Rechargeable Lithium Film Batteries - Encapsulation and Protection

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Summary

Rechargeable solid-state lithium batteries were developed before [1] by physical vapour deposition. These batteries are fabricated with lithium-cobalt oxide ($LiCoO_2$), lithium-phosphorus oxynitride (LiPON) and lithium (Li), respectively for cathode, electrolyte and anode. The $LiCoO_2$ and LIPON were deposited by RF sputtering and the metallic Li by thermal evaporation. The chosen material for current collectors was titanium (deposited by e-beam technique) to prevent chemical reactions in contact with lithium and provide good electrical conductivity.

In this work, the protection of lithium films from oxidation and delithiation is presented. Ti, LiPON, LiPO and layered films combining these materials were compared as protection for lithium. Titanium and LiPO films show good results and potential to be used as short-term protective materials in lithium batteries.

Motivation and results

It's undeniable the fact that batteries are systems with the highest number of applications known up to know. Despite the developments made by the microelectronic industry, the battery technology didn't accompany these breakthroughs [2]. The increasing demand for even small stand-alone microsystems with integrated energy source, led to the exponential interest in solid-state rechargeable lithium batteries [3, 4]. This battery technology [1] provides more energy density than conventional batteries (see Figure 1) and some safety issues like leaking or explosion are prevent since all materials are solid. An artwork of battery is show in Figure 2. However, lithium is a very reactive element, and encapsulation of these batteries in microelectronic circuits is a major problem. The choice of the protection material depends on some constraints: The deposition process should not react with lithium; should offer protection to atmosphere and avoid delithiation. Some techniques were proved to provide effective protection, being parylene the most common material [5]. However, this process is not compatible with microfabrication techniques, and a separated fabrication process must be used. Moreover, sample must be always contained in protective atmosphere prior protection. The methods described in this work allow the manipulation of lithium films for a few hours at air, thus allowing sample transfer for a long-term encapsulation.

Al/Ti contacts (300 nm Al / 300 nm Ti, by e-beam) were deposited prior the evaporated lithium film (3 µm thickness) on glass substrate. Several of these samples were prepared for evaluation of different protection materials (Figure 3). The film oxidation (without protection) was evaluated considering the resistivity change of lithium film when in contact with air. Other samples were covered with protection materials, and resistivity change when in contact with air was also evaluated. The protective layers tested were: 300 nm Ti; 300 nm LiPO; 300 nm LiPON; 3 successive layers of 100 nm Ti; 6 alternate layers of 50 nm LiPO and 50 nm Ti, all deposited on top of lithium without vacuum break. Figures 4 to 6 shows the resistivity measurement of Li film with and without the protective layers. LiPO is the best for the first two hours and titanium for long-term protection. The intercalation of six thin layers of LiPO and Ti presented similar results to single Ti layer.

Acknowledgements

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References

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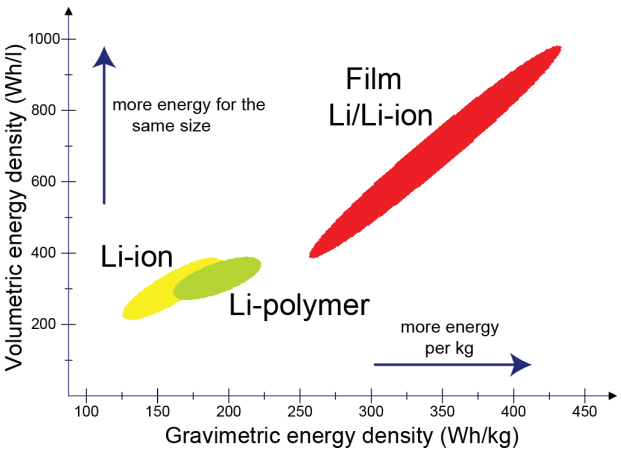

Fig. 1: *Battery capacity* compared for different technologies.

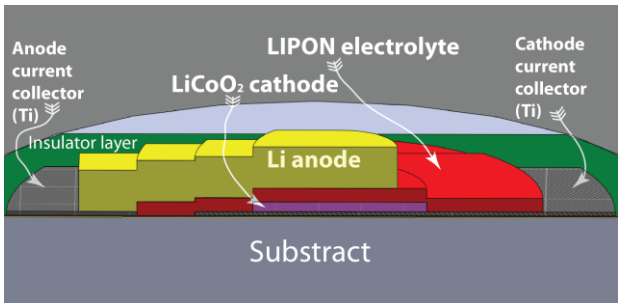

Fig. 2: Design of film battery with materials indication (not on scale for better visualization).

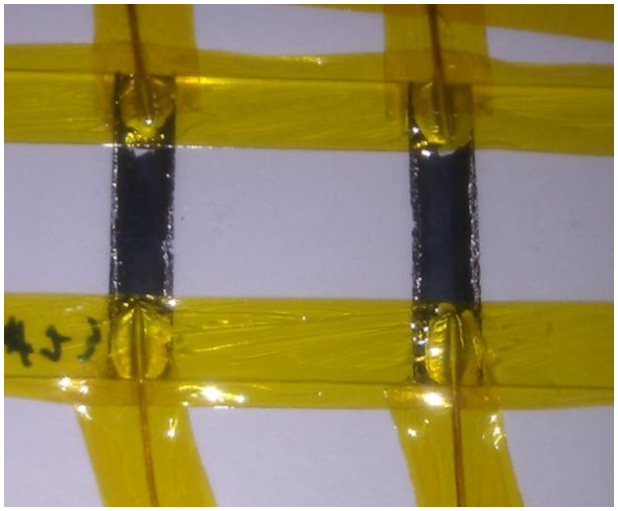

Fig 3: Sample preparation for thermal evaporation of lithium and resistivity measurements.

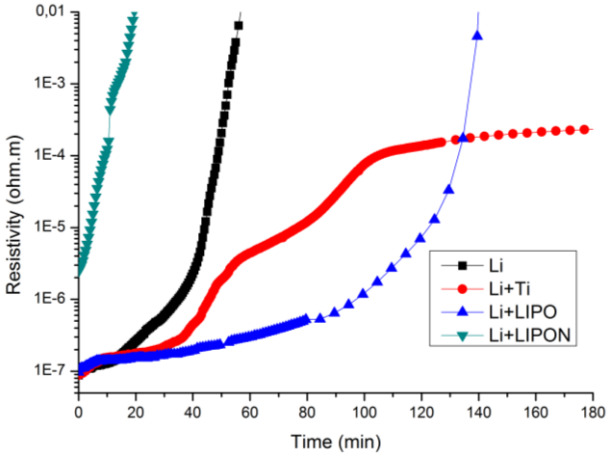

Fig. 4: Resistivity of lithium measured after atmosphere contact and comparing different protective layers.

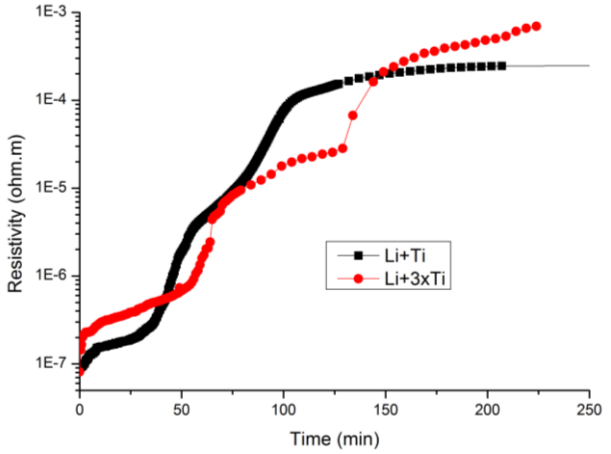

Fig. 5: Resistivity of lithium after atmosphere contact and comparing a thick protective layer of titanium with a three thin layers of titanium deposited consecutively and prefacing the same thickness of first.

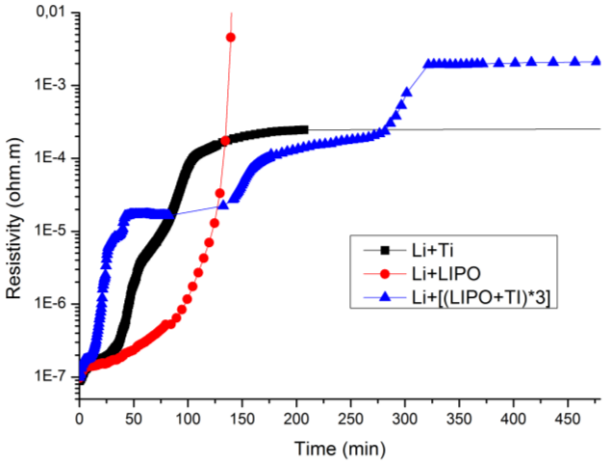

Fig 6: Resistivity of lithium after atmosphere contact comparing different protective layers.