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固态电池技术取得“突破”，半固态电池实装应用，产业化按下加速键 One “Breakthrough” in Solid-State Battery Technology was Realized, and Semi-Solid-State Batteries have Been Put into Use, in Which the Industrialization Progress Got Accelerated

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热点速评 Flash Analysis

(Please see APPENDIX 1 for English summary)

丰田汽车作为全球拥有固态电池相关专利最多的车企，近日对外宣布预计最早于 2027 年向市场投放配备“全固态电池”的纯电动汽车。近日，固态电池产业化发展又一次受到资本市场的关注。丰田汽车对外宣布了其在制造固态电池技术上的重大突破。丰田公司碳中和研发中心总裁海田敬二表示，已经找到了新的方法，可以制造出充电 10 分钟续航里程 1200 公里的固态电池，延长至现有 EV 装配电池的 2.4 倍，而且通过简化制造固态电池所用材料的生产过程，丰田制造的固态电池的体积、重量、价格较现有电池都有望可以减半。此外，丰田宣布将在 2027-2028 年实现全固态电池技术商业化，并向市场投放配备全固态电池的纯电动汽车。丰田已提出扩充 EV，虽然 2022 年的世界销量只有大约 2 万辆，但丰田提出“2026 年之前达到年销量 150 万辆，2030 年之前实现年销量 350 万辆”。

固态电池优势显现，安全性和能量密度在理论上远超目前 EV 主流的液态锂离子电池。 固态电池指采用固态电解质的锂离子电池。与目前主流的液态锂离子电池的主要不同在于电解质，固态电池采用锂、钠制成的玻璃化合物为传导物质，具有锂离子传输功能和隔膜功能，可用来替代液态锂离子电池中由溶剂、锂盐、添加剂组成的电解液。固态电池的优势包括充电速度更快、能量密度大幅提升、安全性更高。在能量密度方面，固态电池若采用高镍三元+金属锂的材料体系，正负极间距将大幅缩减，电芯能量密度有望超过 400Wh/kg，续航将获得重大提升。因此固态电池约是目前铁锂电池的 2 倍，对应续航 1000-1500km；磷酸铁锂电池的能量密度在 200wh/kg 左右，对应续航 300-500km；三元电池的能量密度在 250wh/kg 左右，对应续航 500-700km。在安全方面，液态锂电池电解液中的有机溶剂易燃烧、腐蚀性较高，而且抗氧化性较差，无法解决锂枝晶问题，同时存在热失控风险，分解温度约为 200°C。而固态电池采用固态电解质将易燃的电解液替代，基本上避免锂枝晶导致电池内部短路；固态电池具有更好的热稳定性，其电解质不可燃，无腐蚀，无挥发，分解温度大幅提升，因此能够在更高倍率和更高温度运行。

固态电池作为一种使用固态电极和电解质的电池，核心技术待解，其研发难度和成本远超目前 EV 主流的液态锂离子电池。 与液态锂离子电池采用液体或凝胶形态的电解质不同，固态电池需要解决电极与电解质之间的固-固接触，离子导电率低、界面稳定性差、循环寿命短等问题。固态电池导电率最高的硫化物电解质的生产需要将粉末材料通过高压一次性压实，以保证电池内的固体材料界面能合理接触。理想压力条件达到 100 个大气压以上，否则难以保证固态电解质界面的一致性。另一方面，固-固接触为刚性接触，在固态电池的循环过程中，容易造电极颗粒之间以及电极颗粒与电解质接触变差，造成应力堆积，导致电化学性能衰减，甚至出现裂缝，从而导致容量迅速衰减和循环寿命缩短。因此，解决固-固接触问题，提高电极与电解质之间的界面接触质量，是固态电池研发过程中必须要克服的重要难题。此外，全固态电池技术尚处起步阶段，短期内成本无法大幅下降，迈向大规模商业化应用存在一定距离。

中国动力电池企业需重视丰田在固态电池技术上的突破，加速向新能源产业下一阶段迈进。 在中国，因为技术难度和生产成本，电池企业目前普遍选择“从液态到半固态再到固态”的渐进式发展路线。中国在新能源汽车液态电池领域取得领先，但总体在固态电池的研发进度与重视程度上还不够。在现阶段，部分厂商对固态电池商用化路线保持谨慎的态度并表示，首先，国内主流的电动汽车首先看中的是成本，固态电池

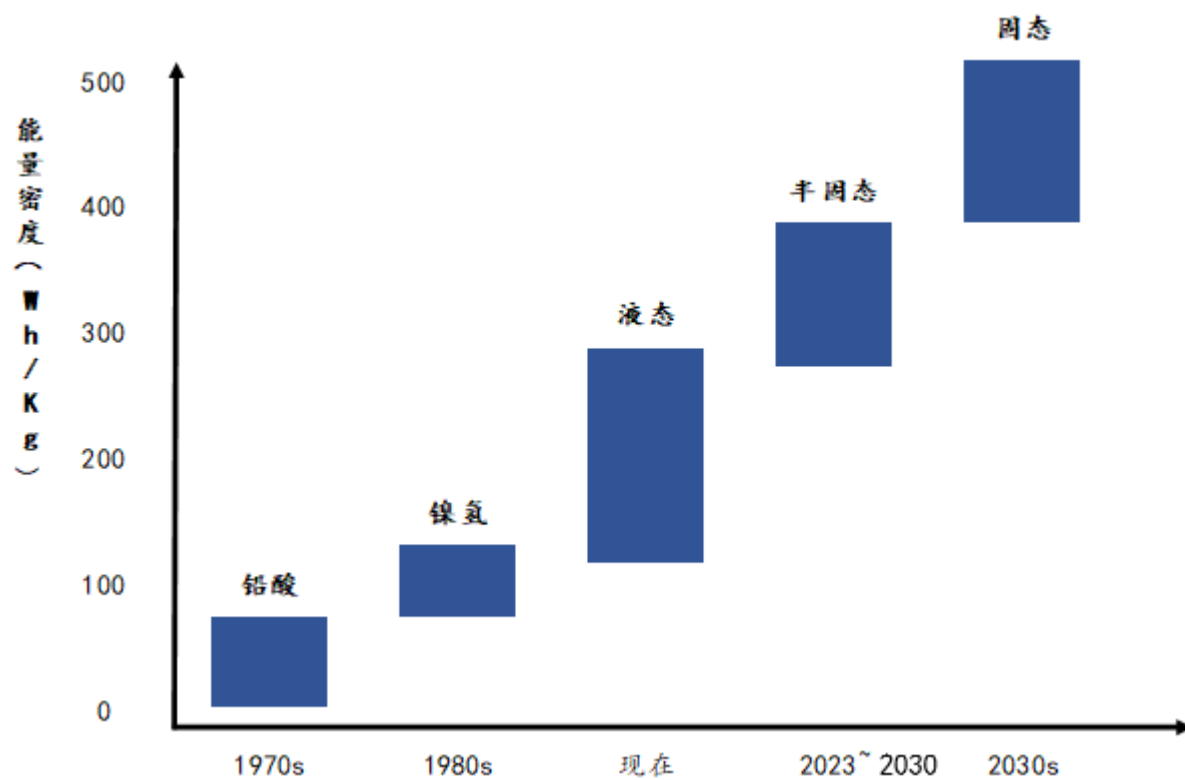
的制造成本较高，目前难以与传统液态锂离子电池相比，未来固态电池路线是否能够帮助车场降低实际成本还有待考量。其次，固态电池的生产工艺和设备还需要进一步完善和优化。另外，固态电池的长期稳定性和耐久性仍需进一步验证。然而中国科学院院士、清华大学教授欧阳明高曾指出，全固态电池技术虽然目前仍然面临着很多挑战，但仍然是我们值得去追求的目标。这个目标不是短期的，可以看作是面向 2030 年值得创新的目标，关乎中国在新能源领域的综合实力，同时强调要对这一技术路线高度重视。

从半固态到固态电池迭代，国内车企和电池制造商提速研发并推进相关产业化布局。半固态电池技术是固态电池技术的一个过渡阶段，目前已经开始量产应用。国内部分车企已经推出了搭载半固态电池的车型，如东风 E70 系列与岚图追风系列等，赣锋锂业三元固液混合锂离子电池也被应用于纯电动 SUV 赛力斯 SERES-5。此前，蔚来、长安深蓝、赛力斯、岚图等多家新能源车企披露了半固态电池装车的进展。随着技术的不断成熟，半固态电池技术预计将逐渐向固态电池技术过渡，成为电动汽车的主流能源储存技术之一。当前，固态电池技术的发展已经引起了全球各大汽车厂商和电池制造商的广泛关注和投入。除了丰田汽车外，国内的比亚迪、上汽集团等汽车企业，以及宁德时代、当升科技、赣锋锂业等锂电企业也在固态电池领域加速探索和研发。由于这些企业所处细分赛道不同，主营业务有所差异，因此发展固态电池的参与程度也有所不同。此外，国内专家表示，中国的固态电池当前处于起步阶段，产业化仍需一定时间。预计 2030 年中国固态电池出货量预计将达到 251.1GWh，2030 年市场空间有望达 200 亿元。

投资建议：中国量产全固态电池是新能源板块的长期战略目标，预期在 2030 年左右实现产业化，仍需 5-10 年的时间。现阶段，重点关注在半固态电池领域加大研发力度且技术领先的代表电池厂商。建议关注的标的：宁德时代、赣锋锂业、亿纬锂能、国轩高科等。

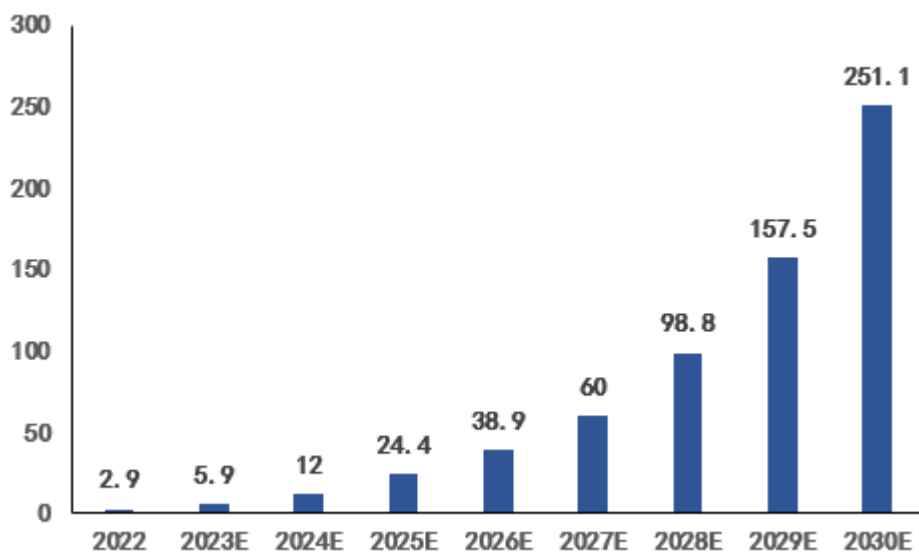
风险提示：上游电池厂商对固态电池的技术研发突破不及预期、下游市场运用进展低于预期。固态电池产业化进度不及预期，锂离子电池技术路线变更或其他新技术持续迭代，测算结果基于一定假设导致的结果不确定性的风险。

图表 1: 电池能量密度发展趋势



资料来源: QuantumScape, HTI

图表 2: 2022-2030 年中国固态电池出货量趋势预测 (GWh)



资料来源: 中商情报网, HTI

图表 3: 液态/半固态/半液态指标、材料对比

指标/材料	液态	半固态	全固态
液体含量	20wt%	5-10wt%	0wt%
能量密度	300Wh/Kg	400Wh/Kg	500Wh/Kg
电解液/质	有机溶剂+锂盐	复合电解质	硫化物、氧化物、 聚合物
正极	三元/铁锂	高镍三元/铁锂	高镍多元/富锂锰基
负极	石墨	锂碳复合	金属锂
隔膜	传统隔膜	隔膜+氧化物涂覆	无隔膜
包装材料	铝壳	铝塑膜	铝塑膜

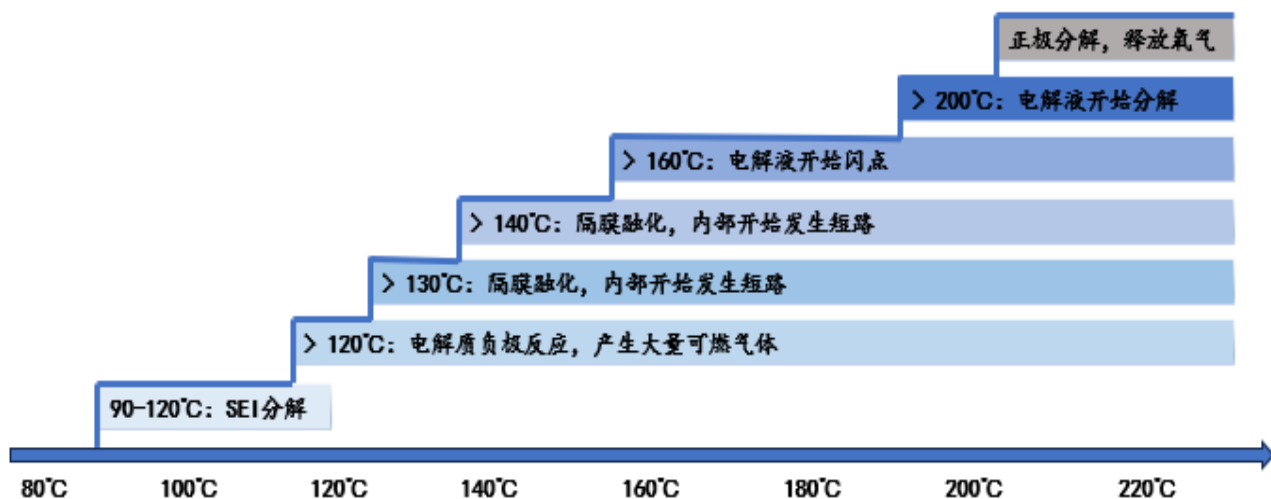
资料来源: OFweek 锂电网, HTI

图表 4: 正极/负极材料主要原材料主要指标对比

指标	理论克容量 (mAh/g)	首次效率 (%)	电压平台 (V)
正极材料			
锰酸锂	148	≥90%	3.0~4.3
磷酸铁锂	170	≥85%	2.5~4.1
钴酸锂	274	≥80%	2.75~4.3
三元NCM	278	≥85%	3.0~4.3
三元NCA	279	≥86%	2.7~4.2
富锂锰基	458	≥80%	2.0~4.8
负极材料			
石墨	340~360	90-92%	0.2
硅基	1520~4200	60-92%	0.35~0.5
锂金属	3860		

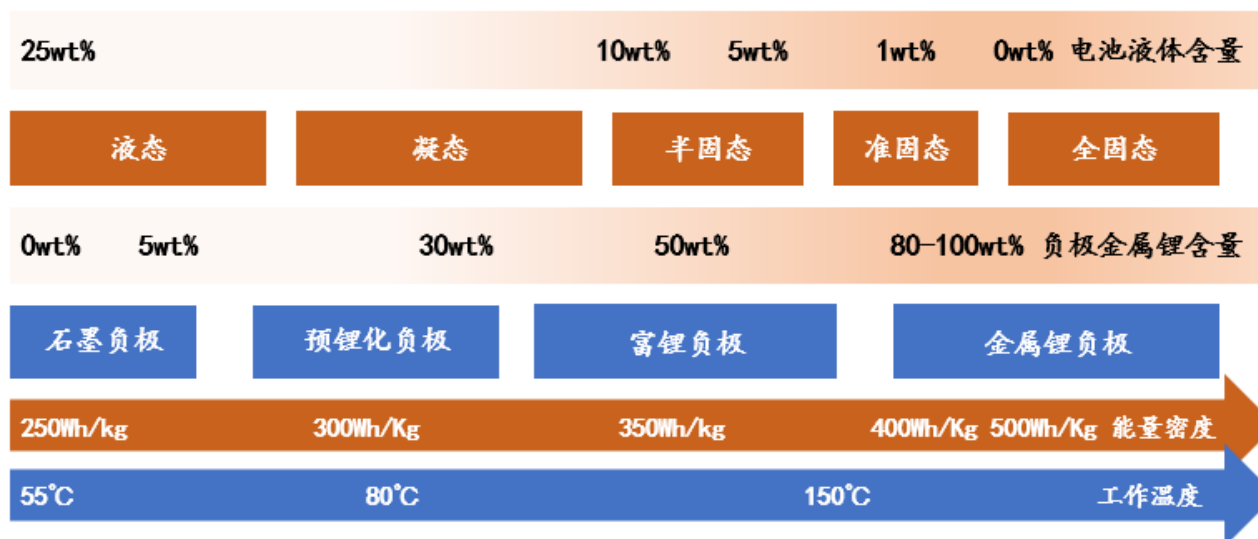
资料来源: OFweek 锂电网, HTI

图表 5: 液态锂离子电池受热不稳定性



资料来源: 卫蓝新能源, HTI

图表 6: 液态-固态电池材料体系及能量发展趋势一览



资料来源: 《固态锂电池发展愿景和策略》, HTI

APPENDIX 1

Summary

Recently, the industrialization of solid-state batteries has once again attracted the attention of the capital market. Toyota's research and development center said that it has found a new way to make a solid-state battery with a 10-minute battery range of 1,200 kilometers, extending to 2.4 times the existing EV assembly battery, and by streamlining the production process of the materials used in solid-state battery batteries, Toyota's solid-state battery is expected to reduce the volume, weight and price of existing batteries by half. In addition, Toyota announced that it will commercialize all-solid-state battery technology in 2027-2028, and it is expected that pure electric vehicles equipped with all-solid-state battery cells will be placed on the market.

Solid-state batteries refer to lithium-ion batteries using solid electrolytes by essence, and the advantages include faster charging speed, significantly increased energy density, and greater safety. In terms of energy density, the solid-state battery is 2 times that of the current lithium iron battery. And the solid-state battery employs a high-nickel ternary + lithium metal material system, it will greatly reduce the positive and negative electrode spacing, so the energy density of the cell is expected to exceed 400Wh/kg, and the battery life will be greatly improved. In terms of battery safety, solid-state batteries replace combustible liquid electrolytic organic solvents, basically avoiding lithium dendrites leading to internal short circuit of the battery; solid-state batteries have better thermal stability, and their media is non-combustible, non-corrosive, so they can operate at higher power rates and higher temperatures.

The research and development of solid-state battery core technology is far more difficult than liquid lithium-ion batteries. Solid-state batteries need to solve problems such as low ionic conductivity, poor interface stability, and short cycle life. The contact between solid electrodes and solid electrolytes is rigid, which is possible to cause the contact to deteriorate during the cycle of solid-state batteries, resulting in sharp capacity attenuation and decreased cycle life. However, the technology to solve the problem of low solid-solid contact quality has not been discovered.

China's solid-state battery industry is still in its early stages, but several automakers and battery manufacturers are already exploring and researching solid-state battery technology from semi-solid phase. While certain companies remain cautious due to the high manufacturing costs and the need for further optimization of production processes, some Chinese automakers have already introduced vehicles equipped with semi-solid-state batteries, which is regarded as a transitional technology between liquid lithium-ion batteries and solid-state batteries. As the technology continues to mature, semi-solid-state batteries are expected to become one of the mainstream energy storage technologies for electric vehicles.

From semi-solid state to solid-state batteries, Chinese automakers and battery manufacturers are speeding up their research and development efforts and promoting related industrial layouts. The development of solid-state battery technology has attracted widespread attention and investment from global automakers and battery manufacturers. Besides Toyota, Chinese automakers such as BYD and SAIC Group, as well as lithium battery companies such as CATL, Easpring Technology, and Ganfeng Lithium, are accelerating their exploration and research in the solid-state battery field.

In addition, experts indicate that China's solid-state battery industry is still in its initial stages, and industrialization will take some time. It is estimated that China's solid-state battery shipments will reach 251.1 GWh, and the market size will reach 20 billion yuan by 2030.

附录 APPENDIX

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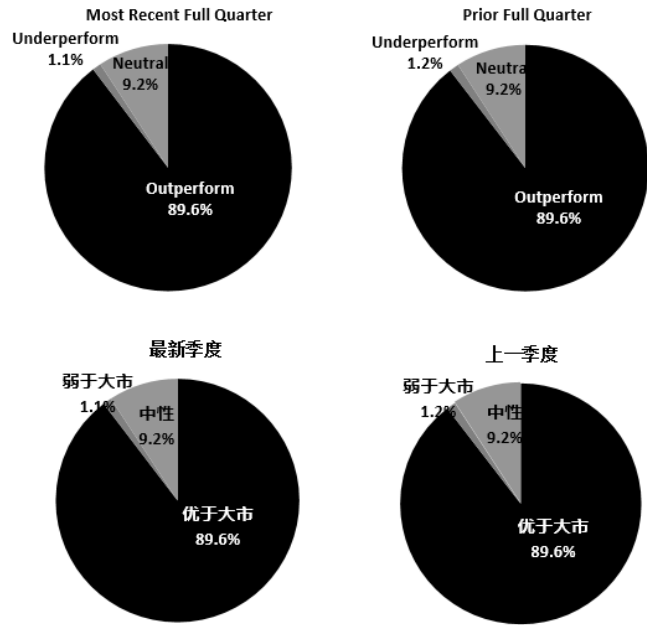
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Underperform: The stock's total return over the next 12-18 months is expected to be below the return of its relevant broad market benchmark, as indicated below.

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买入, 未来 12-18 个月内预期相对基准指数涨幅在 10%以上, 基准定义如下

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Haitong International Equity Research Ratings Distribution, as of Jun 30, 2023

	Outperform	Neutral (hold)	Underperform
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IB clients*	4.7%	5.6%	10.0%

*Percentage of investment banking clients in each rating category.

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