

Solid State Battery with FeS Anode

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Solid state lithium batteries are thermally stable and free from leakage of liquid electrolyte resulting in pollution. Solid state batteries, therefore, are highly safe and attractive energy source or conversion device especially when the batteries are large in size, for example, used in electric vehicles.

Iron sulfides have been investigated as cathode materials in thermal cells owing to high capacity of 609 mAh/g for FeS and 894 mAh/g for FeS₂. FeS₂ shows potential plateaus at 2.3 V vs. Li⁺/Li, while FeS does at ca. 1.6 V.¹ Although Fe metal, to which iron sulfides are reduced during the discharge, is electrochemically inactive in lithium battery systems, Fe particles electrochemically formed from Li₂FeS₂ in a solid electrolyte system show reversible electrode reactions.² The low electrode potential is demerit for cathode material; however, this finding enables us to construct secondary batteries with Li₂FeS₂ as anode in combination with high voltage cathodes.³ The objective of this study is investigating availability of FeS for anode material in place of the Li₂FeS₂ in solid state batteries, because FeS shows electrochemical reduction is similar to Li₂FeS₂, and its theoretical capacity is larger than Li₂FeS₂.

In the present study, we fabricated a new solid state cell with a construction of FeS / solid electrolyte / LiCoO₂ and investigated the battery properties in detail. Since theoretical gravimetric and volumetric capacities of FeS are ca. 1.5 times (609 mAh/g) and ca. 2.0 times (1543 mAh/cc) larger than carbon anode, respectively, the battery is similar in theoretical energy density to carbon / LiCoO₂ batteries in spite of its lower cell voltage.

We used a crystalline solid electrolyte (Li_{3.25}Ge_{0.25}P_{0.75}S₄; SE) in thio-LISCION family, which has the highest conductivity of 2.2×10^{-3} S cm⁻¹ among lithium ion conductive solid electrolytes.⁴ The battery that we fabricated had a construction of FeS (7.0mg)+SE (3.0mg) / SE (150mg) / LiCoO₂ (28mg)+SE (12mg). Discharge capacities for FeS anode were ca. 470 mAh/g and ca 400 mAh/g at current densities of 64 μA/cm² and 255 μA/cm², respectively. On the other hand, the efficiencies of first cycle are 76% and 87% at current densities of 255 μA/cm² and 64 μA/cm², respectively. It implies that the rate of charge-discharge influences efficiency and capacity at first cycle. Details of the battery properties including performance at high temperature, at which commercial cells with nonaqueous liquid electrolytes can not be used, will be presented at the meeting. We will also introduce results from impedance analysis and microstructural observations by SEM and TEM.

References

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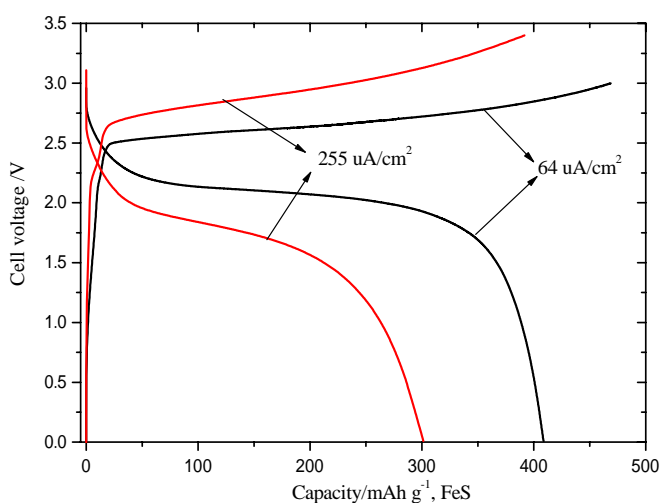


Fig. 1. The charge-discharge profiles of FeS / SE / LiCoO₂ cell.