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Physics-based modelling and simulation of lithium-ion battery capacity fade and degradation

Lithium-ion batteries (LIBs) have revolutionised the automotive industry (mainly electric vehicles)as a sustainable energy storage solution for electric vehicles due to their high-power and energy density. Their widespread adoption is crucial for achieving global decarbonization goals and reducing dependence on fossil fuels. However, the degradation of LIBs over time remains a challenge, leading to capacity fade and loss of battery performance, which ultimately affects the their lifespan and efficiency. Hence, it is essential to understand the aging processes in LIBs for improving battery design and optimising battery operation. This study employs physics-based electrochemical models that are implemented in an open-source battery simulation package – PyBaMM to understand the impact of high charging rates on capacity fade and degradation (solid electrolyte interphase growth and lithium-plating). The simulation was performed for 50, 100 and 200 cycles, using charging rates of 2 C, 8 C, 16 C, 20 C. Results indicate that higher charging rates exhibits faster aging of the battery. At moderate rates (2C, 8C), the SEI growth dominated during the initial cycleswhile at higher C-rates (16 C-20 C) lithium-plating became the primary contributor to capacity loss. Batteries charged at a higher current 20 C showed a 50% capacity loss within 100 cycles.
Keywords: Lithium-ion batteries, modelling, degradation, capacity loss, C-rate, solid electrolyte interphase.

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