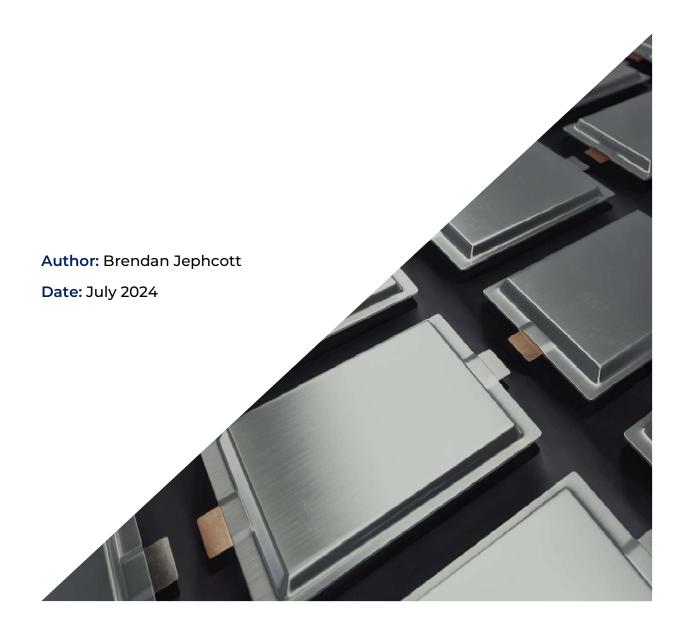
# SOLID-STATE LITHIUM-ION BATTERY

**Market Research Report** 



#### **Table of Contents**

Exec	utive	e Summary	2
1.0	In	troduction	16
1.1		Development History	16
1.2	<u> </u>	Working Principal	18
1.3	5	Component Materials	21
1.4	<b>,</b>	Product Performance	21
	1.4.1	High Energy Density	21
	1.4.2	Longer Lifetime	22
	1.4.3	High Safety	22
1.5	5	Performance Comparison to Traditional Liquid Lithium-ion Batteries	24
1.6	5	Government Development Goals	27
	1.6.1	China	27
	1.6.2	Japan	28
	1.6.3	South Korea	29
	1.6.4	United States	29
	1.6.5	Germany	30
1.7	7	Research and Development	30
	1.7.1	China	33
	1.7.2	Japan	34
	1.7.3	South Korea	35
	1.7.4	United States	35
	1.7.5	France	35
	1.7.6	Germany	35
2.0	Sc	olid-State Battery Component Materials	35
2.1	l	Solid Electrolyte Material	36
	2.1.1	Polymer Electrolyte	42
	2.1.2	Oxide Electrolyte	46
	2.1.3	Sulfide Electrolyte	53
	2.1.4	Halide Electrolyte	56
2.2	2	Cathode Material	58
2.3	3	Anode Material	59
2.4	4	Separator Material	60
3.0	Sc	olid-State Battery Principal Production Methods	61
3.1	l	Solid Electrolyte Separator Production Methods	62
	3.1.1	Wet Processing	62
	3.1.2	Dry Extrusion (Solvent-free) Processing	62
	3.1.3	Powder-based Processing	63
3.2	2	Cathode Production Methods	63

3	3.2.1 Wet Processing	63
3.	3.2.2 Dry Processing	65
3.3	Anode Production Methods	66
3	3.3.1 Li Metal Anodes	66
3.	3.3.2 Graphite/Silicon Anodes	67
3.4	Solid-State Battery Manufacturing Process	67
3.	Electrode and Electrolyte Separator Production	68
3	3.4.2 Cell Assembly	69
3	3.4.3 Cell Finishing	70
3.5	Compatibility Between Component Materials	71
4.0	Industry Development Trends	73
4.1	Short Term Development	73
4.2	Short Term Development Opportunities	74
4.3	Development trends Out To 3030	79
5.0	Cash Cost Forecast	81
6.0	Global Development and Commercialisation	83
6.1	China	85
6.2	Taiwan	104
6.3	Japan	108
6.4	South Korea	112
6.5	United States	114
6.6	France	125
7.0	Market Size and Potential	126
Refere	ences	127
Discla	simer	134

#### **Figures**

Figure 1: Development history of lithium-ion electric energy density from 1990-2025 (unit: Wh /kg)	18
Figure 2: Traditional liquid electrolyte lithium-ion battery vs solid-state electrolyte lithium-ion battery	
Figure 3: Solid-state lithium-ion battery configuration	19
Figure 4: Energy density comparison of traditional lithium-ion batteries and solid-state batteries	24
Figure 5: Size of lithium-ion batteries vs lithium-ion solid state battery	
Figure 6: Support plans for solid-state lithium-ion batteries in various countries (partial)	27
Figure 7: Patents for solid state batteries (by countries, as of 2018)	
Figure 8: Patents for solid state batteries and all solid-state batteries	
Figure 9: No. of patents in the field of solid-state batteries (by country)	
Figure 10: Holders of solid-state battery patents (by organisation)	
Figure 11: Development of solid-state electrolytes	
Figure 12: Radar charts for electrochemical and physical properties of oxide, sulphide, LIPON and poly	
solid electrolytes	
Figure 13: Electrochemical windows and lithium-ion conductivity of polymer, oxide and sulphide s	
electrolytes	
Figure 14: Schematic illustration of two types of lithium-ion conduction mechanisms for SPEs	
Figure 15: Radar chart of the properties of polymer electrolytes	
Figure 16: Decomposition temperatures of different solid-state electrolytes and commercial lic	
electrolytes	
Figure 17: Radar chart of the properties of oxide electrolytes	
Figure 18: (A) Crystal structure diagram of LLZO (B) Research time line of garnet type electrolyte	
Figure 19: (A) Crystal structure diagram of perovskite (Li3xLa2/3xTiO3) (B) Research time line of LLTO	
Figure 20: (A) Crystal structure diagram of NASICON (B) Research time line of NASICON	
Figure 21: (A) Crystal structure diagram of anti-perovskite Li <sub>3</sub> OCI	
Figure 22: Radar chart of the properties of sulphide electrolytes	
Figure 23: (a) skeleton structure and lithium ions involved in ion conduction in Li10GeP2S12 (b) framev	
structure (c) lithium ion conduction pathway	
Figure 24: (a) Different structures of halide SSEs with dilavent metal elements, (b) olivine type Li <sub>2</sub> MCI.	
normal spinel type Li <sub>2</sub> MCl <sub>4</sub> , (d) inverse spinel type Li <sub>2</sub> MCl <sub>4</sub> , and (e) Sukuzi type Li <sub>6</sub> MCl <sub>8</sub>	
Figure 25: Lithium dendrite formation on the surface of lithium metalmetal	
Figure 26: Cathode production process and equipment	
Figure 27: Dry battery electrode preparation processes	
Figure 28: Processing approaches for lithium metal and silicon/graphite anodes	
Figure 29: Solid battery cell production process flowsheet	
Figure 30: Principle of isostatic pressing technology and Samsung WIP solution	
Figure 31: Three different isostatic pressing process types and their comparison	
Figure 32: Comparison of traditional battery packaging (left) and "bipolar" structure battery (right)	
Figure 33: CASIP inauguration	83
Figure 34: Distribution of solid-state lithium-ion battery organisations (Partial)	
Figure 35: Auto companies and partnerships with solid-state lithium-ion battery companies	
Figure 36: CATL condensed battery launch in April 2023	
Figure 37: Funeng Technology semi-solid battery products	
Figure 38: Ganfeng Lithium solid state lithium-ion battery product	
Figure 39: Dongfeng E70 electric vehicle with Ganfeng Lithium solid-state battery installed	
Figure 40: Celes Group SERES-5 equipped with Ganfeng Lithium's solid-state battery	
Figure 41: Guoxuan Hi-Tech solid-state battery technology roadmap	
Figure 42: Left: Qingtao Energy cathode and anode production process, Right: Solid-state lithium bat	
production process	
Figure 43: Qingtao Energy solid-state lithium power battery products	
Figure 44: Qingtao Energy solid-state lithium digital battery products	
Figure 45: Qingtao Energy solid-state lithium special energy storage battery productsproducts	
Figure 46: Qingtao Energy solid-state lithium battery cell products	
Figure 47: Qingtao Energy solid electrolyte material products	99

Figure 48: Qingtao Energy composite separator material products	99
Figure 49: Pure electric prototype vehicle equipped with Qingtao solid-state battery system	100
Figure 50: Weilan New Energy solid state lithium-ion battery productsproducts	
Figure 51: ProLogium building, Taiwan	105
Figure 52: ProLogium lithium ceramic battery products	106
Figure 53: ProLogium BiPolar⁺ solid-state battery pack	107
Figure 54: Logithium rotary web printing machine	107
Figure 55: Mitsui Kinzoku Argyrodite-type sulfide solid electrolyte (A-SOLiD)	109
Figure 56: TDK CeraCharge™ Solid-State Battery cross-section (Schematic Diagram)	111
Figure 57: TDK CeraCharge™ Solid-State Battery	111
Figure 58: Toho Titanium LLTO powder	
Figure 59: Samsung sulfide all-solid-state battery (schematic)	113
Figure 60: Samsung 0.6 Ah class prototype pouch cell	113
Figure 61: BrightVolt PME™ Process Steps	115
Figure 62: PolyPlus glass protected Li metal battery (schematic)	
Figure 63: QuantumScape Zero Li Anode-free Architecture	118
Figure 64: QuantumScape flexible oxide ceramic separator (left), single-layer solid-state battery of	cell sample
(right)	
Figure 65: SES strategic investors	120
Figure 66: SES A-sample joint development agreements	121
Figure 67: Comparison of SES electrolyte (right) and a standard electrolyte found in today's lithiu	m-ion cells
(left)	122
Figure 68: Left: Li-Metal cells made with conventional electrolyte, Right: Li-Metal cells made with	SES liquid
electrolyte	123
Figure 69: Solid Power product roadmap	
Figure 70: Blue Solutions LMP® battery schematic	
Figure 71: Global solid-state battery demand forecast (2023 to 2030E)	127

#### **Tables**

Table 1: Solid-state lithium-ion battery development timeline	16
Table 2: EV-Type LIB energy density planning (by country)	18
Table 3: Types of lithium-ion batteries and their electrolyte characteristics	20
Table 4: Comparison of the properties of liquid lithium batteries, semi-solid batteries and all-solid ba	itteries
Table 5: Lithium-ion battery accidents	
Table 6: Basic properties of various solvents	
Table 7: Performance comparison between liquid lithium-ion batteries and solid-state batteries	
Table 8: China solid-state lithium-ion battery industry development roadmap	
Table 9: Auto companies R&D progress of solid-state batteries	
Table 10: China research progress in application of solid-state batteries	34
Table 11: Types of solid-state electrolyte material	38
Table 12: Performance of different solid-state electrolytes for lithium-ion batteries	
Table 13: Components in solid polymer electrolytes	
Table 14: Performance comparison of modified polymer solid electrolyte	
Table 15: Disadvantages of polymer electrolytes and possible solutions	
Table 16: Disadvantages of oxide electrolytes and possible solutions	
Table 17: Ion conductivity of common oxide electrolytes	
Table 18: Ionic conductivity of common sulfide electrolytes	
Table 19: Disadvantages of sulfide electrolytes and possible solutions	
Table 20: Comparison of different solid-state battery cathode materials	
Table 21: Comparison of different solid-state battery anode materials	
Table 22: Comparison polymer, oxide and sulfide solid-state battery component production methods	
Table 23: Compatibility of solid electrolytes with cathode and anode active materials	
Table 24: China auto company car models equipped with semi-solid-state batteries	
Table 25: R&D progress of electrolyte additives by Chinese companies	
Table 26: R&D Progress of gel electrolyte by Chinese companies	
Table 27: R&D progress by separator in Chinese companies	
Table 28: R&D progress of pre-lithiation by Chinese companies	
Table 29: R&D progress of cathode modification by Chinese companies	
Table 30: Solid-state battery company announcements	
Table 31: Cash cost — NCM811 + graphite anode + conventional system (1USD:7CNY)	
Table 32: Cash cost — NCM811 + graphite anode + semi-solid system (IUSD:7CNY)	
Table 33: Cash cost — NCA high nickel + graphite / silicon carbon anode + semi-solid system (IUSD	
Table 34: Industrialisation progress of Ganfeng Lithium solid-state batteries	
Table 35: Ganfeng Lithium solid state lithium-ion battery productproduct	
Table 36: Ganfeng Lithium solid state lithium metal cell product	
Table 37: Qingtao Energy commercialisation development history	
Table 38: SVOLT products and technical advantages	
Table 39: Weilan New Energy commercialisation development historyhistory	
Table 40: Weilan New Energy solid-state battery technology	
Table 41: Weilan New Energy solid state lithium-ion battery product specifications	
Table 42: Weilan New Energy solid state battery module specifications	
Table 43: SES Cell Data Comparison for Li-Metal Cells	123