



SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Recommended Practice for Determining Material Properties
of Li-Battery Cathode Active Materials

RATIONALE

The rapid electrification of the automobile market has spurred an increase in the production of lithium ion batteries. The cathode active material—the energy storage material on the positive electrode of the battery—is a critical component of the battery, occupying a substantial fraction of its weight and cost. Accordingly, understanding the cathode active material's chemical and physical properties are vital to engineering an appropriate battery and, ultimately, vehicle. In this SAE Recommended Practice, a set of characterization methods is provided to evaluate different cathode active materials under a uniform framework. Pass/fail criteria is not included in this document as it is under the discretion of the individual manufacturer to establish their internal benchmarks.

INTRODUCTION

The most prevalent lithium ion battery cathode active materials are transition metal oxides. These materials can be divided into two classes:

- Layered structures (e.g., LiNiO_2 [identified as LNO], $\text{LiNi}_x\text{Co}_y\text{Al}_z\text{O}_2$ [identified as NCA], and $\text{LiNi}_x\text{Mn}_y\text{Co}_z\text{O}_2$ [identified as NMC], where x, y, and z sum to 1), and
- Non-layered structures such as olivine (e.g., LiFePO_4 [identified as LFP]) and spinel (e.g., $\text{Li}_4\text{Ti}_5\text{O}_{12}$ [identified as LTO]).

While differentiation between these materials is beyond the scope of this document, the market is generally advancing towards high energy materials utilizing elements with less market volatility.

Due to the difference in chemical composition and synthesis conditions, the chemical and physical properties of the cathode active material can vary substantially. Accordingly, in this document, a set of characterization techniques is provided which can be applied to all cathode active materials. A manufacturer can use these techniques to obtain material parameters necessary to evaluate a supplier, set benchmarks for internal engineering, and for product road mapping.

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Documents

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TABLE OF CONTENTS

1.	SCOPE.....	3
2.	REFERENCES.....	3
2.1	Applicable Documents	3
2.1.1	SAE Publications.....	3
2.1.2	ASTM Publications.....	3
2.1.3	External Organizations.....	4
3.	DEFINITIONS	4
4.	SAMPLE PREPARATION.....	4
5.	PHYSICAL PROPERTIES	4
5.1	Bulk and Tap Density	4
5.2	Surface Area	4
5.3	Particle Size (Primary and Secondary Particle, Distribution).....	4
6.	THERMAL PROPERTIES.....	4
6.1	Thermal Stability (Powder Only; Powder in Electrolyte)	4
6.2	Thermogravimetric Analysis (TGA) (Not to be Used with Electrolyte).....	5
6.3	Suggested Test Parameters	5
6.4	Differential Scanning Calorimetry (DSC)	5
6.4.1	Samples without Electrolyte	5
6.4.2	Suggested Test Parameters	5
6.4.3	Samples with Electrolyte	5
6.4.4	Test Parameters.....	6
6.5	Accelerating Rate Calorimetry (ARC)	6
7.	CHEMICAL PROPERTIES	6
7.1	Chemical Content (Li, Transition Metal, Ratio of Li/TM, Impurities)	6
7.2	Residual Lithium Content.....	6
7.3	Water Content	7
7.4	pH.....	7
7.4.1	Equipment and Supplies	7
7.4.2	Calibration of pH Meter	8
7.4.3	Sample Preparation and Measurement	8
8.	CRYSTALLOGRAPHIC AND MORPHOLOGICAL PROPERTIES	8
8.1	Phase Purity/Crystallographic Structure (e.g., XRD; refer to Rietveld)	8
8.2	Morphology (Primary and Secondary Particle) (Method ex = SEM).....	9
9.	ELECTRICAL PROPERTIES.....	9
10.	EXAMPLE REPORT TABLE.....	10
11.	NOTES	10
11.1	Revision Indicator.....	10
Table 1	Example report table	10

1. SCOPE

This SAE Recommended Practice provides a set of test methods and practices for the characterization of lithium ion battery cathode active material.

It is beyond the scope of this document to establish criteria for the test results, as these are usually established between the vendor and customer. It should be noted that materials properties can vary substantially between classes of materials (e.g., LNO and LFP) and caution should be exercised when attempting to directly compare their chemical and physical properties. While these distinctions are important for the manufacturer, this document focuses on the techniques to measure the materials properties and not their absolute or relative values. Future materials such as solid-state batteries and sulfides are beyond the scope of this document.

It is beyond the scope of this document to examine the rheological properties of the cathode material dispersed in a coating slurry since such properties are influenced by the conductive additive, binder, and solvent, which are determined by the coating process.

It is beyond the scope of this document to examine the electrochemical properties of cathode materials since these are influenced by electrode and ultimately cell design. Due to the difference in electrical and electrochemical properties of the cathode material, it is unrealistic to establish an electrode and cell design that would justly compare different cathode active materials.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1715 Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology

SAE J1715/2 Battery Terminology

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM C1274-10 Standard Test Method for Advanced Ceramic Specific Surface Area by Physical Adsorption

ASTM D618-00 Standard Practice for Conditioning Plastics for Testing

ASTM D6304-07 Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils and Additives by Coulometric Karl Fischer Titration

ASTM D7481-09 Standard Test Method for Determining Loose and Tapped Bulk Densities of Powders Using a Graduated Cylinder

ASTM D7785-12 Standard Test Method for Water in Lint Cotton by Oven Evaporation Combined with Volumetric Karl Fischer Titration

ASTM E70-07 Standard Test Method for pH of Aqueous Solutions with Glass Electrode

ASTM E203-08 Standard Test Method for Water Using Volumetric Karl Fischer Titration