Advancing Li Metal Anode Enabled by ZrO_2 Dual Atomic Layer Deposition

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Progressing towards the emerging era of high energy density batteries, stable and safe employment of lithium (Li) metal anodes is highly desired. Li metal anodes suffer from uncontrollable dendrite growths and extreme sensitivity to parasitic reactions raising a significant concern for battery safety and shelf life. Encapsulation with a conformal and ionically conductive- dielectric protective layer can empower stabilization of Li metal. In this work, engineering of zirconia (ZrO_2) protection layer on Li metal enabled by plasma-thermal dual atomic layer deposition (DALD) is employed which delivered enhanced physicothermal and electrochemical properties. DALD involved a combination of plasma sub-cycle and thermal sub-cycle in improving surface functionalization for highly dense and conformal depositions. Li with ZrO_2 DALD demonstrated uniform coating and excellent passivation tolerance to air exposure (23 ◦C) for at least 5 hours when compared to the bare Li which rapidly oxidized in around 5 minutes (Fig. 1). Moreover, the encapsulation by ZrO_2 layer with inherent thermal-resistive nature enhanced the physical thermal property which was confirmed by a heating test conducted at 170-180 ◦C (close to Li melting point) under inert argon environment. The heating test resulted in the bare Li quickly shrinking and developing wrinkle belts while the Li with ZrO_2 DALD protection maintained its physical shape integrity - displaying enhanced thermal stability (Fig. 1). Furthermore, encapsulation of Li metal with ZrO_2 DALD demonstrated enhanced electrochemical properties showing a high potential to turn the vision into true implementing of high energy density all-solid-state batteries.

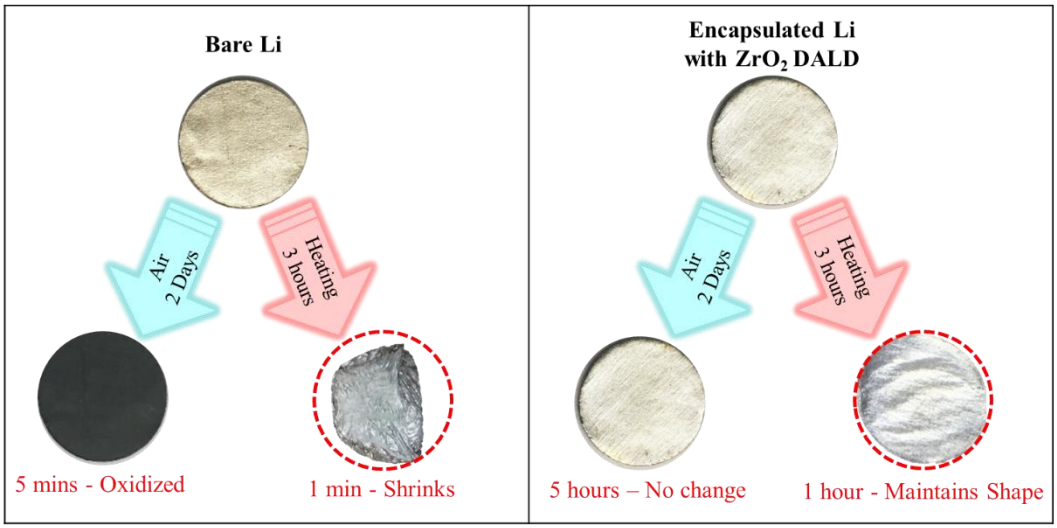

Figure 1. Photograph images of bare lithium (Li) metal and encapsulated Li with ZrO_2 DALD before and after the air-exposure test (23 °C) and the heating test (170-180 °C under argon environment).