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Theoretical evaluation of the performance of high-pressure HASEL actuators for triggering self-healing materials in lithium-ion battery cells

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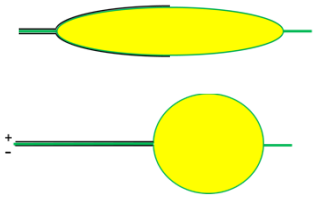
Abstract
In order to reduce the degradation of lithium-ion battery cells and prolong their lifetime, self-healing electrode materials are a topic of development. To close eventual cracks in the material, an external pressure has to be applied. Recently, Hydraulically Amplified Self-healing ELectrostatic (HASEL) zipping actuators have received much interest. They consist of two parallel polymer films partly coated with flexible electrode layers at their outer surfaces and sealed along their edges to a pouch, which is filled with an oil [1]. Due to their high flexibility, these actuators are especially promising for the generation of the required pressure on the battery pouch cell for the self-healing trigger. The generated pressure of the HASEL actuator can be increased by confining the actuator in a thin rigid box. To evaluate the achievable pressure of the confined HASEL actuator, a simple calculation model was established. Calculations of the generated pressure vs. applied voltage on the HASEL actuator with various box dimensions were performed. Results of these calculations were compared with measurement data, which were received with a corresponding experimental setup.

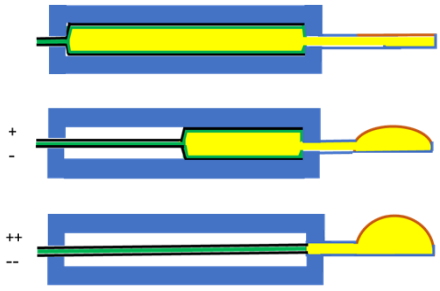
Conventional HASEL actuator

Closed polymer pouch with segmented electrodes on polymer films and filled with oil



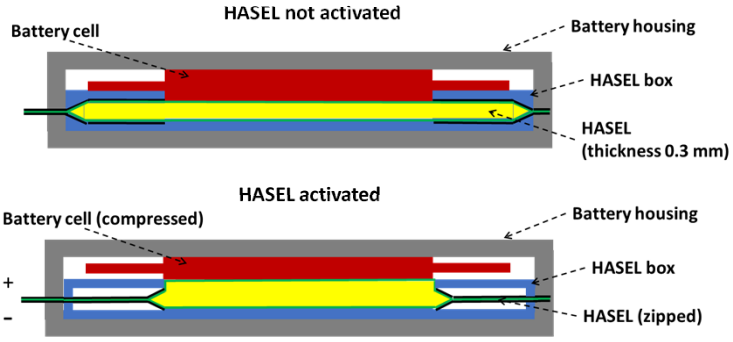
When a voltage is applied between the electrodes, a zipping effect displaces oil from the electrode region to non-electrode region

Principle of HASEL in the box for high pressure generation



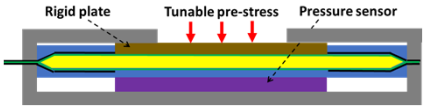
The HASEL pouch is confined in a thin rigid box. When a voltage is applied between the electrodes, the oil is displaced and moved out of the box, thereby generating high pressure.

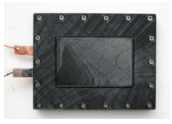
Box design and integration of the HASEL in the battery housing



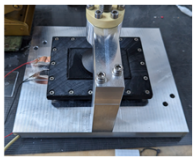
Experimental setup for pressure measurements

HASEL with electrode frame (PET films with 20 µm) thickness





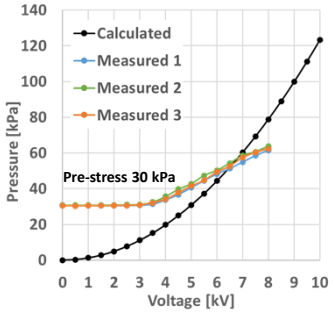
HASEL in the box, center covered by a rigid plate



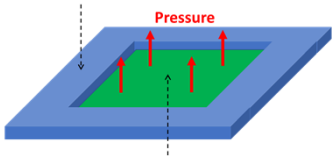
Measurement setup with tunable pre-stress on HASEL

Evaluation of the calculation model

Comparison of calculated and measured pressure vs. applied voltage



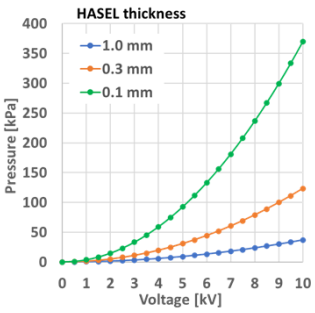
Pressure generation in the active region of the HASEL in the box



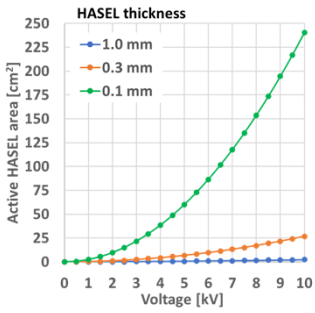
Pressure application to the battery cell in the inactive center region of the HASEL outside of the box (65 cm²)

Prediction of actuator properties

Achievable pressure



Required electrode area for compression of a battery cell with stiffness 1 MPa/mm



Conclusions

- **A HASEL actuator confined in a rigid box can generate high pressure.**
- **The achievable pressure depends on the thickness of the box and on the applied voltage.**
- **HASEL pressure generators can shall be used for self-healing triggers on battery materials.**

Acknowledgement
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Reference

[1] E. Acome et al., Science 359 (2018) 61-65

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