HORIZON 2020

Spatially resolved acoustic, mechanical and ultrasonic sensing for smart batteries

Reporting

Project Information

SPARTACUS

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Project website

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Project closed

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Periodic Reporting for period 2 - SPARTACUS (Spatially resolved acoustic, mechanical and ultrasonic sensing for smart batteries)

Reporting period: 2022-03-01 to 2024-02-29

Summary of the context and overall objectives of the project

SPARTACUS – paving the way to future fast battery charging
The charging of battery cells is usually not performed on the maximum speed since the battery

management systems has to ensure that the cycle-life is not affected and that any defect generation and thermal runways are avoided. In order to increase the speed of charging more
information is needed in order to get a full picture about the state of health (SoH) of the battery.
The SPARTACUS project turns a commercial battery cell into a smart battery that is equipped with sensors in order to measure changes in the Young’s Modulus, the geometry, the temperature and the electrochemical reactions that are linked to the state of the battery. All of these measurements are related to special degradation effects, such as e.g. lithium plating, electrolyte decomposition etc.. Since
these kinds of defects do not necessarily take place homogeneous over the battery cell, sensor arrays are realized that measure the aforementioned values with a spatial resolution.
When more information is available and the SoH can be estimated much better and the batteries cycle life can be increased, the safety enhanced by anticipating a thermal runway and the qualification for 2nd life is
more robust. Moreover, the SPARTACUS sensor set-up as developed in SPARTACUS can assist to qualify
the battery cells during/after production and supports the scientific community to study in detail degradation mechanisms in battery cells by providing additional physical cell parameters.

SPARTACUS project demonstrated 5 types of non-invasive sensors to determine the battery state, such as SoC, SoH or SoS: Ultrasonic sensors,dDielectric elastomer sensors to measure deforming of the battery, temperature sensor array and Odd-random-phase-Enhanced Impedance spectroscopy (ORP-EIS). The data from all different sensors could be used to improve SoC estimation detecting different electrochemical stages during cycling. For ORP-EIS, the SoH could be detected whereas temperature and dielectric sensors could be used for early detection of thermal runway (SoS). A Cell management systems and pre-processing electronic was developed that can take benefits of the sensor information and forward it to the battery management system. Models were implemented in the battery management system. For validation, abusive tests and tests comparing virgin and aged batteries were carried out to show the effects on the sensor signals. From an economic and ecologic perspective, the application of sensors is still not beneficial, mostly due to the electronics that has to be used additionally. Main conclusion is that the use of sensor arrays on cell level provides benefits only, when costs of sensors can be reduced by a lean sensor architecture.
SPARTACUS discussed the results within Battery 2030+ CSA, on conferences and on industrial workshops. The developments found an excellent base for smart batteries with higher TRL and for follow-up projects, such as e.g. in combination with self-healing battery materials. One patent was filed referring to dielectric elastomer sensors for battery application.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

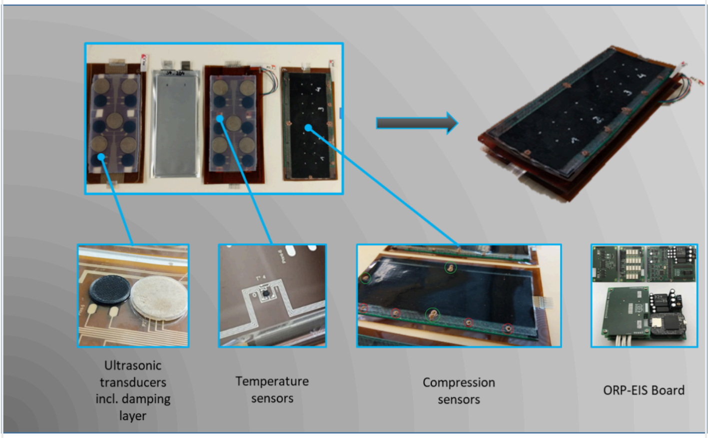
Within the SPARTACUS project, sensors were developed, tested and evaluated
on battery cells during cycling. Piezoelectric sensors were
tested under different conditions and assembled on flexible printed circuit boards to evaluate Time-of-flight signals, and attenuation in dependence on different frequencies and pre-loads. Dielectric

elastomer sensors were manufactured that measure the "breathing" of batteries during cycling; digital temperature sensors were evaluated and selected. For all of
these sensors, electronic boards were assembled that prepare the sensor data for the CMS. Similarly, electronics for ORP-EIS were assembled.
Layouts for Flex-PCBs were designed to which the sensors can be mounted with a small form factor. The layouts were printed and thermal VIAs
were fabricated to improve the thermal contact of the temperature sensors with the battery cell.
In order to build models that correlate to the sensor data, all degradations mechanisms were linked to sensor data. Aging campaigns were designed and performed that provoke the different degradations to be investigated; post-mortem analyses were performed for validation of different degradation mechanisms.
CMS and BMS were designed and manufactured that are fed by the sensor data and the models developed. For reduction of wiring and the number of cables, power line communication strategies were investigated.
The performance of the smart battery was investigated by validation campaigns, such as abusive testing and a comparison of sensor response for virgin and aged battery cells. Most of the outcome need follow-up projects to increase TRL levels. This refers especially to enhance the robustness and the electronics. DES sensor development was protected by filing a patent.
LCA and LCOES analysis was carried out.
For dissemination of the results, a web-page was set-up with 14000 page impressions; social media activities were
carried out (405 followers). The SPARTACUS project strongly supported the battery 2030+ activities in terms of road mapping, dissemination, standardizations, IP strategies, and education.
Results of the project were presented in relevant conferences.

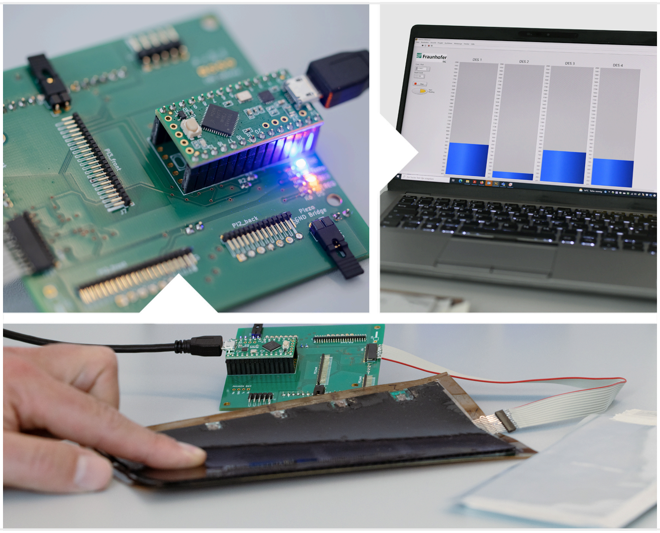
Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

SPARTACUS project worked on new knowledge beyond the state-of-the-art in different dimensions.
(1) SPARTACUS developed sensor, sensor arrays and electronics that are tailored to measure the SoC, SoH, SoP and other SoX on cell level in a non-invasive way. In SPARTACUS, the first time, a multi-mode non-invasive sensor array was implemented and the interaction between different sensors were taken into account as well
(2) SPARTACUS developed models that link the set of sensor data and SoX to potential degradation mechanisms. First, Equivalent Circuit Model (ECM) and Adaptive Extended Kalman filter (AEKF) were considered extended by model parameter estimator. A multi-physics model integrating electrical, thermal, and mechanical dynamics was set up. Based on these models, potential increase in charging speed was estimated.
(3) SPARTACUS developed the aforementioned cell management and battery management systems that benefit from the sensor data by adapting the cycling in correspondence to the new models. This CMS / BMS system is beyond the state of the art since it is capable to work with a variety of sensor data.

(4) SPARTACUS investigated whether smart batteries are economically and environmentally beneficial compared to conventional batteries. Main advantages are most likely possible for temperature and deforming sensors.
(5) Using the compression sensor based on dielectric elastomer sensors an early alert for thermal runaways can be created, several minutes before a thermal sensor would react-
At the end, SPARTACUS can provide a new toolbox to battery manufacturer and battery user. The results of SPARTACUS will foster the selection of appropriate sensors, models, battery management systems in order to improve the control of batteries and to operate them in an optimized and safe way. The extension of battery cycle life and increase in safety are the most obvious impacts. SPARTACUS helped to increase the knowledge about SMART batteries in the consortium and engineers /scientist that follow the SPARTACUS work, extending the base of skilled co-workers in Europe. The sensor technology can be transferred to new battery concepts as well if useful.



Sensors assembled on a battery to measure locally resolved the status of the cell



Dielectric Elastomer sensor to measure deforming of battery cells

Last update: 8 July 2024

Permalink: https://cordis.europa.eu/project/id/957221/reporting