# LAYERED MATERIALS FOR SOLID-STATE RECHARGEABLE LITHIUM BATTERIES

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Energy storage is mostly achieved with batteries and is a huge challenge of 21st century [1]. Despite the developments made by the microelectronic industry, the battery technology didn't follow these breakthroughs [2]. Batteries are ideal power source devices because they provide stable voltage and allow the leveling of energy consumption. This is of special concern when the target applications are in the biomedical field or for long cycle operations without requiring human activity [3, 4]. Solid-state film lithium batteries present the highest volumetric energy density (800 $Whl^{-1}$) and gravimetric energy density (350 $Whg^{-1}$), very high cycle life and charge-discharge rates up to 5C (only exceeded by super-capacitors) [4, 6]. The integration of batteries with solid-state circuits requires the use of solid-state anode, cathode and electrolyte. These batteries are intrinsically safe since all materials are solid and no leaking or explosion could occur. Film battery chemistry is being developed at ORNL (Oak Ridge National Laboratories) [3] with a solid electrolyte between the anode and cathode. These batteries have a potential of 4.5 V, typical capacities below 100 $\mu Acm^{-2}$ and charge times of 2C to 5C. However, due to the process of thin-films deposition, the thickness is limited to few micrometers, resulting in a small capacity.

This work presents a cathode of lithium cobalt oxide ($LiCoO_2$), and electrolyte of lithium phosphate nitride (LIPON) and an anode of metallic lithium (Li).

The $LiCoO_2$ is mostly used as cathode material in lithium batteries due to its excellent electrochemical stability, high capacity of lithium-ion diffusion and provide a high voltage to the battery. The fully crystalline structure facilitates the diffusivity of lithium ions and decreases the resistivity of the $LiCoO_2$. The $LiCoO_2$ film was deposited by RF sputtering and presented the best characteristics with a power source of 150 W, a pressure of $2x10^{-3}$ mbar, 40 sccm of argon and an annealing at 650 °C for two hours in vacuum. Electrical resistivity of 3.7 Ωmm was achieved and crystallization proven by XRD technique (Fig. 1).

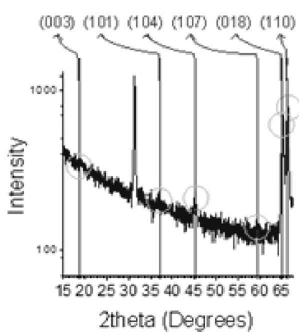


**Fig. 1:** $LiCoO_2$ XRD.

LIPON is a glassy electrolyte and must have a high ionic conductivity and high electrical resistivity. It has an electrical resistivity greater than $10^{14}$ Ω and has an ionic conductivity of $6.3x10^{-7}$ $Scm^{-1}$ for a temperature of 26 °C (Fig. 2). The LIPON was deposited by RF sputtering with a power source of 150 W, pressure of $3x10^{-4}$ mbar and 20 sccm of nitrogen.

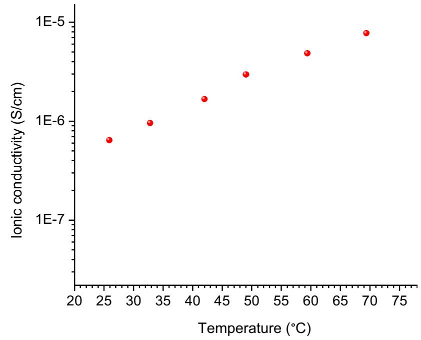


**Fig. 2:** LIPON ionic conductivity.

Although the oxidation in contact with air, the lithium metal is the most common material used as battery anode due to the high amount of lithium ions that can provide to battery discharge. This was deposited by thermal evaporation and its resistance measured during the deposition. A resistance of about 3.5 Ω was measured. The whole battery design, including the substrate ($Si+Al_2O_3$) and current collector's thin-films (Ti) is presented in Fig. 3.

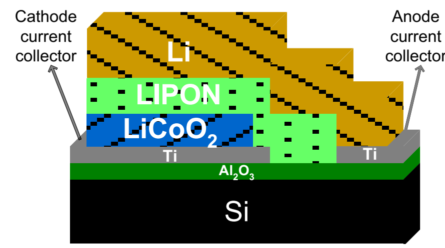


**Fig. 3:** Battery design (not on scale for better visualization).

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**References**

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