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Lock-in Thermography - a novel in-situ measurement method for lithium-ion cells.

Mathias Reichert, Falko Schappacher, Christian Herkt-Bruns, Stefano Passerini and Martin Winter
Institute for Physical Chemistry, University of Münster
Corrensstraße 46, 48149 Münster, Germany

We are introducing the highly sensitive lock-in (IR-) thermography as a new non-destructive and non-contacting (in-situ) measurement method for lithium-ion cells. This method is already known and used in the semiconductor technology to detect failures, like short circuits and oxide-pinholes in integrated circuits [1]. The physical and technical principals are described in detail elsewhere [1-3]. Here only a short introduction in this technique is given:
The principle of lock-in thermography consists of introducing periodically modulated current into an object and monitoring only the periodic surface temperature modulation phase-referred to the modulated heat supply. The information of each pixel of the IR image is processed as if it were fed into a lock-in amplifier.

Measurement Setup – We adapted and optimized this method for the use in lithium-ion battery research. Our measurement setup is described in Fig. 1.
The measurements were carried out with an InSb IR camera.

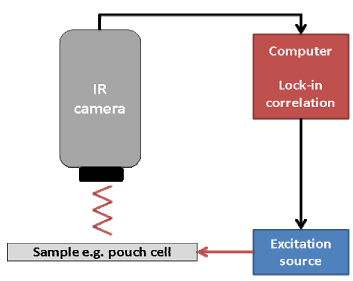

Fig. 1: Adapted lock-in thermography measurement setup.

The sample was a standard pouch cell design with a lithium-nickel-manganese-cobalt-dioxide (NMC) / cathode and a graphite anode in a full cell arrangement. The pouch cell surface was blackened with beamless graphite paint (Graphit 33 from Kontakt Chemie).
The lock-in measurement was carried out with an electric excitation frequency of 1 Hz between 4.2 V and 2.8 V; 300 single experiments were carried out during a five minute measurement time.

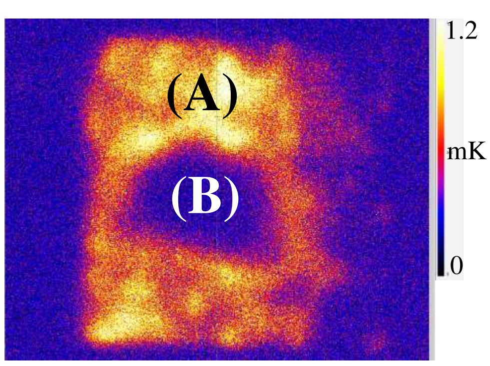

Fig. 2: Detailed amplitude picture with the active part marked as (A) and the inactive electrode site marked as (B). Electrode size: 5 x 5 cm.

Results – The received amplitude image from the lock-in thermography measurement is shown in (Fig. 2). The amplitude image correlate with the temperature change in the cell, were the bright spots represent the highest temperature rise (max. 1.2 mK) and the dark blue areas no temperature increase.
The inhomogeneity of the temperature distribution in the active material is clearly visible in the amplitude picture (Fig. 2). In the middle of the squared electrode an area with no heat production and therefore also electrochemical inactive is detected. Samples are taken from the active (A) and inactive (B) areas from the electrodes.

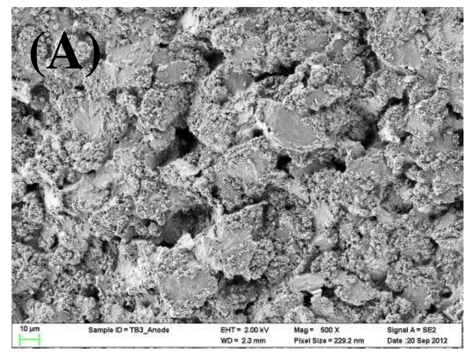

Fig. 3: SEM picture taken from a sample from active area (A) of the graphite anode.

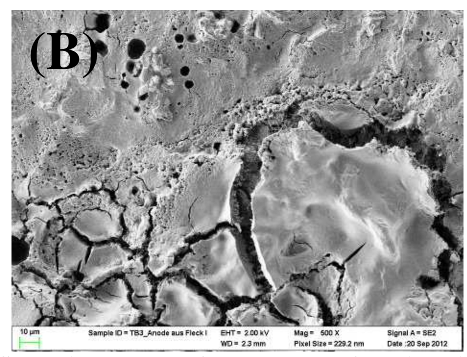

Fig. 4: SEM picture taken from a sample from inactive area (B) of the graphite anode.

The samples were analyzed with a scanning electron microscope (SEM). The thermal active site (A; Fig. 3) of the anode has normal graphite composite electrode morphology, were the inactive part (B; Fig. 4) is covered with a dense and thick surface film. This heavy coating can lead to a very high charge-transfer resistance, which can explain the inactivity of area B, as shown in Fig. 2.

Conclusion – The lock-in thermography as a novel in-situ measurement method for lithium-ion cells is a good addition to existing analyse methods to investigate the local conductivity, electrolyte wetting, electrode quality and aging / abuse mechanism. It is also a promising tool for the detection and understanding of internal short circuits.

References

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