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Trace-moisture measurements using cavity ring-down spectroscopy

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The measurement of trace amounts of water vapor (trace moisture) in gases is a challenging issue that needs to be addressed for various high-tech industries that use high-purity gases. The most well-known example is the semiconductor industry. For example, in the semiconductor industry, so-called bulk gases such as N_2, Ar, O_2, and He are used in large amounts, for instance, as purge gases to remove contaminants in the manufacturing processes. Therefore, these gases must have the highest purity, and any residual moisture needs to be controlled to less than 100 nmol/mol (100 ppb) in amount-of-substance fraction (mole fraction). Reliable measurement of trace moisture is essential to enable these moisture controls. However, the measurement of trace moisture in the range less than 100 ppb is not an easy task. A primary reason behind this is that only a few types of trace-moisture analyzers have sufficient sensitivity in this range.

Cavity ring-down spectroscopy (CRDS) is a highly sensitive technique that enables the measurement of trace species in gases even at parts-part-trillion (ppt) levels, which is expected to be necessary in the semiconductor industry in the near future. In particular, CRDS is advantageous for measuring trace moisture, because CRDS measures the time of ring-down that occurs inside the sample cell (optical cavity), and therefore, does not suffer from the atmospheric moisture outside the sample cell, which is a major disturbance in the measurement of trace moisture in most cases.

We developed some measurement systems for trace moisture based on CRDS, such as dual-laser CRDS[1], wavelength-meter-controlled CRDS[2, 3], and miniaturized CRDS[4]. The performance of these systems was reliably evaluated using primary trace-moisture standards traceable to the International System of Units (SI).

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