History of EVs and measuring battery under external force

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Abstract— This article describes the modern history of electromobility with the prediction of its market growth and the drivers of change. There are mentioned Li-ion battery's anode materials with their basic parameters and one of the conversion materials, silicon, which represent one of the possible materials for enhancing the capacity of the anode. Usage of the Si opens a few problems which are unnoticeable with actual anode materials, but there are some possible ways how to solve them. One of their solutions could be external force applied on the battery surface, which should reduce inflation of the battery and improve internal conduction.

Keywords— Electromobility, Si anode, Li-ion battery, External force

1. INTRODUCTION

Every day, we use devices powered by batteries, whether they are smartphones, wearables, laptops, tablets, or devices that we need for our work. There are more than 7 billion people in the world, and everyone needs transport. One of the clean transporting trends is electromobility. This trend opens a new challenge of researching batteries. The research is mostly focused on longer lifetime, higher capacity, or lighter batteries.

2. MODERN ELECTROMOBILITY

The history of electromobility is older than we can think. Firsts prototypes of electric vehicles (EVs) were made in the first half of the 19th century and the 10s of the 20th century fought face to face with internal combustion vehicles (ICV), but Ford's mass production and longer driving range wins the fight and production of EVs was suspended in the time of WW2. Then during the rest of the 20th century, there were few EVs, their production was typically driven by an oil crisis.

A new restart of the powertrain electrification in the automotive sector started Toyota with their model Prius Hybrid in 1997. Prius was the symbol of ecological travelling, and his sales were successful, the highest sales had on the west coast of the USA.

In 2008 Elon Musk with his company Tesla wanted to test the market with their fully electric car Tesla Roadster. Tesla Roadster is based on the Lotus Elise and is the first serial EV with Li-ion batteries. Thanks to them, Tesla Roadster was able to reach a range of more than 300 km. Tesla sold almost 2500 cars and showed that EVs have a future [1][2].

In the 10s of the 21st century, almost every producer starts to experiment with EVs, some with prototypes, some with production cars. As a representative prototype should be mentioned Škoda Octavia Green eLine, which is based on second-generation Skoda Octavia and served for Press presentation [3]. One of the production cars, which should be mentioned is the BMW i3 which was on the market from 2013 and will ends this year. The special thing about this car is, that in the early sales years had a version called Rex (Range extender), which means that the car had a small IC engine that work as a generator for an extended range of the car. This conception did not work very well, so BMW withdrew it from the market [4].

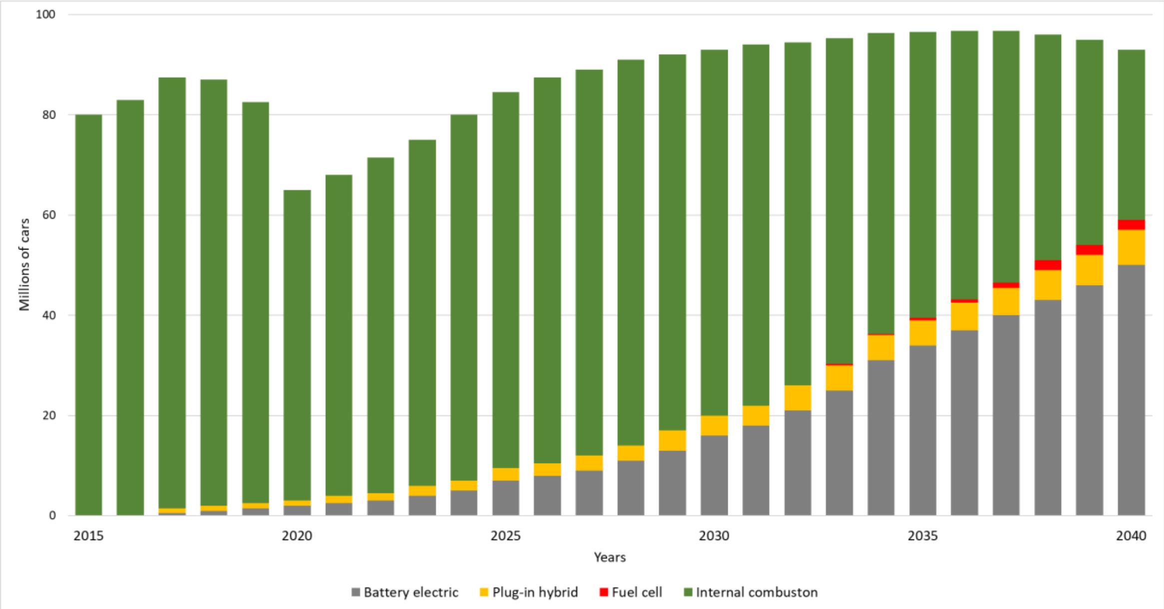

Figure 1:Global annual passenger vehicle sales by drivetrain[5]

Figure 1 clearly shows that electric vehicles will have a place in the future on the market. The assumption is that by 2040 at least half of the cars will be equipped with alternative drives (fuel cell, battery). It can be assumed that these conditions may still change, as some carmakers already mention that they plan to stop selling internal combustion vehicles around the year 2030, alone the EU is considering banning new ICVs from 2035. It is possible to assume that all operations of ICVs will be banned in the EU, as it is written in the Green Deal [5][6].

3. ANODE

Nowadays generation of Li-ion batteries uses two types of anode material. The first and the most common material is graphite in configuration LiC_6 theoretical capacity 372 mAhg^{-1} and potential 50-250 mV vs Li/Li$^+$. This material can be used with all cathode materials[7]. Another type is made from ceramic $Li_4Ti_5O_{12}$ (LTO), this type of anode is used for $LiMn_2O_4$ (LMO) and $LiNi1_{-x-y}Mn_xCo_yO_2$ (NMC) cathode materials. LTO has a working potential of less than 1.55 V vs Li/Li$^+$ with a theoretical capacity of 175 mAhg^{-1} [8].

One of the ways to improve Li-ion batteries is solved by increasing the capacity of the anode. The most promising conversion material, which can lead to the increased capacity of the anode is silicon. This material has a more possible used modification, but mostly tested is $Li_{15}Si_4$ with theoretical capacity 3579 mAhg^{-1} with potential lower than 0.5 V vs Li/Li$^+$[9]. The advantages of silicon are in its low ecological impact and large amount of it in Earth´s crust. On the other hand, there are a few problems with the usage of Si on the anode. The biggest problem is large volume change during cycling (up to 300 %), which leads to damage of SEI and its re-grow and the battery inflation. Another thing connected with volume changes is the cracking and disintegration of Si particles. The result of this is a rapid decrease of capacity, which makes usage of Si on anode difficult[10].

4. MEASURING BATTERY UNDER EXTERNAL FORCE

My research is focused on testing batteries under constant external force, which I moderate on battery by the holder with metal clamps and spring, as batteries we use pouch cells which are used by Škoda Auto in their EVs (see Figure 2). Forces on the springs used for the experiment were 50, 100, and 200 N on each spring. The springs have a maximum (F_m) force of 641.8 N and a spring constant (R) of 13.22 N/mm. For the setting moderated force, we use equation (1), F is moderated force and s is spring stroke.

$$F = R * s \tag{1}$$

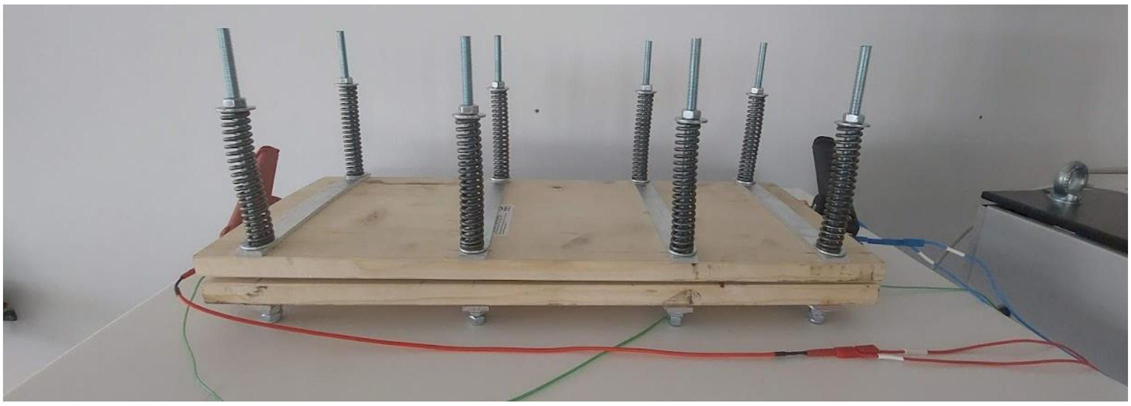

Figure 2:Battery during the measurement

At this moment I am using four pouch cells, one is used for uncompressed measurement and one for each force. The battery is compressed during the cycling and measuring electrochemical impedance spectroscopy and then is uncompressed and run the parametric test.

There are several studies focused on this research. The study of Müller et al. was focused on testing different levels of pressure and style of compression affecting the battery. In their experiment, they used uncompressed cells, flexible compressed (with springs), and fixed compression. Figure 3a shows the results of long-term cycling. Compression had a positive effect on the stability of the capacity drop and increase starting capacity. Best results were achieved with flexible compression, which shows almost two times higher remaining capacity than the uncompressed cell. Figure 3b then shows results of an inflation measurement, where pressure 0.84 MPa wins with low diversification of the result and total swelling only 13 % [11].

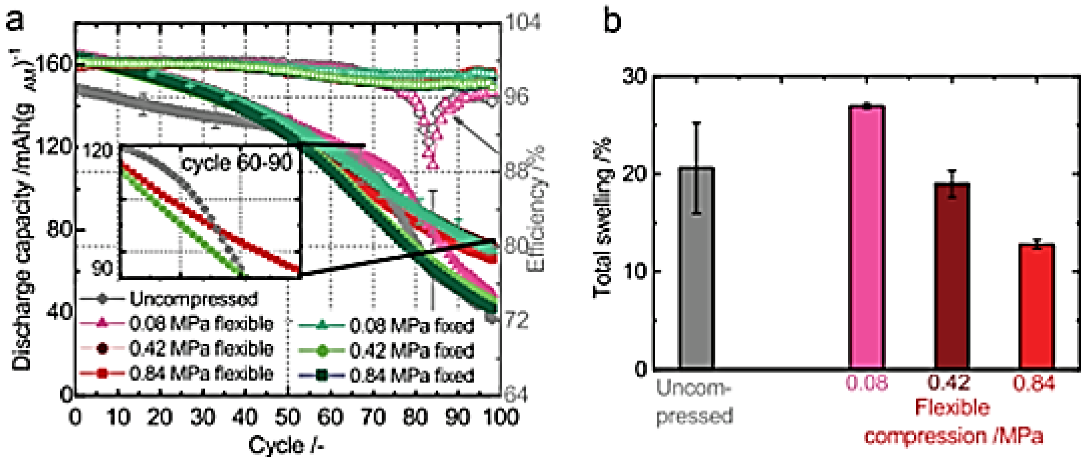

Figure 3: Effect of compression on battery with Si anode [11]

Another study made by Zhou et al. compares the function of NMC pouch cells under pressure (1 MPa) and without pressure (0 Mpa). New cells show that before the experiment the pressure did not affect the capacity, the result was verified by OCV. Their result shows that external pressure can effectively reduce the internal resistance of the battery (in Figure 4). The study also showed tests on the aged battery. The capacity was raised by 1.6 % just by using the external pressure on the battery. The pressure didn't affect OCV on the aged battery. After the measurements, the batteries were left for two weeks and after the decompression of the compressed battery, they measured an irreversible increase of capacity[12].

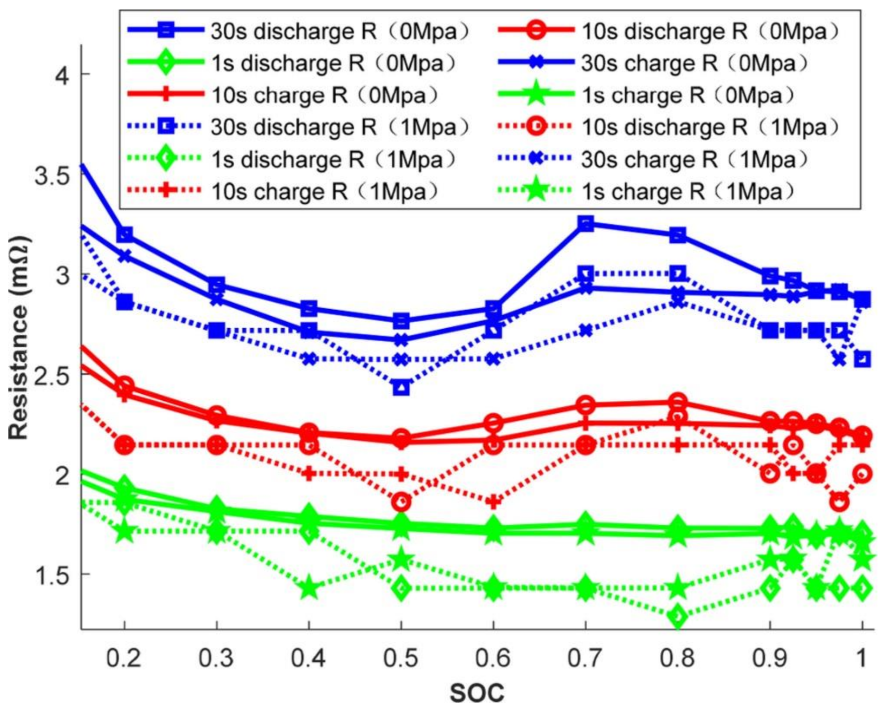

Figure 4: Comparison of internal resistance before and after pressure [12]

5. CONCLUSION

The article is describing the modern history of electromobility and the prediction of the market share of EVs in the future with their drivers.

In the article are described current anode materials with their parameters and new possible material for anode with its advantages and disadvantages. There is described one of the possible ways to reduce the problem with the usage of Si and how external pressure can positively affect the battery.

There is also described my mechanism for generating the external force and the methodology of my measurement.

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