A typical material testing system complete with temperature control unit and impedance analyzer

From the Cradle to the Grave

Aymeric Pelissier, Senior Product Manager at Bio-Logic, a leading global designer and manufacturer of scientific measurement instruments, talks about the importance of scientific measurement instruments across the energy battery chain, from fundamental to applied research and systems integration.

For centuries, mankind has understood the importance of recording detailed scientific information. Scientific measurement instruments shape our everyday lives and continue to drive technological progress. In navigation, the 10th century Kamal, little more than a wooden rectangle and a piece of twine, was the first celestial navigation instrument used to determine quantitative latitude. Eight centuries later, the high-precision of the sextant would enable sailors to determine both their latitude and longitude; opening up huge commercial opportunities and transforming the lives of the everyday sailor. In the 21st Century and a world where the high-tech magic of GPS is now totally taken for granted, the importance of scientific instrumentation is still every bit as important; for one simple reason – a good measurement will lead to a good decision.

Scientific instruments underpin EVs and advanced electro mobility solutions. The ability to characterize and develop new materials, to understand resistance, conductivity and electrochemical reactions is entirely dependent on the quality of scientific instrumentation used by researchers.

The six pillars of R&D driving EV applications

Eurobat, an international association responsible for promoting the regulatory commercial and economic interests of the European EV industry has identified the following factors as critical to the evolution of the EV industry: performance, cost, systems integration, production processes, safety and recycling. In this article we will demonstrate how scientific measurement equipment contributes to these different segments of the electro mobility value chain.

Performance: tools to help industry reach its objectives. If there is one standout tool in the Researcher's armory to improve performance it is the potentiostat- galvanostat. The "Swiss-Army knife" of electrochemical research the device is used in potentiostat and galvanostats modes to help understand electrochemical reactions for DC currents, and in EIS (electrochemical impedance spectroscopy) mode for AC currents. EIS is playing an increasingly important role in EV applications through its ability to monitor SoH (state of health), and SOC (State of Charge) two fundamental factors governing the performance of the car's power source.

Consequently, a need has grown for a vast range of potentiostat-galvanostats replying to detailed individual research needs. Bio-Logic has developed a vast product portfolio ranging from highly powerful

The Bio-Logic VMP3 is a multi-channel "workhorse" well known in research circles. The system (combining control software and instrument hardware) has evolved considerably since its launch in 2000 in line with researchers' needs. 18 years ago, researchers focused on characterizing the same values during battery cycling experiments. Researchers now use the multiple channels and high-end analysis capabilities of such instruments to explore battery behavior in much detail.

> And it's give and take. The process can work two ways, with second life batteries being used for EV vehicles or the grid. "Researchers from the California Center of sustainable energy estimate that the potential second life battery supply already in existence could total 850 megawatt hours of electricity, at 425 megawatts worth of power, assuming 50% of the battery packs in use as of 2014 can be repurposed with 75% percent of their nameplate capacity."[2]

single channel potentiostat-galvanostats used by researchers working in fundamental research, to sophisticated multi-channel instruments that can undertake multiple experiments simultaneously. The EIS functionality in advanced potentiostat/galvanostats gives researchers a detailed, non-invasive, understanding of how and where electrochemical reactions will affect battery performance. This ability to understand the in-operando functioning of a battery, be it alive or dead (post-mortem analyses are prevalent in fundamental research) makes the potentiostat/galvanostats such a valuable research tool.

However, performance is not entirely driven by applied or industrial research alone. The Lithium-ion battery is not far from its 30th birthday, making it the grandfather of EV battery chemistries. Its age makes it a mature, and well-understood technology. Research has consequentially shifted to a "marginal gains" type strategy where industry looks to fine-tune devices by making small, but important changes to electrolyte, electrode or other component materials rather than reinventing the wheel.

For materials, a specific range of equipment will be used: an impedance analyser such as Bio-Logic's MTZ-35 will be coupled with a temperature control unit and sample holder. This triumvirate of specialized equipment is used to better understand key material characteristics such as conductivity, capacitance and impedance – key variables that determine the development of improved battery function.

The ability to test materials' performance across different temperature ranges is hugely important. Temperature extremes (especially cold) can hamper Li-ion performance dramatically and heat can affect battery safety. Research to develop materials that function correctly in these environments relies heavily on such measurement equipment.

Cost & recycling: Developing a product that meets market needs

The improved performance of materials and components brought about by research using EIS will without doubt impact positively on cost for economic reasons: because as battery autonomy and EV range increases, it is likely that demand will increase, and prices will decrease.

However, there are other, more direct ways, in which scientific instrumentation will help to drive down costs. One such example is through advances made in Battery Cycling techniques and technology.

Battery Cyclers are instruments similar in principle to potentiostat/galvanostats that have been specifically adapted for use in large laboratories (most notably because of the large number of channels, that they offer, enabling industrial R&D experts the scope to carry out more measurements simultaneously).

The traditional means of battery

testing (battery cycling) is based on evaluating battery performance in real life conditions through the continuous charging and discharging of a battery, sometimes using increased temperature in order to increase cell degradation.

HPC (High-Precision Coulometry), however, is a relatively new technique put forward by a renowned battery scientist, Jeff Dahn of Dalhousie University, Nova Scotia. According to Dahn, HPC enables researchers or industrial R&D experts to determine battery behavior, with a much smaller quantity of data, drawn potentially from weeks, rather than months of testing, potentially saving time and money. However, the high-end specifications necessary for this technique make it unsuitable for many cyclers. The reliability of electrochemical measurement equipment can significantly help bring R&D costs down. Cycling experiments can last weeks or even months and an equipment breakdown can result in valuable data being lost. Similarly, a lack of precision can mean that scientists need to average out results over multiple channels rather than carrying out an experiment on one very precise channel, resulting in an inefficient use of resources.

Breathing "second life" into new EV applications

"It has been estimated that more than a 50% reduction in battery costs is necessary to equalize the current economics of owning PEV's and conventionally fueled vehicles. By extracting additional services and revenue from the battery in a post vehicle application, the total lifetime value of the battery is increased "[1] From both an environmental and economic perspective, second life applications offer significant value to stakeholders working in electro mobility applications. Electrochemical measurement systems can play a significant part in the triage process following category sorting, where Li-ion batteries are first identified. High-precision Potentiostat/galvanostats are needed to carry out RX analyses and check the residual capacity of batteries. The more precise the instrument, the more reliable the triage process will be that decides a) whether a battery is suited for second life activities at all and b) which second life application it is best suited for. The two techniques typically used in this process are Current Interrupt (a DC technique) or EIS.

Systems integration: From Laboratory to upscale

In applied research, potentiostat/galvanostats are generally used to evaluate the performance of individual cells, but advanced software can also enable the evaluation of series-connected batteries, fuel or Photovoltaic cells within the systems integration process. Multi-channel instruments are necessary for this type of "stacking "procedure where the voltage stack represents the sum of all individual elements. In most instances a separate product, such as a Bio-Logic's Flex-P booster may be needed to manage the power (voltage & current) of the full pack. Multi-channel in-stack configuration can significantly help industrial R&D experts to measure the individual potentials of each cell in a module as well as solve balancing issues between cells, help design BMS functionality and allows bipolar technology evaluation. In real-life ageing activities (sometimes referred to as Urban Profile Simulations), electrochemical instruments are also used in, to monitor driving conditions in real-time and real-life conditions (motorway, hill-climb, stop-start town driving). The effect of these different driving conditions will be analyzed at electrochemical levels, enabling researchers to optimize battery chemistries and ultimately the end-user driving experience.

Conclusion

Electrochemical instruments play a vital role in advancing electro mobility technology. From materials used in car sensors to evaluate temperature, pressure or humidity, to the latest advances in EIS measurement to advance the new battery chemistries of the future – a myriad of electro mobility applications depends on the cutting-edge scientific instruments developed by measurement companies like Bio-Logic. Electro mobility applications are driven by strong socio-economic needs. In environmental terms, we know that the damage caused by fossil fuels must be halted and quickly. In economic terms, we also know that we are reaching the bottom of the barrel for traditional fuel sources. The stakes are high and scientific measurement instruments will play an important part in the search for new electro mobility solutions, by guiding researchers in their research projects and providing them with a compass that will enable them to make the right strategic R&D decisions.

1: A second life for Electric Vehicle Batteries: Answering questions on Battery degradation and value
Neubauer, Wood, Pesaran International Journal of Materials and Manufactuing
2 Reuse and repower; How to save money and clean the grid with second-life vehicle batteries.

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