Abstract—Solid-state chemical sensors have a unique set of testing challenges which derive from their performance metrics and operating environment. The calibration scheme employed in the sensor application will dictate the level of testing required and the yield of usable devices.

Emerging biomedical, industrial and consumer applications are expanding the need for liquid chemical sensing. For example, the trend in clinical diagnostics is toward portable equipment which can be used to quickly provide data at the patient’s side. The monitoring of biological fluids for illicit drugs or for hazardous chemicals is increasingly important. Verification of safe levels of toxic substances in industrial effluents, lakes, and public water systems is now a priority, and individual consumers are increasingly concerned about the quality of their drinking water. While analytical instruments and laboratory procedures are available for collecting the required data, these approaches are often unacceptably expensive or slow.

Miniature solid-state liquid chemical sensors can be used to make these measurements quickly and economically. These sensors, which are made with a combination of thin- and thick-film techniques and proprietary chemistry on silicon, glass or plastic, come in a variety of types: potentiometric, conductometric, amperometric, and optical, with variations implemented by enzymatically or immunologically coupling these to the analyte of interest. The commercialization of these sensors has been slowed by device testing challenges. Potentiometric sensors, which generate a voltage that is logarithmically related to the concentration of the ion of interest, as shown in Fig. 1, will be used to illustrate some of these issues.

Solid-state potentiometric sensors can be made by depositing onto a conductor, a polymeric membrane doped with an ionophore to provide specificity. The electrochemical parameters which must be verified to assure accurate readings with any chemical sensor are functionality (good circuitry and insulation), selectivity toward the chemical of interest (over that of interfering chemicals), slope (gain), detection limit (lowest detectable concentration), initial settling time, baseline voltage (offset), stability (drift over time), and response time. In addition, the sensors must be tested for shelf life and lifetime in use. Because the sensors are used in solution, encapsulation integrity and membrane adhesion often dictate lifetime.

The application determines much about the type of testing needed. In many cases, these sensors are made to be disposed of after a single use. In other applications, they will be used over a period of weeks or months, making many measurements before being replaced. In addition, the calibration scheme used in the application will affect the testing scheme. Target values for parameters such as selectivity, detection limit, settling time, response time and stability must be achieved during design of the sensor and optimization of the membranes. Rigorous manufacturing control and sample testing of sensor lots is adequate to assure high functional yields and to keep these parameters within specification.

Analytical chemists almost always do at least two-point calibrations of a sensor before using it to make a measurement. When this calibration approach is used, the reference and slope are determined at the time of the sample measurement, allowing sensors having slightly different slopes and offsets to produce accurate results. A single-point calibration method has been used with some solid-state chemical sensors, putting severe requirements on the reproducibility of slope, which has increased testing cost and reduced yields to the point of unprofitability.

Testing and packaging are intimately connected, and represent significant parts of the cost of chemical sensors. Therefore, they should be considered in the design of sensors and sensing applications from the start. Instruments which incorporate these sensors should be able to use devices having a range of parameters and to detect a bad device through a multi-point calibration, thereby relaxing the demands on production testing.