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## **In-Plane Conductivity vs. Through Plane Conductivity Measurements**

Membrane conductivity can be the result of charge transfer from ions or electrons. This discussion assumes that the membrane conductivity is the result of charge transfer from ions. If a researcher suspects conductivity that is a result of charge transfer from electrons, work in addition to that discussed below will be necessary.

Measurements of membrane conductivity must separate the:

- Voltage losses associated with ion creation, from
- Voltage losses associated with ion conduction.

## **Through Plane Conductivity Measurements**

Through-plane conductivity is the measurement of interest in an operating fuel cell. However, to obtain a good through-plane conductivity measurement, the membrane must be assembled in a Membrane Electrode Assembly (MEA) with a high quality catalyst layer that is well-bonded to the membrane. A two-electrode measurement, using AC impedance or current interrupt, is used to obtain the conductivity measurement.

In order to make accurate membrane conductivity measurements, the effects of the following variables must be considered:

- Contact resistances between the diffusion media and the catalyst layer.
- Contact resistances between the diffusion media and the current collector.
- Diffusion media resistance.
- Interactions within the catalyst layer.
- Catalyst membrane interface.

While through-plane conductivity is a more direct measurement of the membrane's conductivity in a fuel cell, the equipment and resource costs are much higher than that required for in-plane conductivity measurements.

### **Advantages**

1. When the MEA includes a high quality, well-bonded catalyst, this is a very good measure of a membrane's ability to conduct ions.
2. This approach will also yield other fuel cell data.

### **Disadvantages**

1. This approach takes time – building the MEA, building the fuel cell, and interpreting the data collected.
2. This approach is expensive. The researcher will need a complete fuel cell testing system in order to obtain membrane conductivity data.
3. The researcher will need to know how to build a high-quality fuel cell, and test it, in order to obtain accurate membrane conductivity data.



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## **In-Plane Conductivity Measurements**

Four-electrode, in-plane conductivity measurements obtain the conductivity of a pure membrane sample using a robust, re-usable catalyst (such as platinum gauze). These measurements obtain the bulk conductivity of a membrane using AC impedance or a DC voltage sweep. In isotropic membranes, in-plane conductivity is the same as through-plane conductivity. In very anisotropic samples, the absolute values of conductivity will differ. But, the character of the in-plane curve (conductivity vs. RH) will be the same as the character of the through-plane curve. The advantage of measuring the character of the sample, even if the absolute conductivity value is not exact, is that the polymer chemist can quickly determine if the polymer is more or less dependent on water than Nafion.

### **Advantages**

1. Assembly of the sample under test is much simpler. It is not assembled into an MEA. Instead, the pure membrane is clamped into the BekkTech Conductivity Cell.
2. This approach requires less equipment and supplies than that needed for fuel cell testing, making it a less expensive approach.
3. This method does not require an MEA. So, any variables introduced by the MEA are eliminated.
4. When done properly, a four-electrode, in-plane measurement provides a more direct measurement of the conductivity of the membrane.

### **Disadvantages**

1. This approach may be less effective on anisotropic membranes. However, the character of the membrane (conductivity vs. RH curve) will remain constant even in anisotropic samples.
2. Some care must be taken to ensure that the measurement is measuring ion conduction and not electron conduction.
3. In some cases, the measurement may be of surface conduction and not a true bulk characteristic. In this case, samples of varying thicknesses must be used to confirm that the measurement is a bulk measurement.

### **For additional information**

Please contact us with questions or for further information on the approaches discussed above.

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