic mail and shall contain a cover letter, a complete copy of your proposal and, a signed copy of the RFPI Agreement. If you have any questions concerning the RFPI, please contact Zoe Zhou @ (313) 248-1896 or Maureen LaHote @ (313) 910-3720.

NOTWITHSTANDING PROPOSER'S MARKINGS TO THE CONTRARY, ALL INFORMATION SUBMITTED IN RESPONSE TO THIS USABC RFPI SHALL BE TREATED ON A NON-CONFIDENTIAL BASIS.

ALL PROPOSALS ARE TO BE SUBMITTED TO THE CONSORTIUM IN ACCORDANCE WITH THE ATTACHED RFPI AGREEMENT WHICH MUST BE EXECUTED WITHOUT MODIFICATION AND ACCOMPANY THE PROPOSAL. NO PROPOSAL SHALL BE EVALUATED BY THE CONSORTIUM WITHOUT PRIOR EXECUTION OF SUCH RFPI AGREEMENT.

SEND, VIA ELECTRONIC MAIL, YOUR PROPOSAL (including signed RFPI Agreement) TO:

Maureen LaHote
Business Manager
United States Advanced Battery Consortium
E-mail: mlahote@uscar.org

6.1 Company Background

In order to become fully familiar with your company(s), the USABC needs information about your business. If your proposal is for a team, furnish the requested information for each company that makes up your team. Please answer/furnish the following information:

- Describe your company's structure, ownership, product lines, and customer base, including domestic and foreign facilities for research and production.

- Please describe how previous R&D successes (especially with USABC or DOE) have been incorporated into the current proposal.

- Please describe the company's experience (if any) in the high volume manufacture of Li-ion battery electrolytes.

- If publicly owned, include the last 3 years of Annual, 10k, and 10Q Reports. If privately held, include the last 3 years of Balance Sheets, Income Statements, and a Sources & Uses of Funds Statement.

- Enclose a copy of your company's Business Plan for areas related to electrochemical energy storage technology.

- Describe the resources (headcount, expenses, and facilities) devoted to electrochemical energy storage technology development for the previous three years, currently, and forecasted through 2016.

- Describe the modeling methods your company uses to estimate costs at sales volumes of 4M t/year and greater.

- Do you currently hold any licenses and/or patents or pending patent applications for advanced electrochemical energy storage technology and manufacturing processes? If so, please describe. Are there any restrictions on licensing this technology to the Consortium?

- Provide any projections on potential production for the proposed technology. Also, describe key technical innovations that could lead to high performance and cost effective electrochemical energy storage subsystems.

- Provide a brief resume on key personnel to be dedicated to the project.

6.2 Proposed Electrolyte Technology

The proposed electrolyte technology should provide a significant improvement over currently known electrolytes for Lithium-ion batteries in one or more of the following areas: (1) cost, (2) high-voltage stability, (3) low-temperature performance, and (4) abuse tolerance.

A thorough technical review of each proposed technology is required prior to the award of any contract for development. In preparing a reply to the RFPI please provide a response to each of the following points.

Provide a brief technical description of the proposed technology that will meet the electrolyte goals and characteristics listed in Appendix A. Table A1 contains the USABC goals for an advanced electrolyte, Table A2 the USABC requirements for conventional electrolytes, and Table A3 is optional for unconventional electrolytes.

Summarize the present status of the proposed technology, with experimental data and test methods used to acquire the data, including:

- Physical, performance, and life characteristics of all relevant formulations developed and tested at your facilities, or at independent test facilities.
- Any environmental and safety issues relating to manufacturing, recycling, use and disposal of the proposed technology.
- Dominant failure mechanisms that limit the operating life of lithium-ion batteries using this technology, and use restrictions desired/required to maximize the life of the subsystem.
- Summarize the characteristics of the current technology by using the tables provided in Attachment A.
- Summarize the electrochemical cell performance of the current technology using the guidelines provided in in Appendix B.
- Provide any relevant quality-related metrics.

6.3 Proposed Technology Development Plan

Propose how the technology would be developed to meet the USABC technical criteria including:

- Barriers that must be overcome (should be closely based on the objectives listed in the Appendices);

- Task objectives needed to overcome the barriers, approaches, success criteria, and demonstration tests;

- Feasibility and scale-up issues that must be resolved; and

- Transition from feasibility demonstration to prototype hardware.

Separately propose how the technology could be produced in high volume. Define the raw materials, processes, capital equipment, and labor required at the desired production levels. Discuss the overall timing required to achieve initial production, including prove-out. Define any intermediate steps required to reach initial rated production including pilot plants, technical challenges regarding the manufacturing process, and their time frame.

Define any additional technical issues, and their possible resolution, concerning the proposed technology relevant to vehicle applications. Propose a warranty structure for the subsystem corresponding to the initial commercial production level.

Provide a projected cost breakdown of the proposed technology, including costs projected for the desired production volumes. Costs related to warranty and/or replacement, and recycling should be clearly indicated. The manner in which the projected costs, volumes and time schedules are expected to be achieved should also be provided.

The proposals must be accompanied by a development time chart characterizing the following:

1. Length of time the technology has been under development by the developer;
2. Length of time remaining to full scale, prototype availability; and
3. Time line for commercialization, including any preproduction phases that may be planned.

6.4 Proposed Program Schedule, Deliverables, Cost, and Cost Sharing

Developers must clearly identify their milestone objectives. The setting of major milestones and timing will be reviewed and agreed upon between each USABC Work Group and the corresponding subsystem developer/supplier team. It is anticipated that there will be intensive interaction between both parties in setting program milestones. The involvement of all team member organizations in the setting of program milestones is strongly encouraged. The delivery of samples for testing and evaluation will be scheduled, on a continuing basis, as developments warrant. Details of scheduling would be agreed upon with the developer and the USABC Work Group. The evaluation of deliverable samples will be undertaken at several testing facilities, such as the National Laboratories and those of the USABC partners. The battery test schedule will be agreed upon by the USABC Work Group, subsystem developer, and the test facilities.

Hardware deliverables will be expected to demonstrate and evaluate the performance of the electrolyte in a viable cell (preferably in pouch cell format of 2 Ah size or larger for electrochemical performance; and 10 Ah or larger for thermal abuse tolerance testing; the 18650

cell format is one acceptable format, for electrochemical performance testing). The evaluation of deliverable electrolyte samples will be undertaken at testing facilities with recognized expertise in performing such testing. The cell test schedule will be agreed upon by the USABC Work Group, the electrolyte developer, and the test facilities. Developers who do not have the experience or capability to make sufficient viable cells are encouraged to find partners who can. The USABC can, upon request, recommend experienced cell manufacturers.

The USABC is interested in advancing the development of commercially viable energy storage products, and prefers to focus on technologies, including cell chemistries, that are most likely to achieve commercial success in the near term. The current cell chemistry of interest is a NMC cathode paired with a graphite anode, although other chemistries may be proposed and/or selected. The preferred positive electrode for high-voltage electrolyte, is LNMO spinel, paired with a graphite negative electrode. For chemistries other than NMC/graphite or LNMO/graphite, the developer should explain the rationale behind the selection. The developer must clearly identify the cell to be delivered (including the intended electrodes, separator, electrolyte package, the size and format of the cell, and where they will be built). The goals listed in the Appendices are intended to be aggressive. It is not required that every program achieves all goals, but it is expected that successful programs will significantly advance the state of the art in electrolyte cost and performance. The USABC electrolyte gap chart from Appendix C and the gap chart pertinent to the cell performance for the targeted automotive application (HEV, PHEV, or EV) will be used to track progress throughout the development program.

All Developers are expected to contribute or cost share in the developmental costs. The Developer should submit proposals indicating cost sharing as a percentage of the total proposed program development amount. The extent of cost sharing may be negotiated between USABC and the development team, taking into consideration whether the company is domestic, foreign, or foreign controlled, rights to license background and foreground technology, benefits to US economy, and other factors. However, a minimum of 50 percent developer cost share is contractually required. The Developer will agree that at least 75% of the direct labor billed to the USABC for this project will be incurred within the United States.

The proposer shall provide cost breakdown between labor, materials, indirect costs, etc. and a separate analysis of total costs for each major task. The tasks that each subcontractor will complete and the funding they will receive should be clearly indicated in the cost breakdown.

Contractors will provide quarterly reports to USABC, including test data and development progress. Additional reporting (i.e., oral) may be scheduled with the USABC Work Group, as appropriate. A final written report will be submitted to USABC at the end of the contract period.

6.5 Cooperative Relationships

The proposal should indicate any additional resources that may be required beyond those of the contractor to achieve program goals. This would include the development of cooperative relationships between component developers, component manufacturers, and subsystem integrators. Other cooperative relationships could involve National Laboratories or Universities

for materials research, test facility development, test and analytical procedures, or other techniques available only at specialized locations.

6.6 Export Control Compliance

The proposer will be required to acknowledge that export control rules limit or prohibit the transfer of covered technology to foreign nationals and agrees to establish and maintain internal controls and procedures adequate to insure accurate determination by the proposer of whether and when its technology falls within the ranges and definitions of the currently effective export control regime.

RFPI AGREEMENT

NOTWITHSTANDING PROPOSER'S MARKINGS TO THE CONTRARY, ALL INFORMATION SUBMITTED IN RESPONSE TO A UNITED STATES ADVANCED BATTERY CONSORTIUM (USABC) REQUEST FOR PROPOSAL INFORMATION (RFPI) SHALL BE TREATED ON A NON-CONFIDENTIAL BASIS.

AGREED:

BY _____

TITLE _____

PROPOSER _____

DATE _____

APPENDIX A. USABC Advanced Electrolyte Characteristics

The proposed electrolyte technology must demonstrate a significant advantage over existing electrolytes by addressing one or more of the goals listed in Table A1.

Table A1. USABC goals for improved electrolytes.

#	Parameter	Unit	Goal
1	Cost @ a yearly production volume no more than 20,000 ton/year	$/kg	<10
2	Low temperature (-30^{o}C) conductivity	mS/cm	>4
3	High voltage stability	V vs. Li/Li^{+}	5.0
4	Vapor pressure at 30 ^{o}C	mm Hg	<1
5	Flashpoint	^{o}C	>100
6	Components Purity	%	>99.99

There are additional requirements, depending on composition of the electrolyte. If a conventional electrolyte is proposed, i.e., an electrolyte comprised mostly of ethylene carbonate and linear carbonates with lithium hexafluorophosphate salt, then the additional requirements in Table A2 should be met and Table A3 is not required. However, if an unconventional electrolyte is proposed, such as a novel salt or a substantial fraction (>10 wt.%) of a novel solvent, then provision of the additional information as listed in Table A3 is optionally desired.

Table A2. USABC requirements for conventional electrolytes.

#	**Parameter**	**Unit**	**Goal**
1	Conductivity at 30^{o}C	mS/cm	>12
2	Li^{+} Transference No.		>0.35
3	Viscosity 30 ^{o}C -30 ^{o}C	cP	 <5 <20
4	Water content	ppm	<20
5	HF content	ppm	<50
6	Components Purity	%	>99.99

Table A3 Set of test data useful for the evaluation of unconventional electrolytes.

#	Property	Salt Concentration, M
1	Density	Base, 0.9 x max, 0.5 x base
2	Conductivity	Same as above
3	Viscosity	Same as above
3	Diffusion coefficient	Same as above
4	Li^+ Transference No.	Base only
5	Activity coefficient	Base, Max, 0.1 x base

Notes:

1. The tests temperatures for all properties listed in Table A3 are -30 ^oC and +30 ^oC.
2. These physical property measurements are required to fully characterize transport properties. Room temperature data are a minimum acceptable. "Base" represents the recommended salt concentration; "Max" refers to maximum allowed concentration.
3. Thermal stability data with cell components at above-ambient temperatures (DSC or ARC to 250 ^oC) would be very desirable.

APPENDIX B. USABC Cell-Level Goals for Advanced Electrolytes

In addition to characterizing electrolyte properties, the electrolytes must be tested in viable lithium-ion cells. Specific USABC goals and procedures should be used which pertain to the targeted application, such as HEV, PHEV, or EV. These can all be found on the USABC website, http://www.uscar.org/guest/article_view.php?articles_id=86.

USABC goals are system level goals; cell level goals can be derived from the system goals by using translation factors appropriate for the application, for example cells may comprise 50% of the weight, volume, and cost for a LEESS system, and up to 70% for an EV system. Appropriate factors can be obtained from the USABC.

All parameters should be determined using USABC test methods, as described in the test manuals available on the USABC website, and should be carried out on both a control and the improved electrolyte. Additional tests should be added to demonstrate the improvement. For example, if the electrolyte provides high temperature stability, then the calendar life test should be carried out at a higher temperature. Or if the electrolyte provides high voltage stability, then the calendar life test should be carried out at a higher voltage.

Actual program goals depend on the specific target application and can be calculated from the system goals listed on the USABC web site for the target application. System goals can be scaled to cell level using appropriate factors included on the web site. Life tests are measured using three replicates for each test condition. Calendar life tests require three temperatures in order to estimate an activation energy and use time/temperature superposition to estimate calendar life.

APPENDIX C. USABC Gap Chart for Advanced Electrolytes[1,2]

Parameter		Unit	USABC Goal	Present Status
Electrochemical Stability (100 μA/cm^2 threshold)	Upper Voltage	V vs. Li/Li$^+$	5	
	Lower Voltage		0	
Specific Conductivity	at 30°C	mS / cm	>12	
	at -30°C		>4	
Lithium Transference Number			>0.35	
Viscosity	at 30°C	cP	<5	
	at -30°C		<20	
Impurities	H_2O	ppm	<20	
	HF		<50	
Purity of Each Component		%	≥99.99	
Vapor Pressure (25°C)		mm Hg	<1	
Flashpoint		°C	>100	
Lithium Salt Solubility		M	>1	
Cost @ a yearly production volume no more than 20,000 ton/year		$/kg	<10	

[1] It is expected that one or more stretch goals from the gap chart will be met or exceeded, with the balance demonstrating performance no less than present state of the art.

[2] This gap chart will be used as a tool for tracking the progress of development programs and is provided here for information purposes only.