High Throughput Experimental Solutions for Solid State Lithium Ion Battery Research

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Solid State Lithium Ion Battery

High Throughput Methodology

Li₁₀GeP₂S₁₂

P₂S₅

GeS₂

Li₂S

Li₂O

Al₂O₃

PO₄³⁻

GeO₂

Li₂GeP₂S₁₂

LAGP

Li₂O

Al₂O₃

PO₄³⁻

GeO₂

Li₂O

SiO₂

P₂O₅

GeO₂

Li₂O

SiO₂

P₂O₅

GeO₂

Li₂GePO₄₃

LICGC

High Throughput
High Throughput Methodology

Since 1994

Electrolyte Powder + Heat Process + Pressing + Characterization + Electrochemical Testing = 75.5 hour / 1 test

High Throughput

12 hour + 12 hour + 0.5 hour + 1 hour + 50 hour = 75.5 hour / 16 tests

LAGP

Li$_2$O Al$_2$O$_3$

PO$_4^{3-}$ GeO$_2$
Solid Inorganic Electrolyte

**Powder Dispensing**
- 4-source
- 0.1 - 20 g dry powder
- Parallel: 4
- Total: 32
- Ar glove-box

**Ball Milling**
- 16-container
- Up to 2 ml sample
- Parallel: 16
- Total: 16
- Ar glove-box

**Pellet Press**
- 16-channel, 10 Ton
- Up to 25 mm Dia. die
- Parallel: 1
- Total: 16

**Heat Treatment**
- 16-channel, 1700 °C, with quenching
- Up to 10 g sample
- Parallel: 16
- Total: 16

**Polishing**
- 16-channel, 20 kg
- Up to 25 mm Dia. die
- Parallel: 16
- Total: 16
Novel Sintering Technique

Spark Plasma Sintering

Cold Sintering Process

LAGP Pellet


Spark plasma sintered/synthesized dense and nanostructured materials for solid-state Li-ion batteries. R. Kali, A. Mukhopadhyay, J. Power Sources, 247, 2014
Composite Electrolyte

LAGP-LiTFSI-PEO Flexible Solid Electrolyte

Liquid Dispensing
- 12-source
- 20 - 1000 ul fluid
- Parallel: 1
- Total: 96
- Ar glove-box ✓

Mixing
- 6-channel
- Up to 5 ml high viscosity fluid
- Parallel: 6
- Total: 6

Coating
- 4-channel
- 35 mm coating (150 mm total)
- Parallel: 4
- Total: 4
- Ar glove-box ✓
Composite Electrolyte

Liquid Dispensing
12-source
20 - 1000 ul fluid
Parallel : 1
Total : 96
Ar glove-box √

Mixing
6-channel
Up to 5 ml high viscosity fluid
Parallel : 6
Total : 6

Coating
4-channel
35 mm coating (150 mm total)
Parallel : 4
Total : 4
Ar glove-box √

Hot Calendar / Press
4-channel
200 mm total width
Parallel : 4
Total : 4
Ar glove-box √

Die Cutting
4-channel
20 mm Dia. die cutting
Parallel : 4
Total : 8
Ar glove-box √
Characterization and Testing

**XRF with 32-Position Stage**

- Up to 20 mm Dia. sample
- Parallel: 1
- Total: 32
- Glove-box ✓

**Crimper**

- Coin Cell Crimper
- Parallel: 1
- Total: 16
- Glove-box ✓

**Split Cell**
Conclusion

- High throughput experimental solutions increase productivity by 16 times

- Existing experimental techniques are modified for high throughput application and are commercially available

- Spark plasma sintering and cold sintering process enable reduced processing time and low production cost
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Thank you!

Any Question?

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