Vacuum technologies as a solution to energy problems; future trends

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Problem

Lithium (Li) metal is an ideal anode material for rechargeable batteries due to its extremely high theoretical specific capacity (3860 mA h g^{-1}), low density (0.59 g cm^{-3}) and the lowest negative electrochemical potential (−3.040 V *vs.* the standard hydrogen electrode). Unfortunately, uncontrollable dendritic Li growth and limited Coulombic efficiency during Li deposition/stripping inherent in these batteries have prevented their practical applications over the past 40 years. With the emergence of post-Li-ion batteries, safe and efficient operation of Li metal anodes has become an enabling technology which may determine the fate of several promising candidates for the next generation energy storage systems, including rechargeable Li–air batteries, Li–S batteries, and Li metal batteries which utilize intercalation compounds as cathodes [1].

Benefits of ultra-thin metal anode

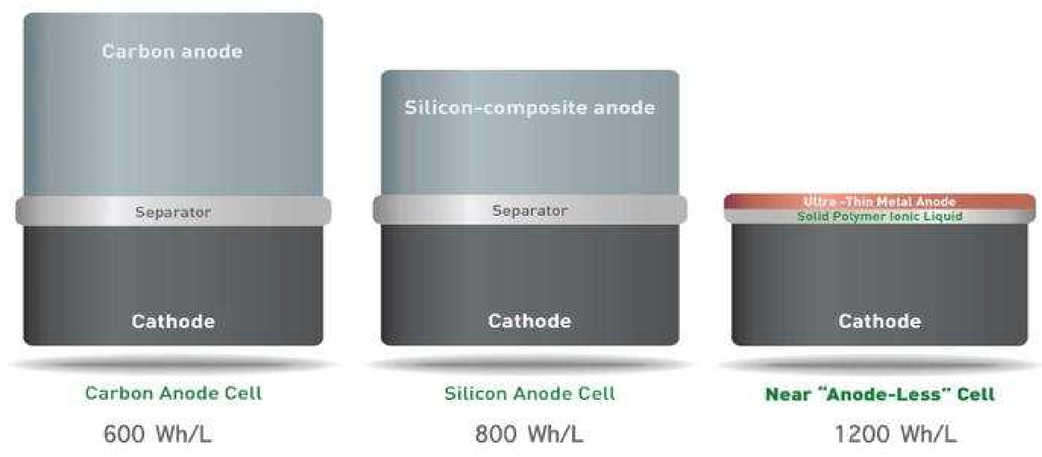

Fig. 1. Comparison of energy density of three types of anodes used in production of Li ion batteries [2].

Using of metalic anode allows decrese of total cell volume almost twice. Conventional anodes are produced with rolling methods and anode thickness is up to 40 microns. Physical vapour deposition (PVD) in vacuum makes it possible to have anode thickness of several microns.

PVD method allows deposition of 1...20 microns thick Lithium layer in one pass onto thin metallic foils or metallized polymer films. Since Lithium is deposited in high vacuum ($1*10^{-5}$ Torr), it comes out in a «pure» state: vacuum deposited Lithium has minimal oxide layers. Lithium batteries hence benefit by high levels of purity.

Coating deposition conditions provide high Lithium surface activity, what is inaccessible for traditional rolling.

Additional benefit of PVD processing is low cost as less metal is required.

Capabilities of PVD Lithium coating equippment in Sidrabe laboratory

Sidrabe has research and development areas for Li coating investigation and samples manufacturing under contracts with potential customers. We have two Sidrabe made laboratory roll-to-roll Li coaters associated with Dry room. Coated material is transferred into glove box where it is packaged into sealed metal-polymeric bags filled with Argon.

Fig. 2. Dry room in Sidrabe facilities.

Both web coaters are equipped with the process drums, where coating deposition heat is transfered through the gas gap [3]. The effective web cooling allows deposition of thicker layer of material in the same pass thus increasing production speed. During the preliminary works we obtain actual information on process parameters for respective production scale equippment.

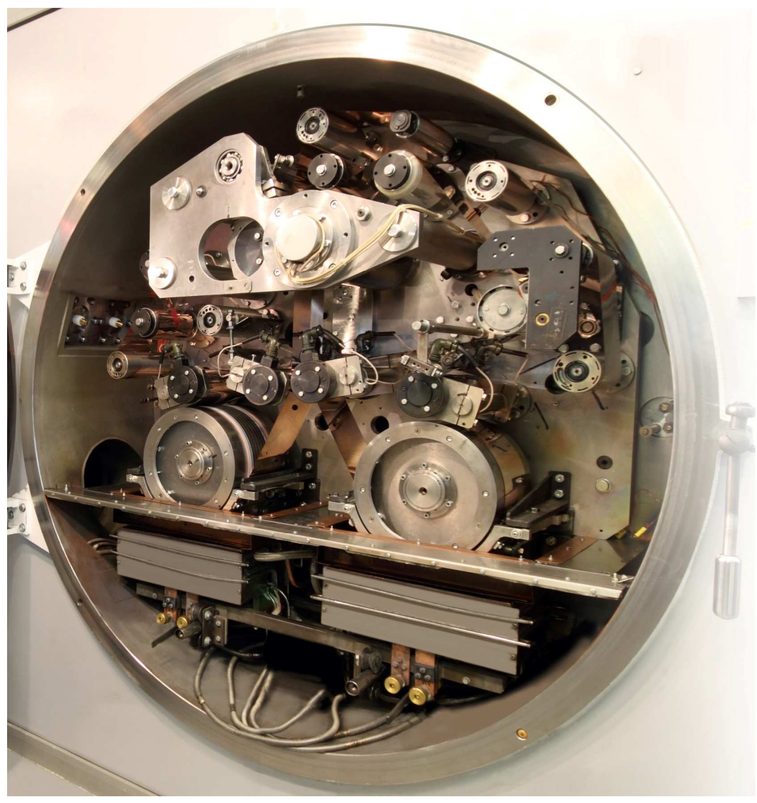

Fig. 3. View of open chamber of Lithium evaporator.

Current equippment allows coating of 150 mm wide copper foil both single and double sided. The length of coated film is 30-50 m. After the planned modernization the maximum coated length will be 200 m. As another modification longitudional masking option is designed and scheduled to me made in 2015.

Sources:
[1] Wu Xu, Jiulin Wang, Fei Ding, Xilin Chen, Eduard Nasybulin, Yaohui Zhangad and Ji-Guang Zhang: *Lithium metal anodes for rechargeable batteries.* Energy Environ. Sci.; 2014, Vol 7, p. 513-537.
[2] Image taken from Solidenergysystems.com.
[3] E. Yadin and G. Pipkevich: *Improvement of Web Heat Condition by the Deposition Drum Design.* In Proc. 50th annual technical conference of Society of vacuum coaters; 2007, p. 749-753.
[4] R. Swisher, E. Yadin, G. Pipkevich: *Progress in Vacuum Deposited Lithium Metal Anode Structures.* 18th International Seminar & Exhibit on Primary and Secondary Batteries; March 5, 2001, Ft. Landerdale, FL, USA .
[5] R. Swisher, E. Yadin, G. Pipkevich : *Web Coating with Lithium—Technical Solution for Metal Anode Structures in Li Batteries.* In Proc. 45th annual technical conference of Society of vacuum coaters; 2007, p. 535-538.
[6] E. Yadin, G. Pipkevich, R. Zeilia: *Method and apparatus for vacuum deposition by vaporizing metals and metal alloys*. Patent WO 2005/116290 A1