Chemical Characteristics of Li-ion Battery Combustion Emissions

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Objectives

- Characterize particle emissions from combustion of lithium iron phosphate (LFP) & lithium-polymer (Li-po) battery cells.
- Explore emission dependence on battery type, state of charge (SOC), & combustion behavior.
- Discuss toxics generated by cell combustion.

Examples of the two Li-ion cell types tested:
- Cylindrical 18650 LFP cells (back)
- Pouch-style Li-po cells (front)

Experimental Setup

- Battery cells at different SOCs were triggered into thermal runaway through external heating.
- Gas & particle emissions were routed from the chamber exhaust to instruments & filter assemblies.
- Emissions were collected on three filter materials for lab analysis:
  - Teflon for gravimetric mass & elemental analysis (XRF)
  - Quartz fiber for carbon & light element analysis (ICP MS)
  - Cellulose for acidic gas analysis

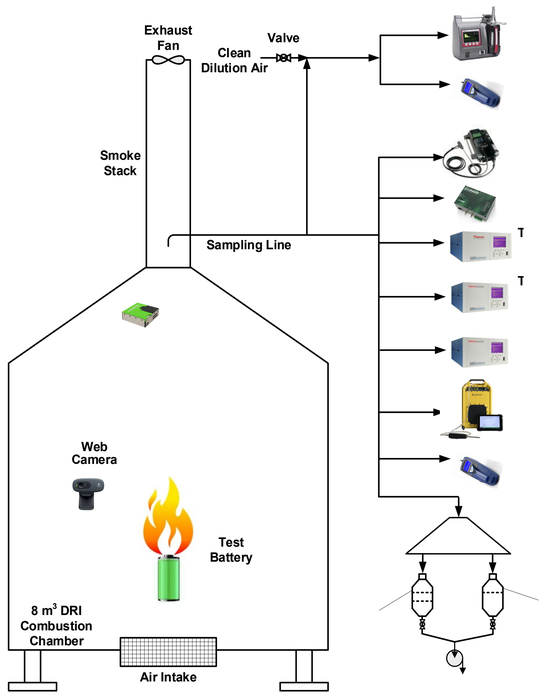

Figure 1. Schematic diagram of burn chamber & instrument setup.

Combustion Behavior

Figure 2. Smoking & flaming phases of Li-po cell combustion. Note vigorous smoking & sparking before ignition occurs.

- Both smoking & flaming combustion were observed, usually in sequence.
- $PM_{2.5}$ emissions were summed during each phase to characterize combustion behavior.
- Proportions of mass fraction during flaming combustion are shown in Figure 4 & 6-f.
- Differences in combustion behavior between cell types likely related to having a liquid (LFP) or polymer (Li-po) electrolyte.

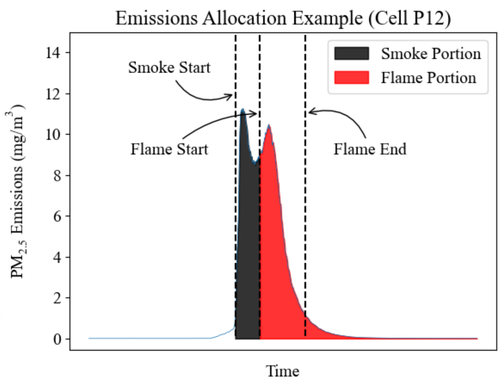

Figure 3. $PM_{2.5}$ timeseries split by combustion phase.

Chemical Characteristics of Cell Combustion

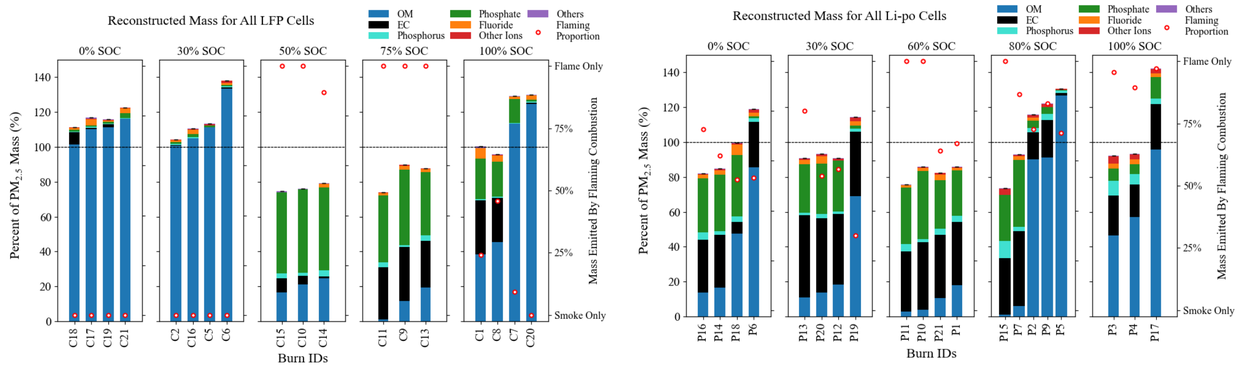

Figure 4. Reconstructed mass fractions for each cell, grouped by cell SOC. Cells are ordered by OM mass fraction within each SOC group. The estimated portions of emissions originating from flaming combustion are shown in red.

- Emissions were dominated by organic carbon (OM), elemental carbon (EC), & phosphate (PO_4^{3-}). Elemental phosphorus (P) & fluoride (F^-) were also significant.
- Increased flaming combustion generally increased EC & phosphorous emissions.
- Most P was emitted as phosphate, accounting for 80-90% of total P.

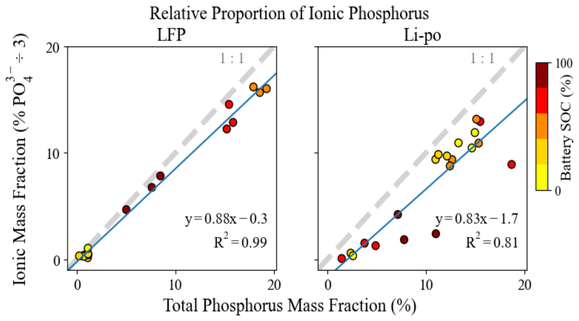

Figure 5. Proportion of total P emitted as phosphate.

Dependence on Cell SOC

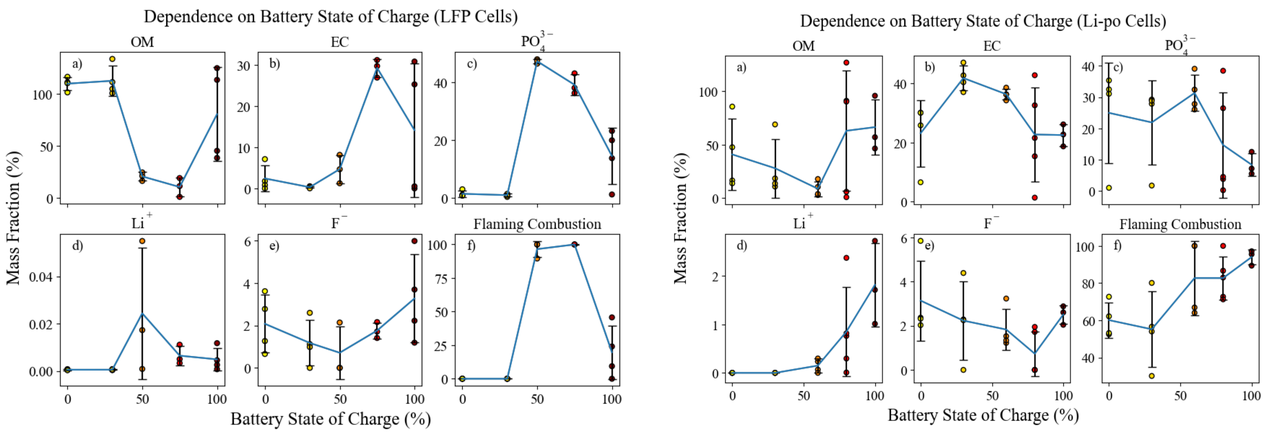

Figure 6. Dependence of major emission components on cell SOC. Trends & variation depend on both component & battery cell type.

- OM trend is generally inverse of EC, phosphorus, & flaming portion trends.
- Lithium emissions are most significant for high SOC Li-po cells (~ 2% of total).
- Phosphate emissions are highly SOC dependent for LFP cells, but not Li-po cells

Conclusion

- Distinct emission patterns exist related to cell SOC & combustion behavior.
- Flaming combustion generates more EC & phosphorus emissions, & less OM.
- Flaming combustion peaks at mid SOCs for LFP cells, high SOCs for Li-po cells.
- Toxic HF, lithium, & phosphorous compounds are present in emissions.
- Further analysis of gas emissions & particle size distribution is in progress.

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