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Solid Electrolytes for Better Batteries: A Report on Current Research

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Image Source: https://www.smithsonianmag.com/smart-news/researchers-figured-out-how-stop-lithium-batteries-spontaneously-combusting-180955641/

Lithium-ion Battery Chemistry

- "A battery is a galvanic cell, or series of galvanic cells, that can be used as a portable, self-contained source of direct electric current."[1]
- Lithium-ion battery advantages vs. other chemistries[1]:
  - Large cell potential
  - Low mass
  - Hundreds of charge cycles
- Wet cells (liquid electrolyte)[2]

The Holy Grail: Solid-Electrolyte Lithium Batteries

- "Solid-state batteries are less likely to catch fire than lithium-ion batteries"[2]
- Shorter charging time[2]
- "Could allow companies to squeeze more battery cells into the same size pack"[2]

Research into New Solid Electrolytes

- Heri, J.; Syahrial, A.Z.; Sudaryanto.; Kartini, E. Synthesis and Electrochemical Characterization of New Li_2O-P_2O_5 Compounds for Solid Electrolytes. *Int. J. Technol.* [Online], **2017,** *8*, 1516-1524, https://www.researchgate.net/publication/322081690_Synthesis_and_Electrochemical_Characterization_of_New_Li2O-P2O5_Compounds_for_Solid_Electrolytes (accessed Oct 16, 2018).

- "In this study, new compositions of the xLi_2O-P_2O_5 compounds, where $1 \leq x \leq 2$, were prepared through solid-state reactions."[3]
  - Nonstoichiometric compounds: "any solid chemical compound in which the numbers of atoms of the elements present cannot be expressed as a ratio of small whole numbers"[4]

Research into New Solid Electrolytes: Synthesis Process

- Lithium carbonate (Li_2CO_3) and ammonium dihydrogen phosphate ($NH_4H_2PO_4$)[3]
  - "mixed using magnetic stirrers for two hours"[3]
  - ground in ceramic crucible with agate mortar for one hour[3]
  - Heated to 673 K for one hour to release H_2O, NH_3, CO_2 molecules[3]
  - Slowly heated to 923 K for four hours[3]
  - "quenched in demineralized water and smoothed in an agate mortar for one hour"[3]

Research into New Solid Electrolytes: Characterization Techniques

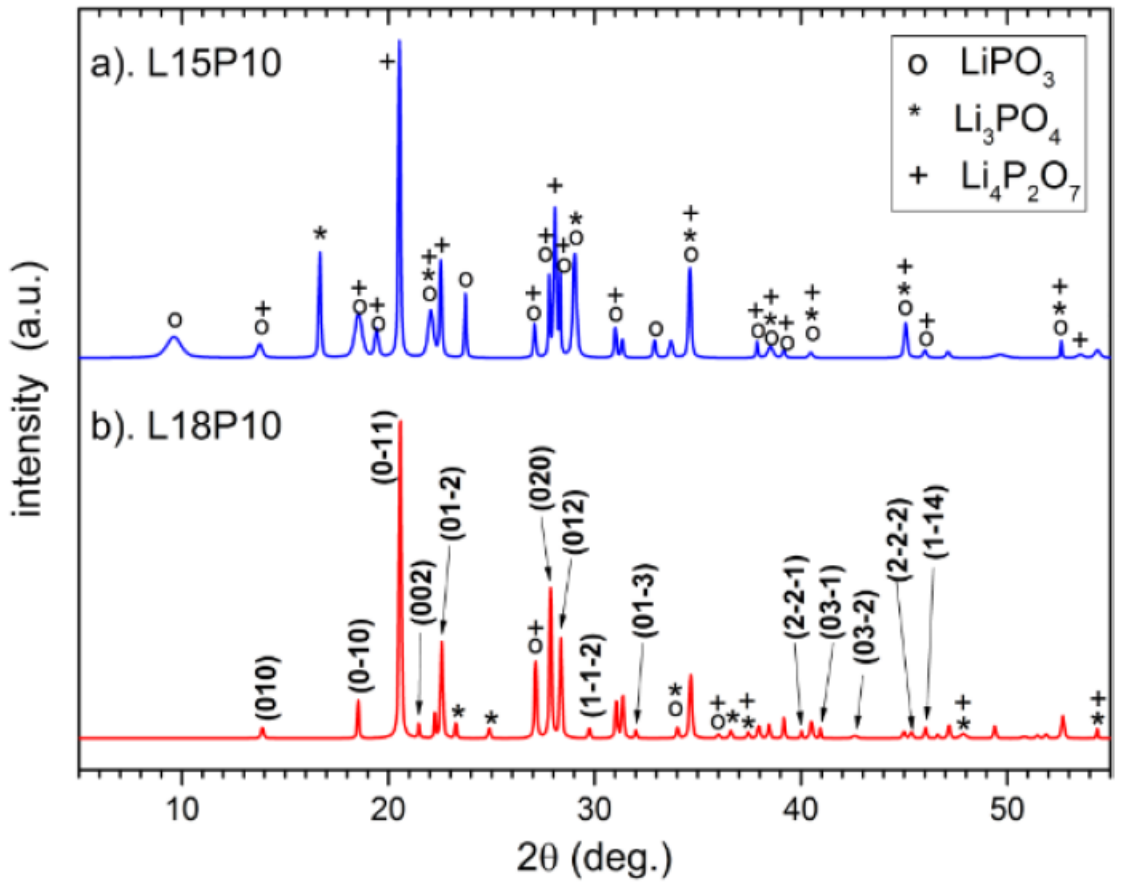
Techniques used by the researchers[3]:

- X-ray Diffraction Spectrometry
- Scanning Electron Microscopy
- Electrochemical Impedance Spectroscopy

Research into New Solid Electrolytes: X-ray Diffraction Spectrometry

- "used to identify crystals which are present in a mixture"[5]
- Sample placed in front of an x-ray beam, which is diffracted by the crystals as it passes through[5]
- Used to identify elements in sample and their proportions[5]

Research into New Solid Electrolytes: X-ray Diffraction Spectrometry

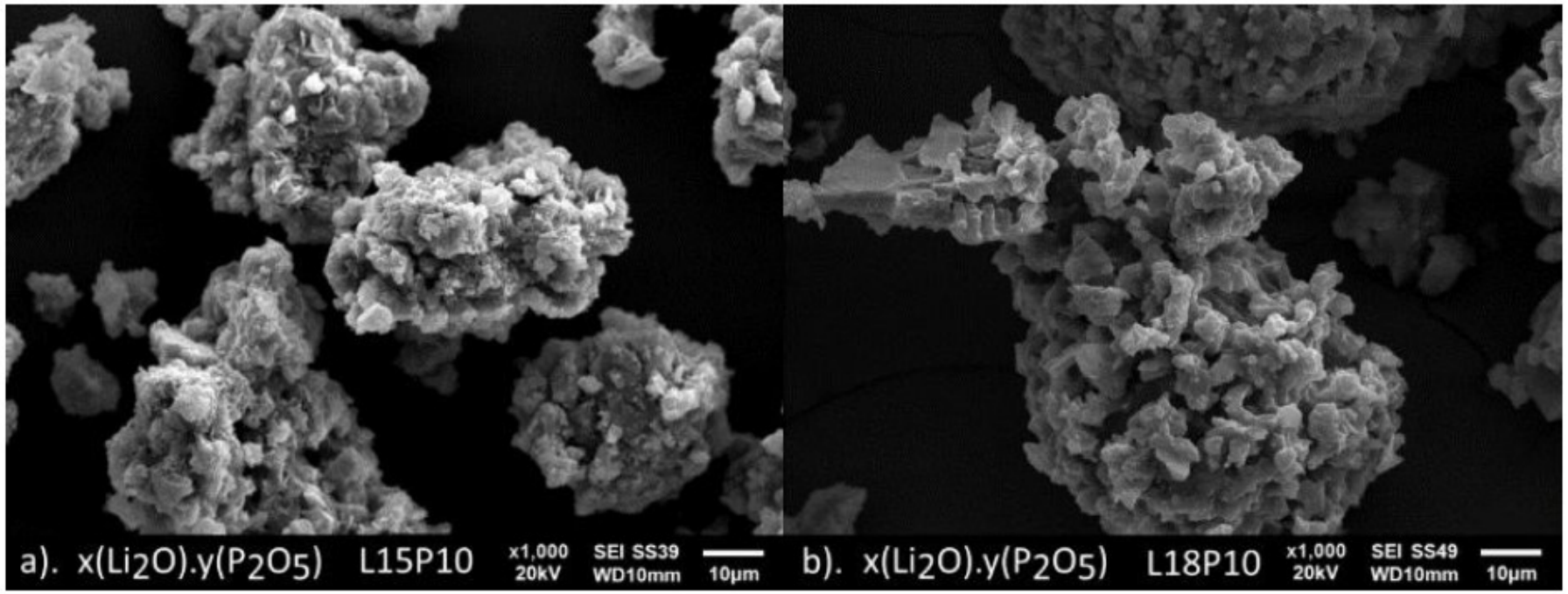


XRD pattern of xLi_2O-P_2O_5 compounds[3]

Research into New Solid Electrolytes: Scanning Electron Microscopy

- "uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens"[6]
- reveals chemical composition, structure and orientation of crystals, morphology/texture[6]
- Images down to 5 microns (5×10^{-6} m)[6]

Research into New Solid Electrolytes: Scanning Electron Microscopy

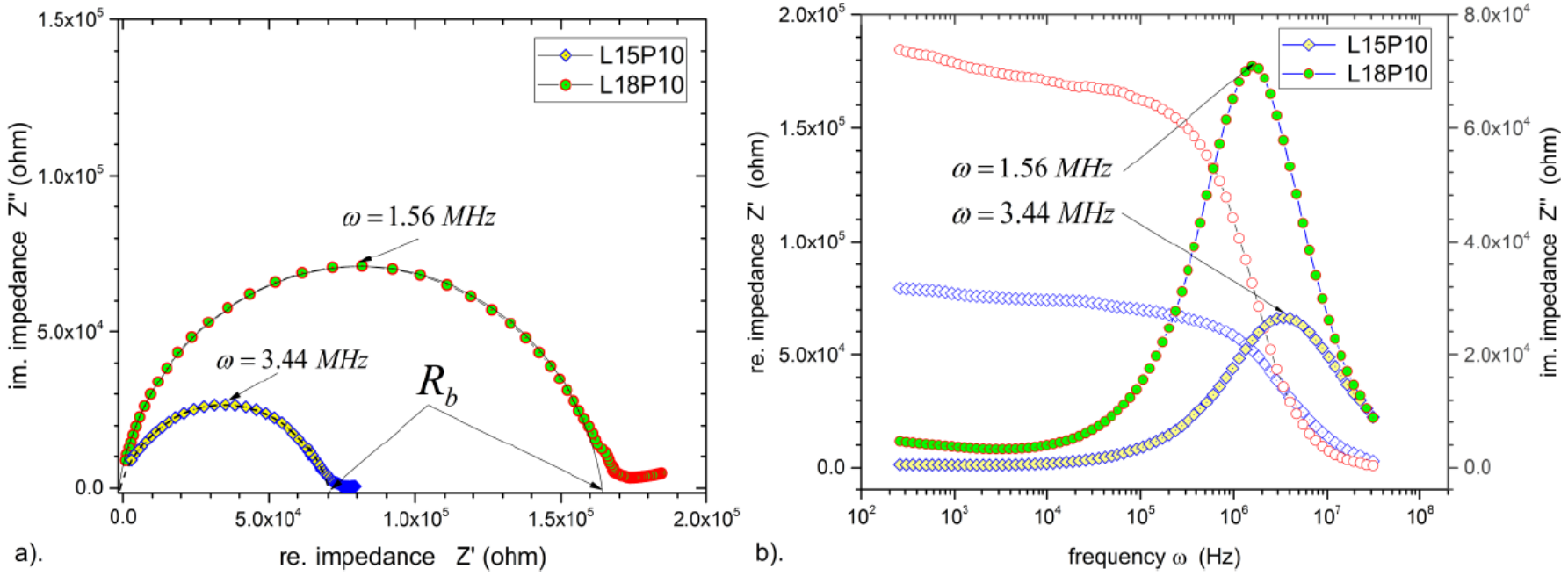


SEM micrograph of xLi_2O-P_2O_5 compounds[3]

Research into New Solid Electrolytes: Electrochemical Impedance Spectroscopy

- Impedance: Total opposition of an electrical component or circuit to current flow[7]
- EIS "characterize[s] a chemical process in terms of electrical measurements"[8]
- Response of chemical system to electrical stimulus reveals properties of the system[8]

Research into New Solid Electrolytes: Electrochemical Impedance Spectroscopy



Plots of impedance and frequency dependence of impedance of $xLi_2O\text{-}P_2O_5$ compounds[3]

Research into New Solid Electrolytes: Characteristics of the New Compound

- Produced two compounds: $1.5Li_2O\text{-}P_2O_5$ and $1.8Li_2O\text{-}P_2O_5$ [3]
- Similar structure in both compounds and similar impedance[3]
- $1.5Li_2O\text{-}P_2O_5$ had lower resistance and better conductivity[3]
- Conductivity of both compounds was 3 orders of magnitude higher than Li_3PO_4,[3] a common electrolyte in lithium-ion batteries[9]

Where To From Here?

- “There are a few next-generation battery technologies we’re looking at, and the most promising is an all solid-state battery.” Takeshi Uchiyamada, Chairman, Toyota Motor Corporation[10]
- “The solid-state battery will mark a turning point for e-mobility.” Heinrich Axel, VW Group Research[11]

Where To From Here?

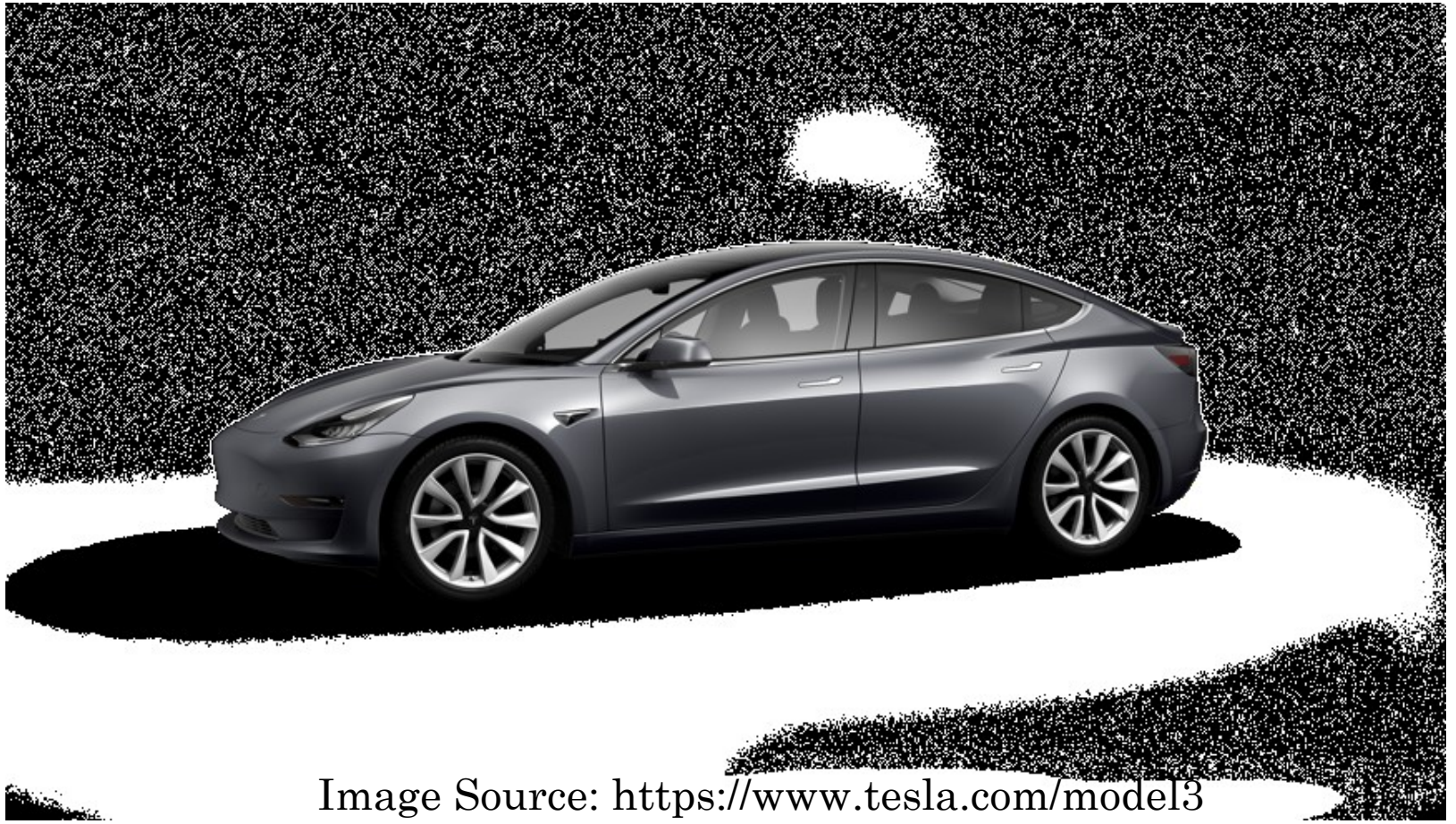


Image Source: https://www.tesla.com/model3

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