Unique Li-ion Batteries for Utility Applications

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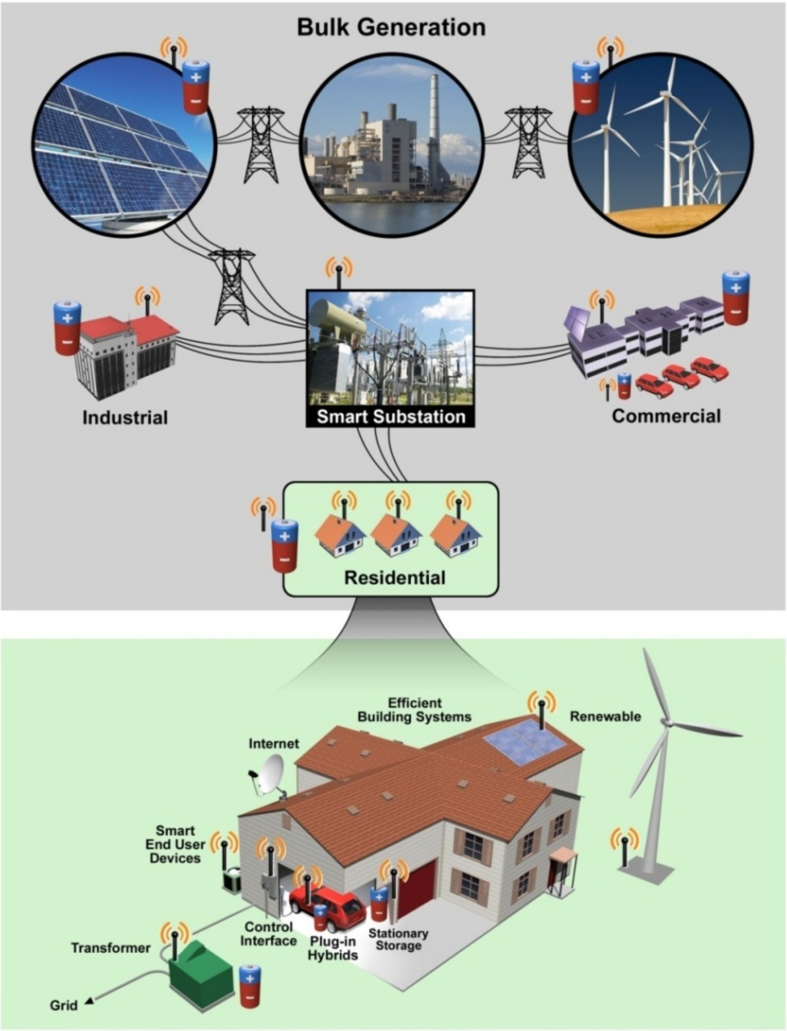
Objectives



- Investigate the Li-ion battery for stationary energy storage unit in ~kWh level.
- Fabrication and optimization of $LiFePO_4$/ $Li_4Ti_5O_{12}$ 18650 cell.
- Li-ion battery energy storage with effective thermal management.
- Improve rate and cycle life of Li-ion battery.
- Screen possible new cathode/anode electrode materials and its combinations suitable for large scale Li-ion battery.

Ref) Z. Yang *et al.* ***Chem. Rev.***, 111(5), p. 3577-3613 (2011)

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$LiFePO_4$ / $Li_4Ti_5O_{12}$ 18650 Full Cell

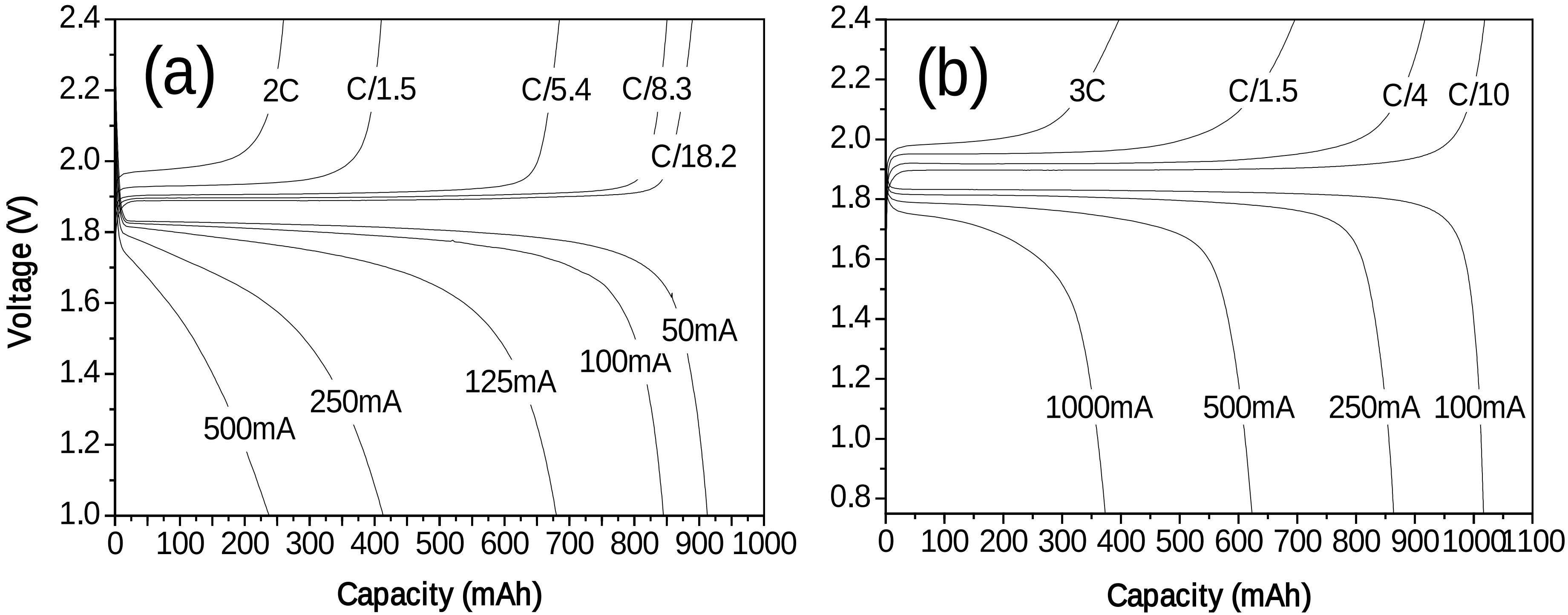

Figure 1. (a) first batch $LiFePO_4/Li_4Ti_5O_{12}$ 18650 cell, (b) second batch with various charge/discharge rates at room temperature (measured C-rate).

- Single cell weight 43g with theoretical capacity of 1,100mAh giving cell energy density of 48.6Wh/kg.
- From first batch, theoretical capacity was reduced by 4.5% and cell weight was increased by 13% thus reducing energy density by 15%.

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$LiFePO_4$ / $Li_4Ti_5O_{12}$ 18650 Full Cell

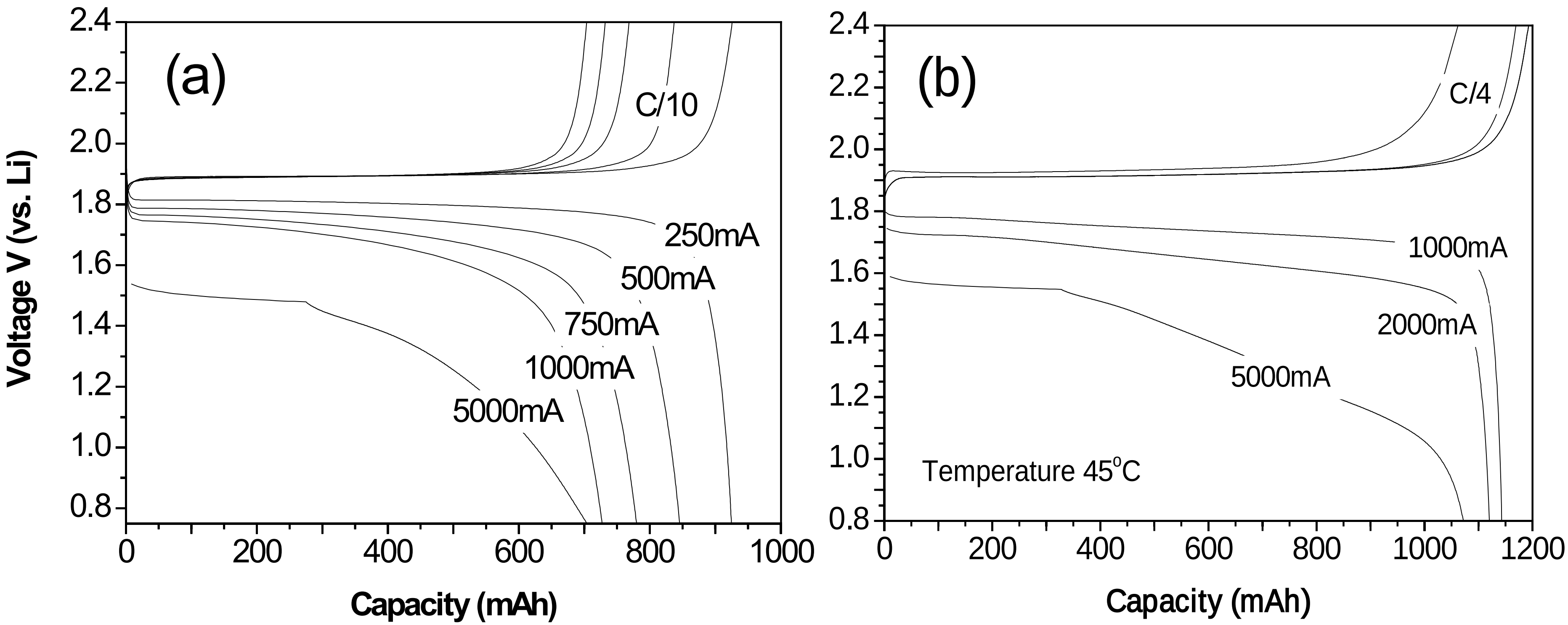

Figure 2. Second batch $LiFePO_4/Li_4Ti_5O_{12}$ 18650 cell under full charge followed by various discharge rates at (a) room temperature of 25°C and (b) 45°C.

- Charge rate is limiting the capacity when tested at same charge/discharge rate.
- More than 1,000mAh was achieved at 5C rate at 45°C.

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$LiFePO_4$ / $Li_4Ti_5O_{12}$ 18650 Full Cell

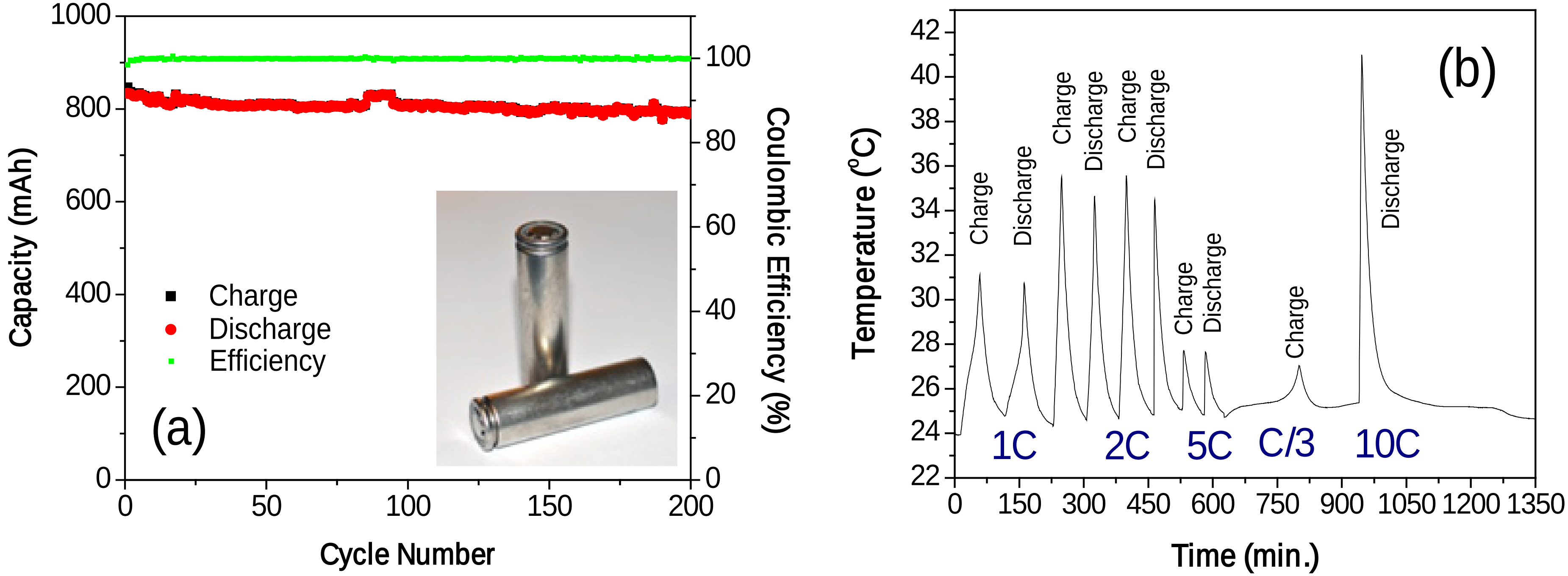

Figure 3. (a) cycling stability at C/4 charge/discharge rate and (b) cell temperature measured during various rates at room temperature using accelerating rate calorimeter (ARC).

- Second batch 18650 cell shows excellent cycling stability.
- Coulombic Efficiency > 99.8%, Energy Efficiency ~90% at C/4.
- Highest increase in cell temperature was ~15°C at 10C.

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Polyanion Type Cathode

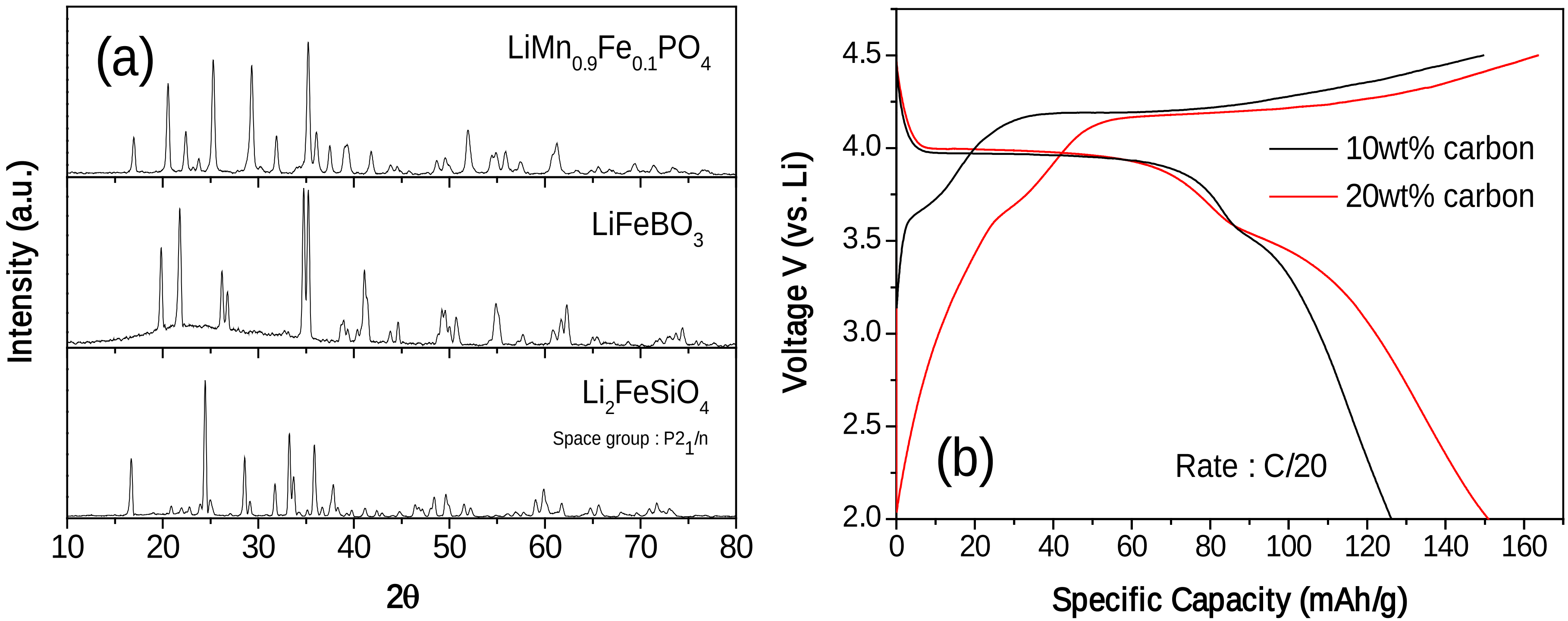

Figure 4. (a) XRD patterns of the synthesized $LiMn_{0.9}Fe_{0.1}PO_4$, $LiFeBO_3$, and Li_2FeSiO_4 and (b) electrochemical voltage profile of $LiMn_{0.9}Fe_{0.1}PO_4$ electrode.

- Single phase $LiMn_{0.9}Fe_{0.1}PO_4$, $LiFeBO_3$, and Li_2FeSiO_4 was synthesized by solid-state reaction.
- Lowering carbon content is important to be competitive with other cathodes.
- Charge rate is limiting $LiMnPO_4$ cathode for power application.

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Polyanion Type Cathode

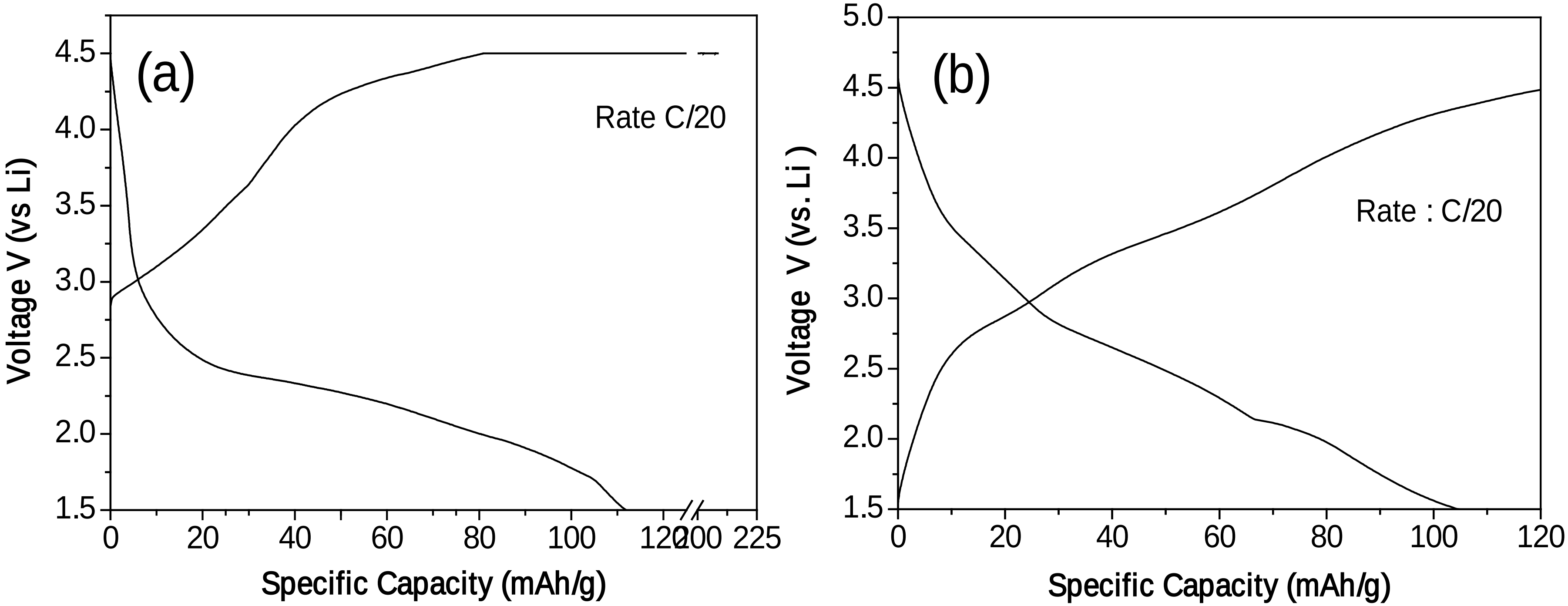

Figure 5. Electrochemical voltage profile of (a) $LiFeBO_3$ and (b) Li_2FeSiO_4 cathode electrode.

- Single phase $LiFeBO_3$ has been synthesized at 650°C but obtained half of the theoretical capacity of 220mAh/g.
- Single phase Li_2FeSiO_4 has been synthesized at 700°C but obtained 63% of the theoretical capacity of 166mAh/g (single Li).
- More work is required to fully understand $LiFeBO_3$ and Li_2FeSiO_4 cathode.

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Novel High Capacity Anode

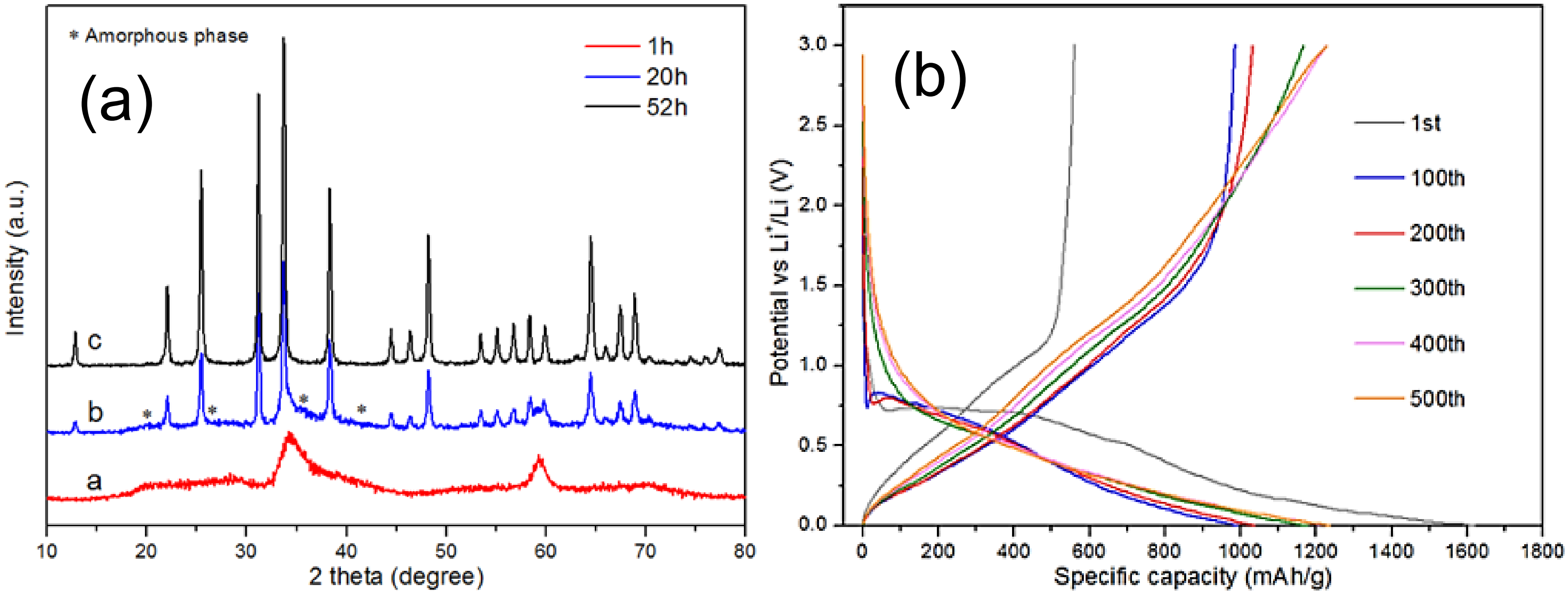

Figure 6. (a) XRD patterns Zn_2GeO_4 with different heat-treatment time and (b) electrochemical voltage profile of Zn_2GeO_4 anode heat-treated for 1h.

- Zn_2GeO_4 heat-treated for 1h show amorphous structure compared to extended heat-treatment.
- Zn_2GeO_4 (heat-treated 1h) show specific capacity >1,000mAh/g close to theoretical capacity of 1,416mAh/g.

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Novel High Capacity Anode

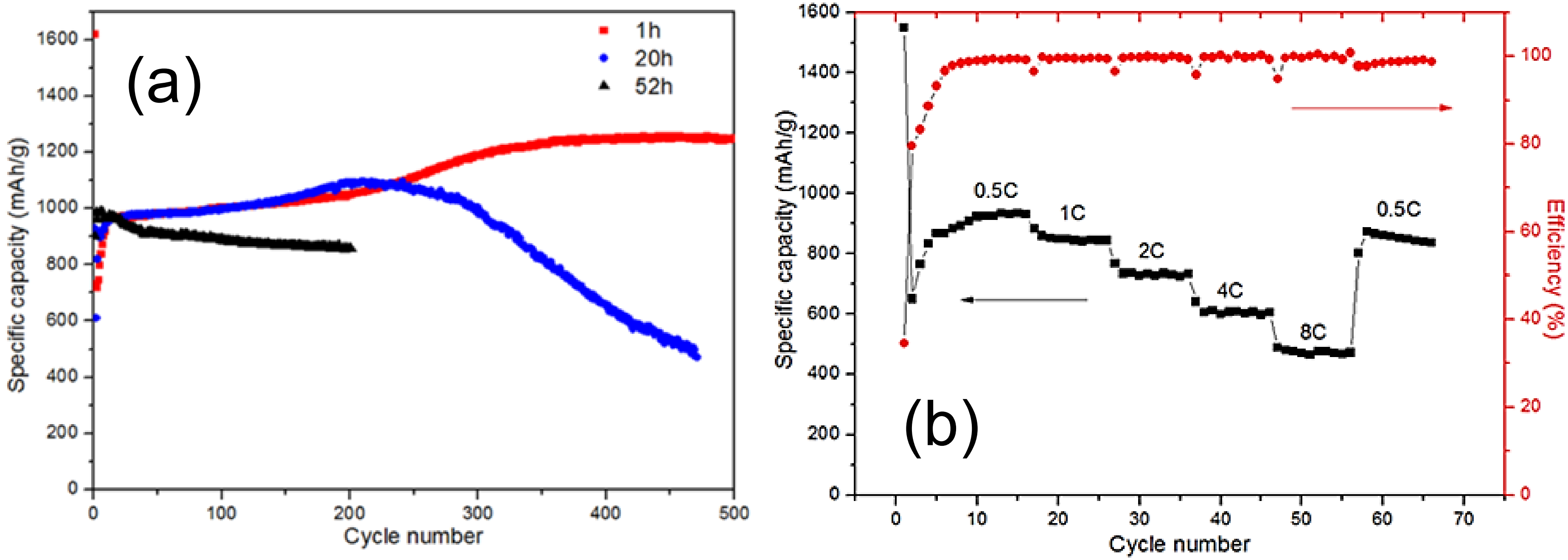

Figure 7. (a) cycling stability and (b) rate performance of Zn_2GeO_4 anode electrode heat-treated for 1h.

- Zn_2GeO_4 heat-treated for 1h delivers stable cycling up to 500cycles with over 1,000mAh/g.
- Along with stable cycling, specific capacity of > 400mAh/g was delivered at 8C rate.

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Summary

- Second batch $LiFePO_4/Li_4Ti_5O_{12}$ based 18650 cell was fabricated.

- Initial rate and cycling performance indicate that the second batch show much improved electrochemical response. Further characterization and optimization is underway.

- $LiMn_{0.9}Fe_{0.1}PO_4$, $LiFeBO_3$, and Li_2FeSiO_4 was synthesized and electrochemically characterized.

- Zn_2GeO_4 anode with specific capacity of ~1,000mAh/g was developed where both the rate and the cycling stability showed promising results.

Future Tasks

- Full characterization and comparison of second batch 18650 cell with commercially available batteries.
- Fabrication of third 18650 cell with enhanced charge rate of 80% SOC at >1C rate based on $LiFePO_4/Li_4Ti_5O_{12}$ chemistry.
- Modify synthesis of $LiMn_{1-x}Fe_xPO_4$, $LiFeBO_3$, and Li_2FeSiO_4 based cathodes to achieve higher rate performance.
- Explore other non-commercialized novel high capacity electrode materials suitable for energy form of stationary Li-ion battery.

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