Nanoscale cathode materials for high power microbatteries

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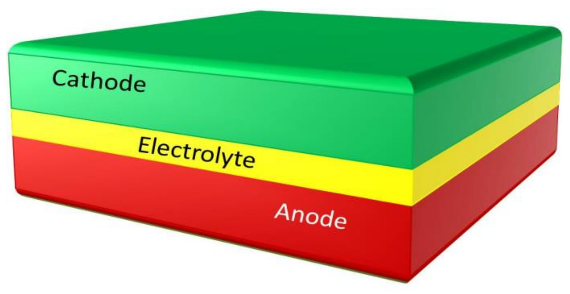
1. Challenges facing energy sources for wireless sensors

The need for the integration of Li-ion batteries on chip results in space being at a premium.

Thin-Film (micron scale) solid-state batteries are an option for wireless sensors but they must overcome:

1. Low electronic conductivity.
2. Slow Li-ion diffusion.
3. Limited capacity.
4. Limited current capabilities.



Thin-Film Battery

$$\text{Diffusion Time} \sim \frac{(Thickness\ (cm))^2}{Diffusion\ Coefficient\ (cm^2 s^{-1})}$$

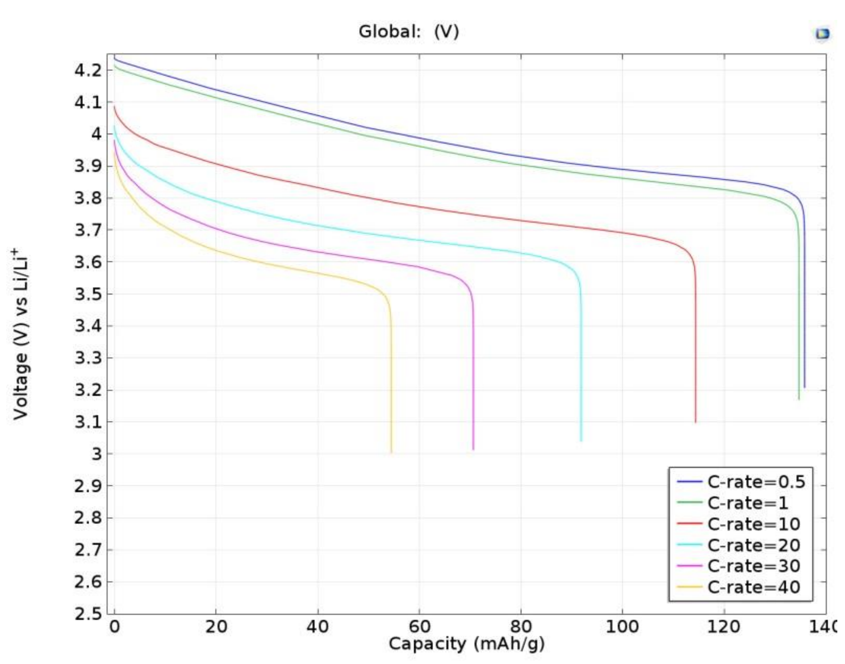
2. Thin-Film vs. 3D Nanostructures

3D Nanostructures advantages:

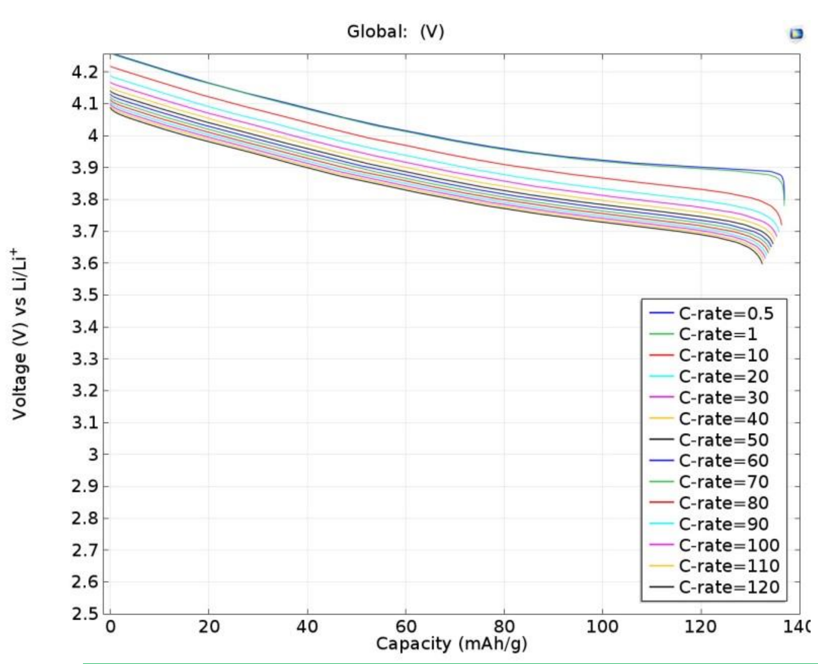
- Reduce Li-ion diffusion length.
- Improve conductivity.
- Improve mechanical stability.

Results in:

- More uniform Li-ion distribution.
- Higher discharge rates can be reached.



Typical thin-Film Microbattery
If electrolyte conductivity 1 mS/cm



NanoCore-Shell
(ø200 nm Core, 250nm Shell)
If electrolyte conductivity 1 mS/cm

3. Results

35 and 100 nm DC sputter deposited nano-films of $LiCoO_2$.

Fastest theoretical charge and discharge time:

$$\text{35 nm Diffusion Time} \sim \frac{(Thickness\ (cm))^2}{Diffusion\ Coefficient\ (cm^2 s^{-1})} = \frac{(0.35x10^{-5})^2}{2.0x10^{-12}} = 6\ \text{s}$$

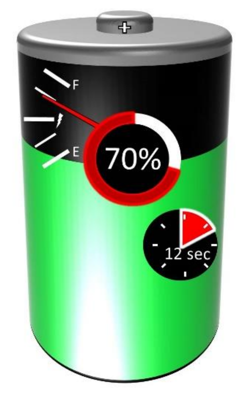
$$\text{100 nm Diffusion Time} \sim \frac{(Thickness\ (cm))^2}{Diffusion\ Coefficient\ (cm^2 s^{-1})} = \frac{(1.00x10^{-5})^2}{2.0x10^{-12}} = 50\ \text{s}$$

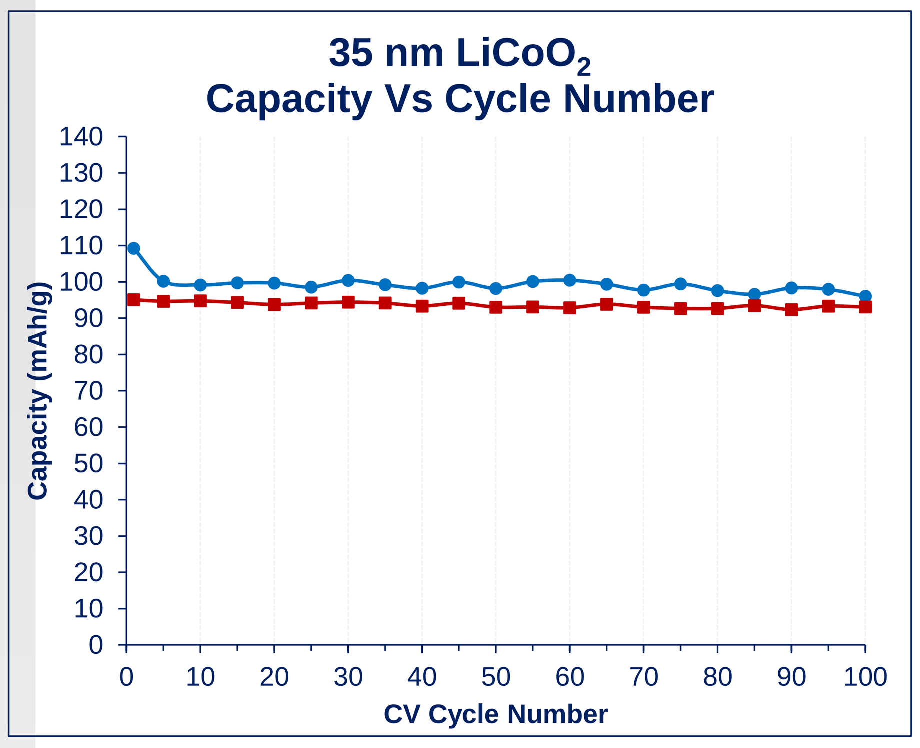
- $LiCoO_2$ Theoretical Capacity is 136.95 mAh/g

$$1\ \text{C} = 136.95\ mA/g$$

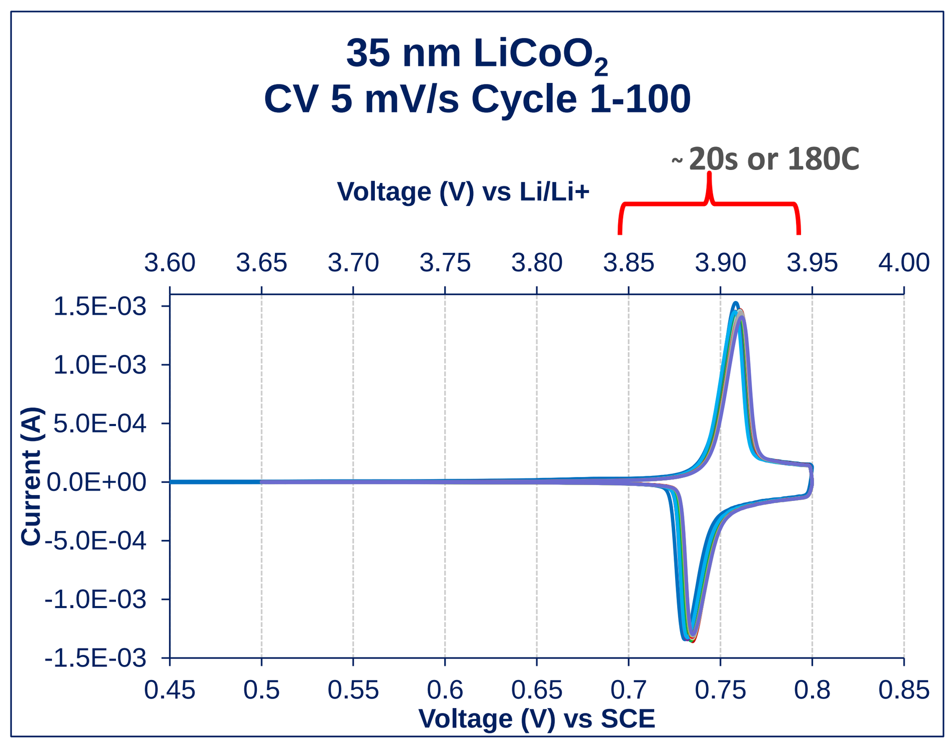
$$\mathbf{310\ C} = 136.95 * 310 = \mathbf{42,454.5}\ \boldsymbol{mA/g}$$

$$\mathbf{310\ C} = \frac{3600\ (s)}{310\ (s)} = \mathbf{12\ s}$$

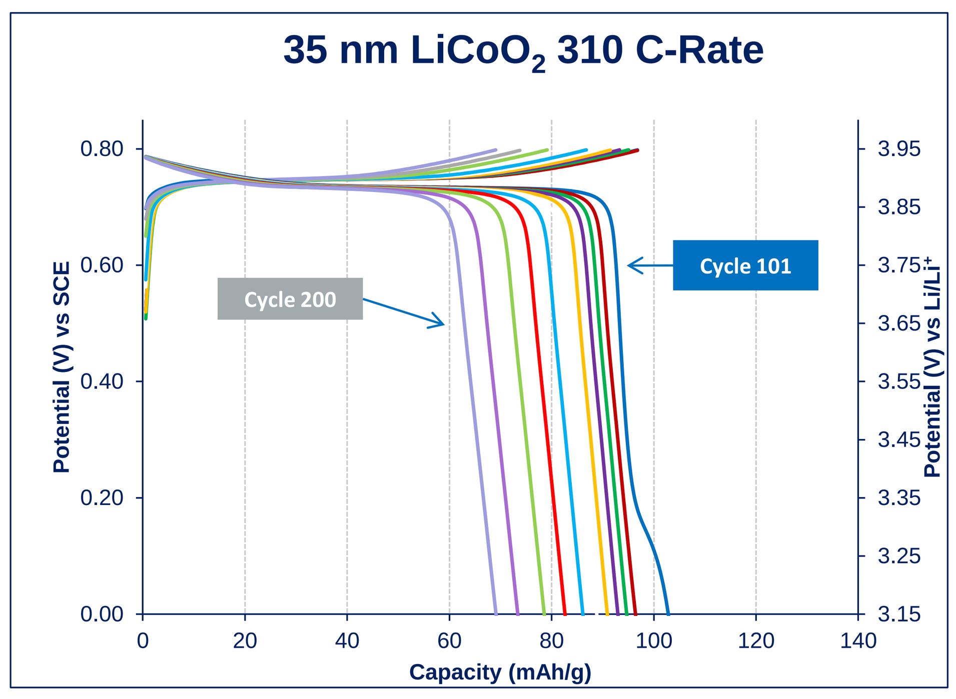


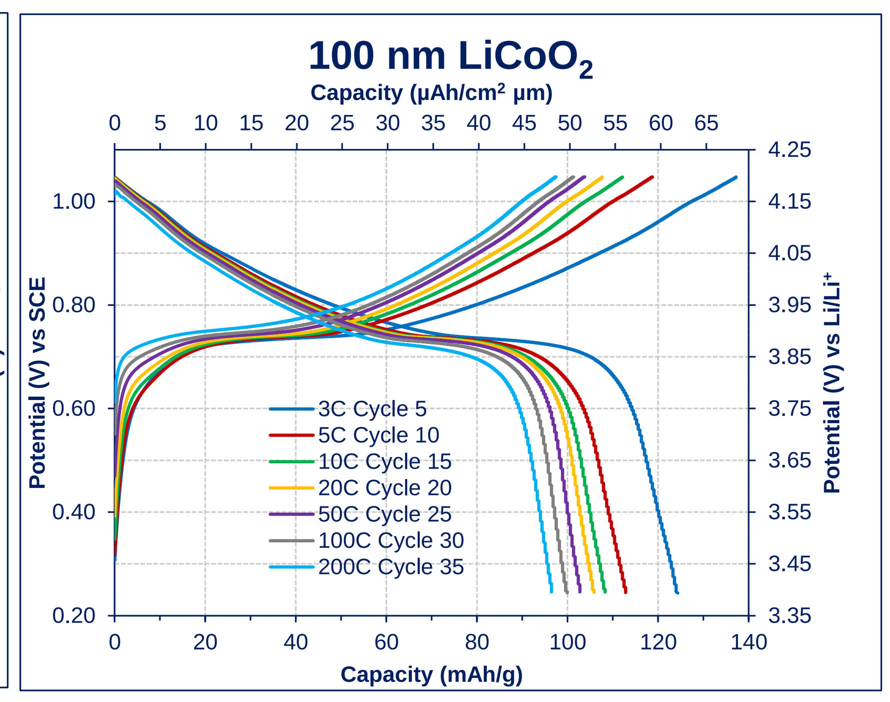


Capacity of $LiCoO_2$ nano-films retained with cycling



$LiCoO_2$ cycled at high rate





High capacity achieved for $LiCoO_2$ even when cycling at high 310 C rate

Capacity only approaches 100 mAh/g for very high rate 200 C cycling (18 s charge and discharge)

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