BioLogic

Applications of scanning probe electrochemistry– Sustainable Energy

SCAN-Lab

December 2020

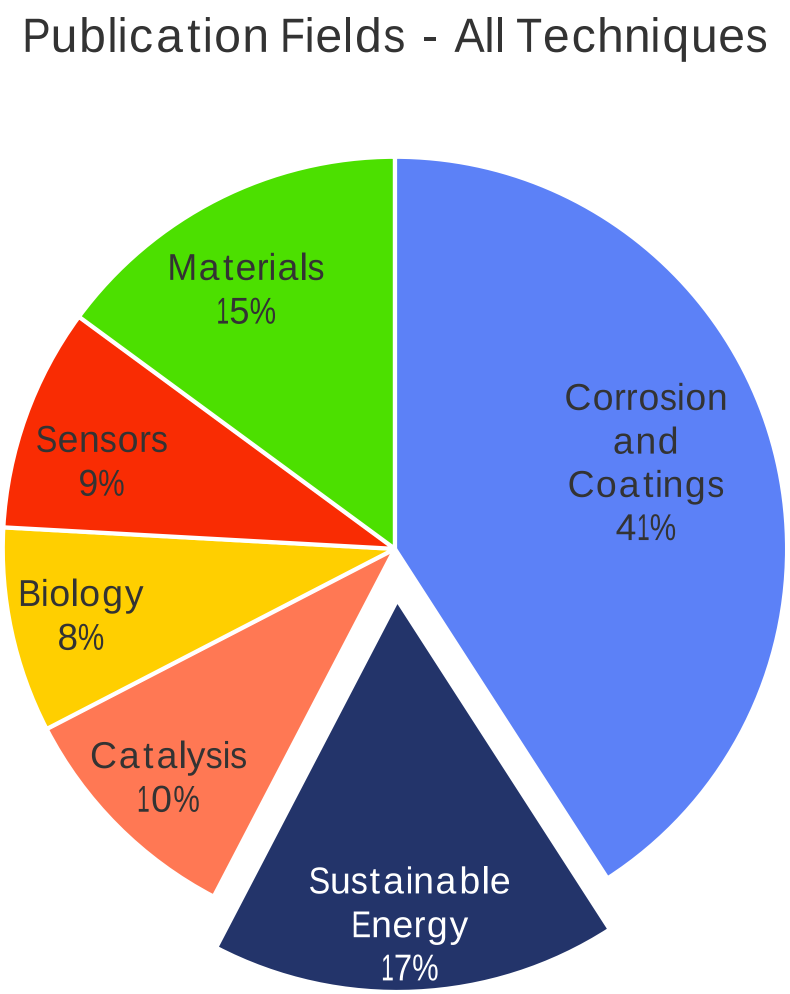
Version 1.0

Background

Background

17% of commercial scanning probe electrochemistry instruments are used in the field of sustainable energy.

This document will further investigate the role of scanning probe electrochemistry in the field of sustainable energy.

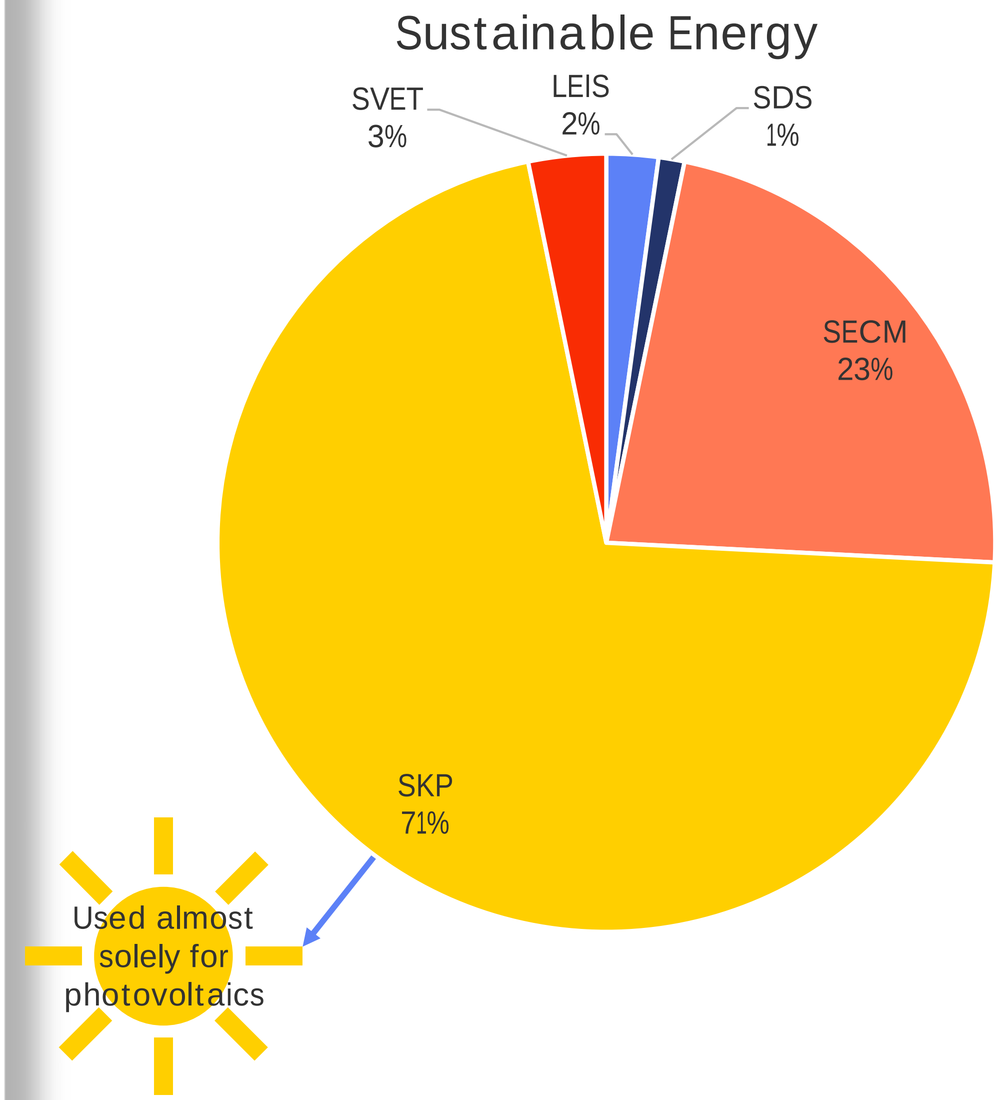


Why is scanning probe electrochemistry applied in sustainable energy?

Scanning probe electrochemistry is used to perform fundamental R&D studies in sustainable energy research to:

- Investigate swelling of battery electrodes
- Study the effects of grains and grain boundaries on solid electrolytes
- Follow the formation, evolution, and damage of the solid electrolyte interface
- Screen combinatorial libraries for energy storage materials
- Determine the energy position of the top of the valence band for solar cell materials
- Investigate the activity of fuel cell catalysts
- Study novel materials for sustainable energy applications

What techniques are used?



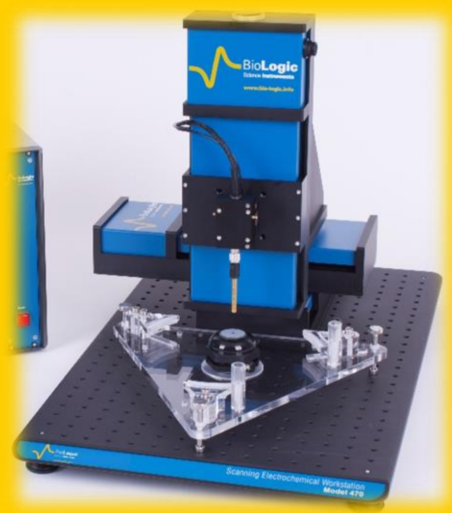
While all SCAN-Lab techniques have been used in sustainable energy studies SKP is by far the most popular. SKP is almost exclusively used to investigate photovoltaics. SECM is the next most popular, having been applied to a wide range of sustainable energy fields.

Source: Analysis of scientific publications citing commercial instruments. Each research group was only counted once per technique.

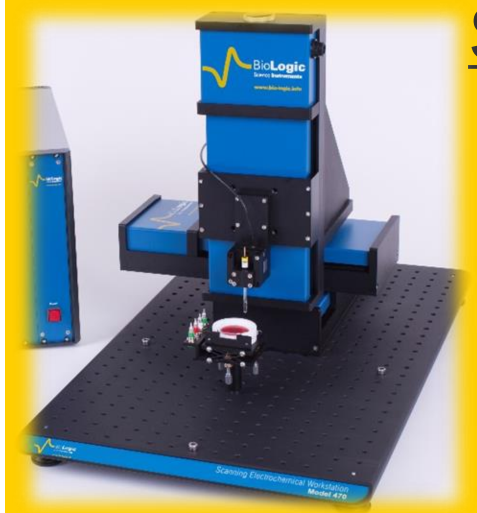
What techniques to consider for sustainable energy?

SVET

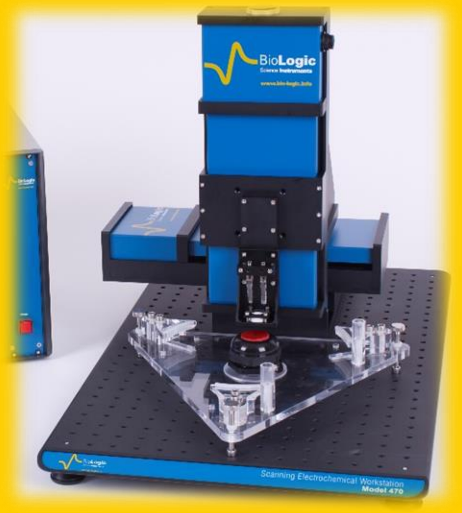
SKP*



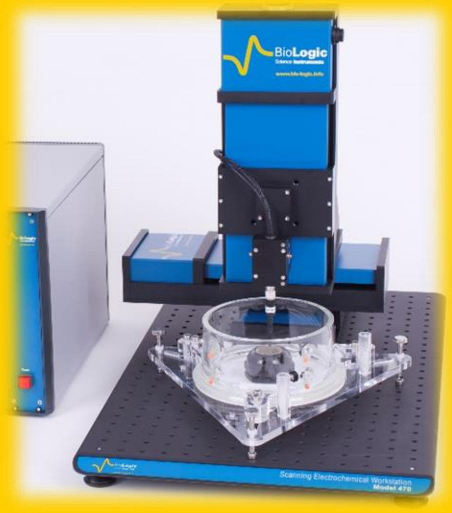
SECM



SDS



LEIS



*SKP is of particular interest for photovoltaic researchers

Batteries and Capacitors

What are the research problems?

Battery materials are heterogeneous in nature. Insulating impurities in these materials can affect its properties. While bulk techniques exist to study battery materials the insulating impurities are difficult to investigate and pinpoint by bulk techniques.

- Solution: Visualize local electrochemical activity at a point in time

The Solid Electrolyte Interface (SEI) forms during the initial charge/discharge cycles, which must be understood for battery development. It is of interest to follow the formation and evolution of the SEI, however, due to being a very fragile, and electrically insulating layer few techniques to study this exist.

- Solution: Visualize changes in activity over time
- Solution: Non-destructive measurement

Understanding the formation of conductive or insulating layers as a function of applying potential to or cycling a battery electrode, as in real world use, is important.

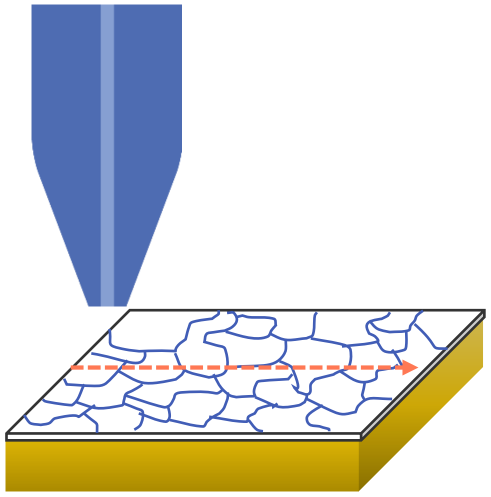
- Solution: Perform *in situ* measurements on biased samples

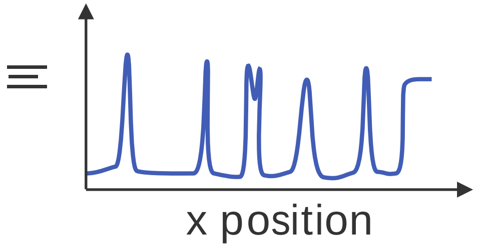
Solution: Visualize local electrochemical activity at a point in time

How this is met by scanning probe electrochemistry:

In scanning probe electrochemistry only the area under the probe is measured. The electrochemical characteristics measured by the probe, for example work function or current **density, relate to a sample's electrochemical** activity.

By raster scanning the probe across the sample an x-y map of electrochemical activity can be produced.



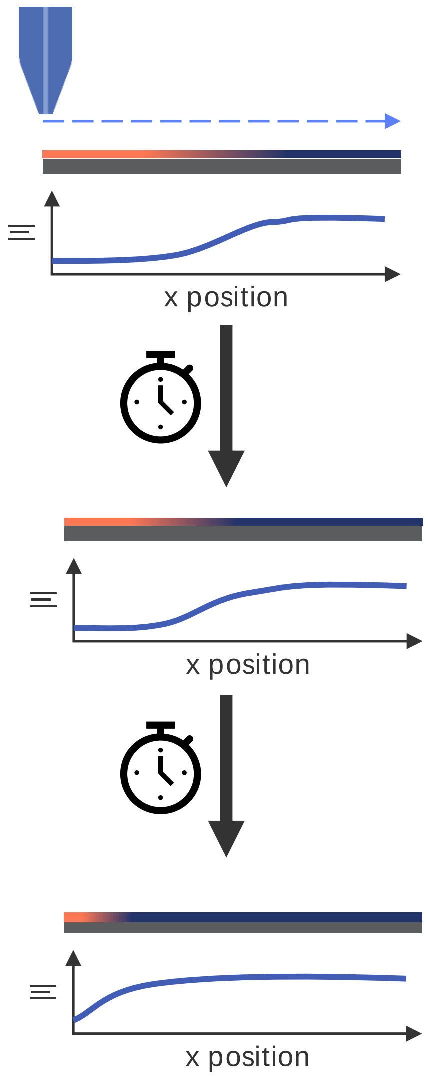


Solution: Visualize changes in activity over time

How this is met by scanning probe electrochemistry:

To follow changes to the system over time, for example formation of the SEI, researchers measure multiple area maps of the same region of a sample at given time intervals. Changes in the magnitude of the probe response allow processes to be followed as they occur.

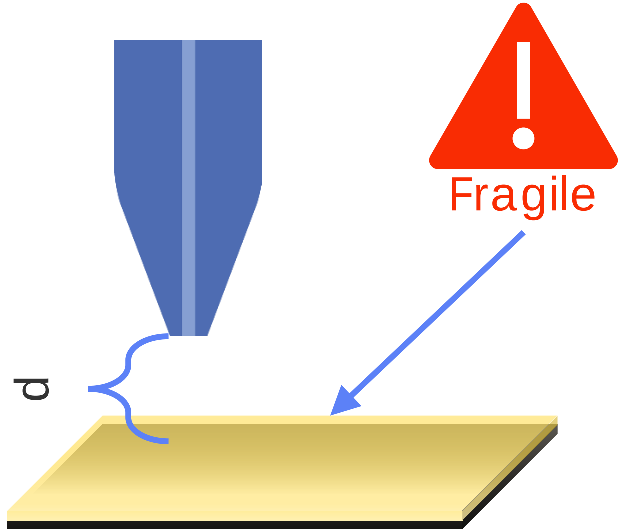
The SCAN-Lab softwares have the option to automatically loop experiments. By looping any area scan type the response over hours, days, or more can be followed.



Solution: Non-destructive measurement

How this is met by scanning probe electrochemistry:

Scanning probe electrochemistry, such as Scanning Electrochemical Microscopy (SECM), performed at a user defined probe to sample distance. These measurements can be performed at much larger probe to sample distances than other techniques typically used, on the orders of microns. This allows measurement without contact to the sample, which could otherwise damage delicate samples.



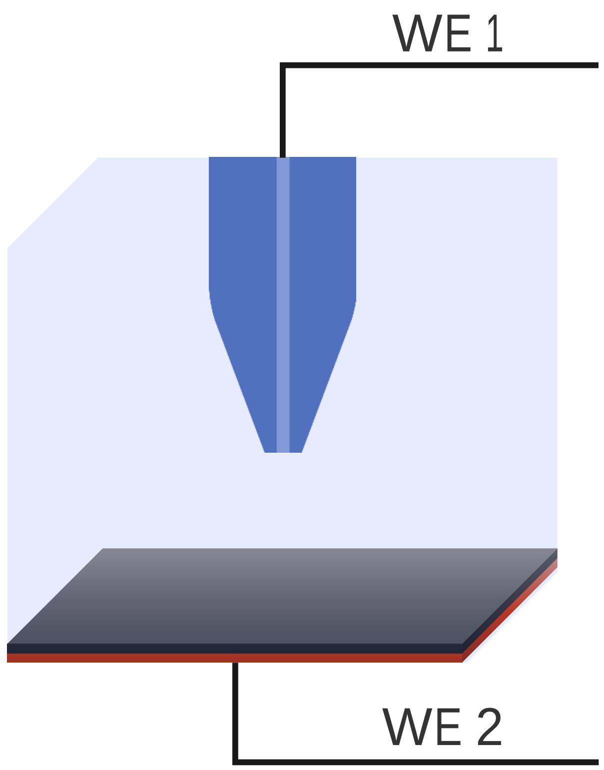
Furthermore, scanning probe electrochemistry measures a fundamental characteristic of the sample, removing the need for damaging sample pretreatments.

Solution: Perform *in situ* measurements on biased samples

How this is met by scanning probe electrochemistry:

A key requirement of many scanning probe electrochemistry techniques is that they are performed in electrolyte. This means the ability to perform *in situ* measurements is built into the technique.

In scanning probe electrochemistry measurements the sample acts as the only, or a second working electrode in the measurement. It is possible, therefore, to apply a known bias to the sample throughout the measurement.



Fuel Cells

What are the research problems?

In the search for novel fuel cell catalysts it is critical to understand the catalytic activity of a novel material. Catalytic activity can be affected by the structure and composition, which can be highly localized.

- Solution: A method to quickly screen local catalytic activity

When studying fuel cell catalysts it is important to understand how they behave in real world conditions. For fuel cell catalysts this is a liquid environment.

- Solution: *In situ* measurement of catalytic activity

In fuel cell research the selective measurement of protons is important. When investigating fuel cell catalysts selective measurement of protons provides information on the catalytic activity. If proton exchange membranes are of interest selectively measuring the proton allows transport through the membrane to be studied.

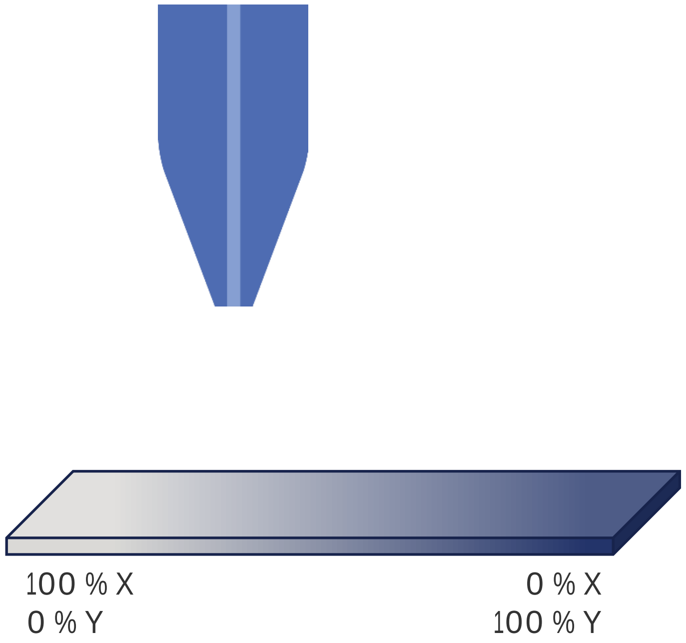
- Solution: Measurement with chemical selectivity

Solution: A method to quickly screen catalytic activity

How this is met by scanning probe electrochemistry:

To quickly screen the effect of composition on catalytic activity high throughput screening of combinatorial libraries is used. Scanning techniques can measure an entire library in a single experiment, without changing samples.

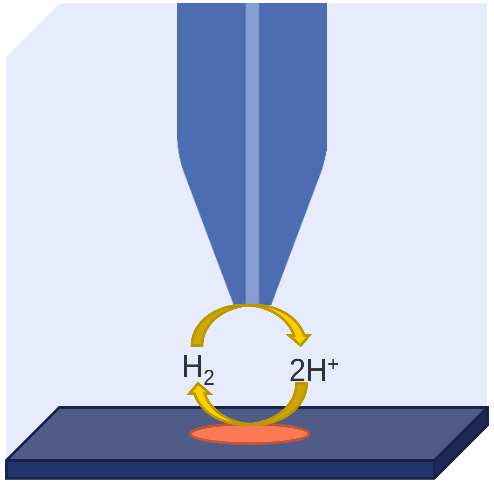
Scanning probe electrochemistry can be used to map combinatorial libraries *in situ*, individually probing the electrochemistry of a wide range of compositions in a single experiment. Performing screening in a single measurement allows hugely reduced screening times compared to traditional electrochemical screening methods.

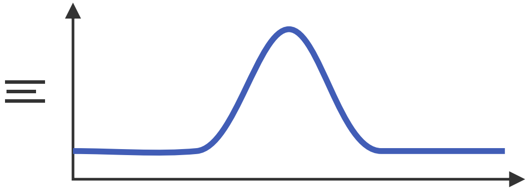


Solution: *In situ* measurement of electrocatalytic activity

How this is met by scanning probe electrochemistry:

A key requirement of many scanning probe electrochemistry techniques is that they are performed in electrolyte. This means the ability to perform *in situ* measurements is built into the technique to allow the activity of fuel cell catalysts to be investigated under real world conditions.



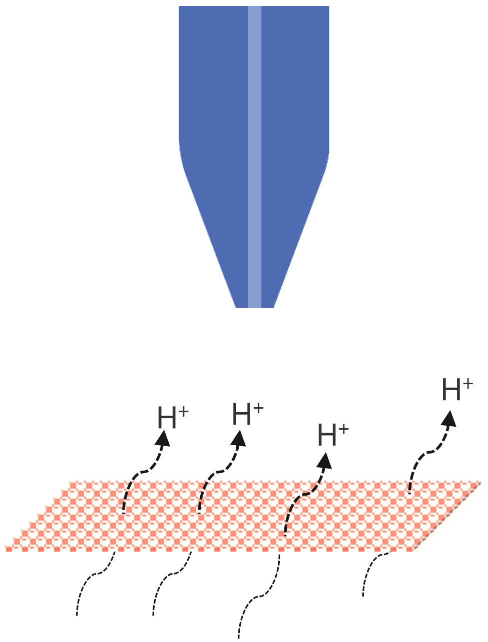


Solution: Visualize local proton distribution

How this is met by scanning probe electrochemistry:

In SECM the probe can be biased to detect a specific electrochemically active species, which in the case of fuel cells is often protons. Furthermore because the resulting signal is directly related to the concentration of the active species it is possible to quantify the proton distribution.

This sometimes leads to SECM being referred to as the chemical microscope.



Photovoltaics

What are the research problems?

In novel photovoltaic devices the device efficiency is dependent on the relation of the work function of the positive and negative electrode to each other. It is important, therefore, to know explicitly what the work function of a novel electrode is, very few techniques exist to measure this.

- Solution: Ability to measure the work function of a material

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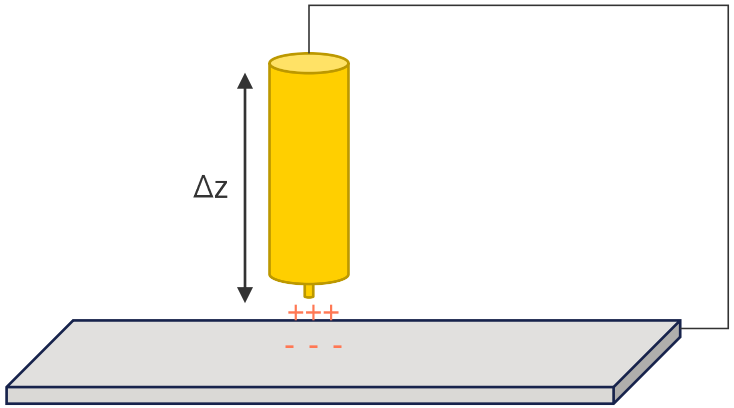
How this is met by scanning probe electrochemistry:

Scanning Kelvin Probe (SKP) is one of very few techniques which can be used to determine the work function of a sample. SKP measures the potential difference between the sample and a calibrated probe to determine the work function of the sample. The work function of a single point can be determined, or it can be averaged across a sample.



Conclusions

Summary

- Scanning probe electrochemistry is used to understand the effect of heterogeneity on battery and supercapacitor materials, and how these change over time
- With scanning probe electrochemistry it is possible to screen the catalytic materials used in novel fuel cells
- In photovoltaics research the work function of novel materials can be determined by SKP
- In sustainable energy studies SECM and SKP are of the most interest

Why BioLogic?

With **BioLogic's** scanning probe electrochemistry instruments sustainable energy researchers can visualize the local electrochemical processes and properties of their samples *in situ*. BioLogic scanning probe electrochemistry users can expect high quality, easy to use instruments with the highest level of support.

Learning Center Article

A series of Learning Center articles has been created to help determine the most appropriate technique for a given research problem. This includes articles dedicated to sustainable energy research:

[Scanning Probes & Battery Research]

[Scanning Probes & Fuel Cell Research]

[Scanning Probes & Photovoltaics Research]

Acronyms

- LEIS: Local Electrochemical Impedance Spectroscopy. Localized Electrochemical Impedance Spectroscopy also used
- SECM: Scanning ElectroChemical Microscopy
- SDS: Scanning Droplet System. Scanning Droplet Cell (SDC) also used.
- SKP: Scanning Kelvin Probe
- SVET: Scanning Vibrating Electrode Technique. Vibrating Probe and Scanning Vibrating Probe (SVP) also used.