

ilium technology, inc.

Whitepaper Abstract

How to Measure Conductivity over a Wide Range and at Ultra-low Levels

Ilium Technology's Model 2100 conductivity meter and associated probes provide unprecedented range and sensitivity in conductivity measurements in liquid systems, from milli-Siemens/cm down to as low as 1 femto-Siemen/cm. To do so, they employ a number of proprietary and patent (pending) technologies. This paper will present some background on conductivity measurements and describe the technical approach used in order to provide a better understanding of the instrument's capabilities.

What is conductivity?

Conductivity is a material property that quantifies the amount of current that will flow through a material in response to an applied electrical potential relative to the cross-sectional area of the sample and the distance the current travels through the material. It is measured in Siemens/cm. One Siemen equals one amp of current per Volt of applied potential. Some older measurements may be seen in the literature using the unit Mhos/cm, a unit which is no longer used but which remains interesting because the name itself reflects the inverse relationship between resistance (R, measured in Ohms) and conductance (G, measured in Siemens formerly Mhos). Likewise, resistivity (ρ , measured in Ohm-cm) is the inverse of conductivity (σ , measured in Siemens/cm) (equation 1).

$$(1) \quad G = 1/R \text{ and } \sigma = 1/\rho$$

It is important to distinguish between conductivity and conductance. The relationship is exactly analogous to the relationship between resistivity and resistance. Conductance and resistance are properties of specific circuit elements, while conductivity and resistivity are properties of materials. Both are governed by Ohm's law (equations 2 and 3) relating current flow (I) to the applied potential (V).

$$(2) \quad R = V/I$$

Substituting $G = 1/R$ we get

$$(3) \quad G = I/V$$

Conductivity can be a property of almost any material. The discussion that follows is limited to measurements of conductivity in liquid systems.

Why measure conductivity?

Conductivity measurements provide fast, continuous, inexpensive indications of changing electrical and material properties. This is useful in many research, development, analytical, quality control, and process control applications. Typical applications include:

- Solvent purity, additive concentration, additive titration, total dissolved solids.

- DI water purity - deionized (DI) pure water is a relatively poor electrical conductor compared to tap or salt water. At 25°C and pH 7, it has a resistivity of 18.2 million ohm-cm (meg-ohm-cm) or a conductivity of 55 nano-Siemens/cm. It is the amount of ionized substances dissolved in the water which increases water's ability to conduct electricity above this value.
- Clean-in-place for solvents and water – the cleaning process is monitored by measuring the purity of the effluent solvent as indicated by its conductivity.
- Personal care and cosmetics – the purity, acidity, presence of additives, etc. of natural (e.g., vegetable) and synthetic (e.g., silicone) oils used in these products can be tracked by conductivity measurements.
- Jet fuels and other flammable, non-polar solvents - avoiding conditions leading to static discharge during pumping, transferring, filtering and mixing operations requires the conductivity of these materials to be kept above a minimum level of about 1 pico-Siemen/cm.
- Inks - conductivity of ink dispersions is affected by both soluble components and charge on pigment particles. Conductivity measurements provide a means to track dispersant concentration and effectiveness.
- Paints and coatings - conductivity of paint formulations is affected by both soluble components and charge on pigment particles. As with inks, conductivity measurement provides a means to track dispersant concentration and effectiveness.

Why do I need a wide range of measurement?

The range of conductivity measurements varies widely from application to application (figure 1), and may vary widely within a single process or experiment. A wide ranging measurement capability permits the user to:

Follow a process - In non-aqueous systems, conductivities can easily swing over many decades with only relatively small changes in concentration of additives or impurities. The ability to follow that change with a single meter during a process can provide valuable, real-time information.

Replace multiple meters – Many commercial, industrial and academic laboratories must address a range of applications with a wide range of relevant conductivities. A single meter with a sufficiently wide range can eliminate the expense of multiple meters and the inconvenience and wasted time involved with switching meters for different applications.

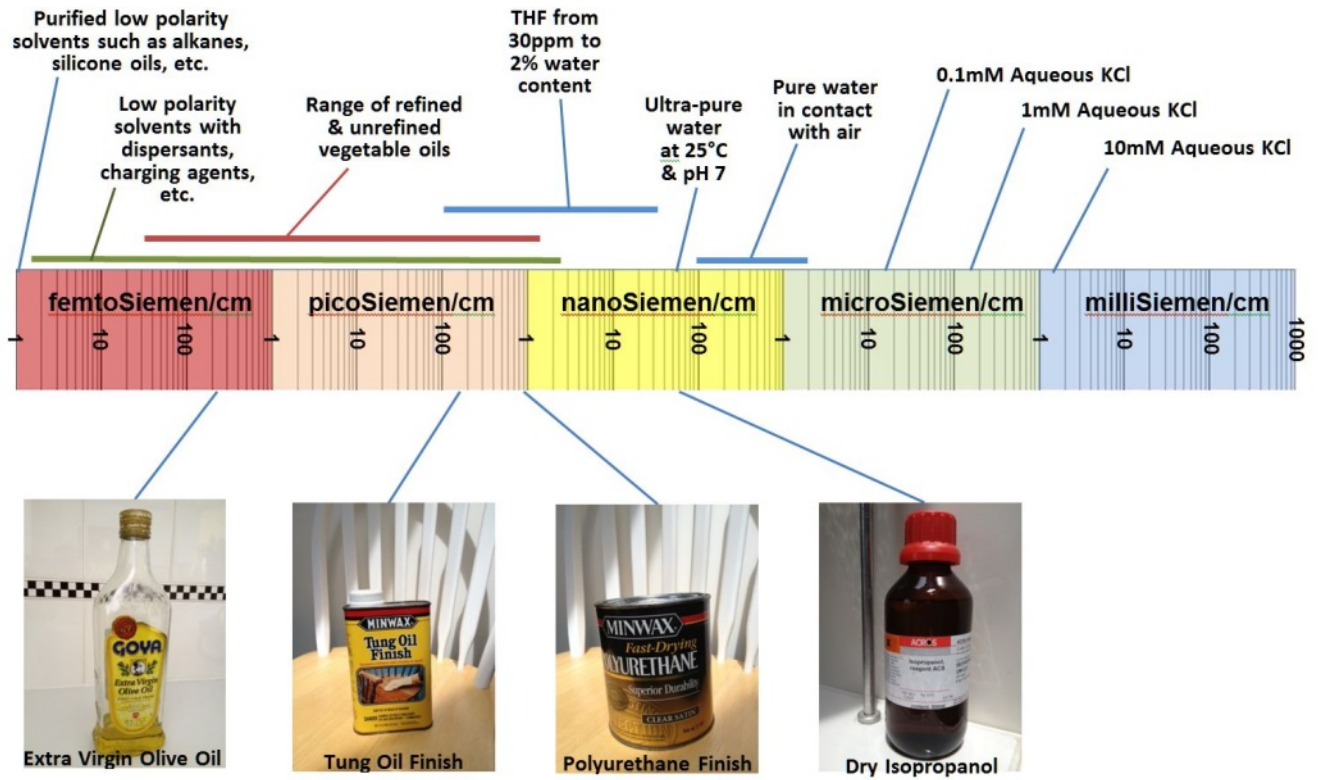


Figure 1. Illustrating the conductivity measurement ranges associated with various applications.

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