Secondary resistance standards in quantum resistance measurements

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VSL Dutch Metrology Institute

With their very good long-term stability and low TCR, the VHA518-11 Bulk Metal® Foil resistors proved to be high-quality secondary resistance standards in quantum Hall resistance experiments.

Industry/Application Area: Calibration and measurement standards

Products Used:

- VHA518-11, K-foil, 12K9 Ohm, hermetically sealed 4-terminal resistor
- VHA518-11, K-foil, 6K45 Ohm, hermetically sealed 4-terminal resistor

The Challenge

The quantum Hall resistance (QHR) standard is the internationally-agreed primary quantum standard for resistance, with values of around 12.9 kΩ and 6.45 kΩ. As secondary resistance standards, VSL required high-quality resistors with values close to the QHR values, with well-defined four terminal configuration, low noise, low sensitivity to environment (low TCR and no RH effect), and excellent long-term stability.

The Solution

The VHA518-11 ultra-precision secondary standard resistor from Vishay Foil Resistors was chosen since the integration of 11 elements into a single housing results in lower TCR and lower long-term drift values than a single element. Furthermore, the device has 4-terminal connections, is hermetically sealed and filled with oil, so that sudden temperature changes have less effect on the resistance value and any effect of humidity is eliminated.

The User Explains

Figure 1: VSL quantum Hall resistance standard.

The VHA518-11 components were tested for their TCR and subsequently mounted in an enclosure thermostatted at (29.00 ± 0.02) °C for further reduction of TCR effects. They were subsequently measured against the QHR for a period of more than 5 years.

The measurement results are given in the figures below. The actual TCRs of the two VHA518-11 elements appeared to be less than 0.5 ppm/°C over the temperature range of 18 °C – 28 °C, with a (very) small second order temperature coefficient Beta – see the insets of the two figures. This is well below the 2 ppm/°C specification over the temperature range of -55 °C – 125 °C.

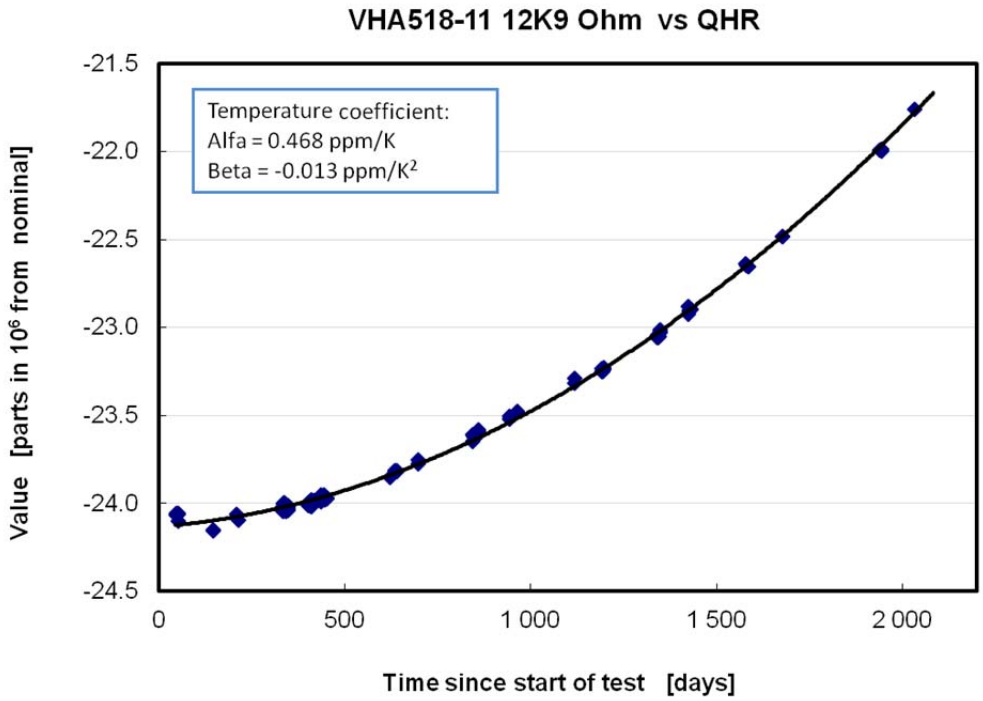

Figure 2: Resistance variation of a 12K9 Ohm VHA518-11 element over time

The 12K9 resistor was within 30 ppm (0.003 %) equal to the required nominal value at the start of the experiments and shows a resistance variation of around slightly over 2 ppm (0.0002 %) over a period of 5.5 years. The drift over time in these initial 5 years can be quite closely approximated with a quadratic behaviour, with a variation of less than 0.1 ppm around the drift line.

The 6K45 resistor was within 10 ppm (0.001 %) equal to the required nominal value at the start of the experiments and shows a somewhat larger resistance variation of around 11 ppm (0.0011 %) over a period of 5.5 years. This drift over time is larger, but also more linear than the 12K9 element.

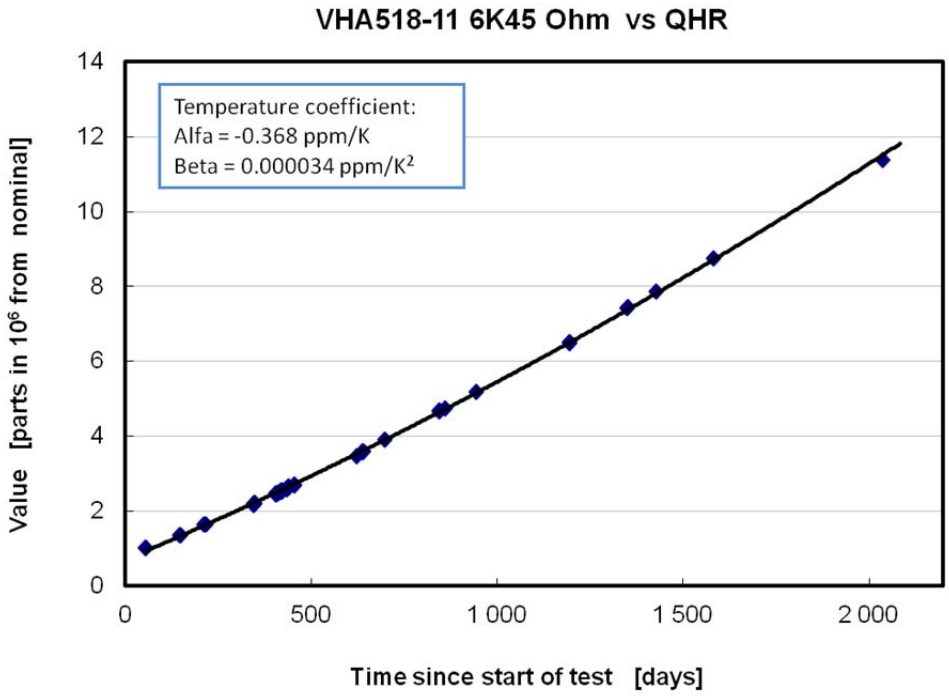

Figure 3: Resistance variation of a 6K45 Ohm VHA518-11 element over time

"Vishay Foil Resistors' hermetically sealed VHA518-11 resistors have been subjected to a 5 year test to verify their long-term drift. The actual TCRs of less than 0.5 ppm/°C and long-term drifts of better than 2 ppm/year make the VHA518-11 suitable and very cost-effective secondary resistance standards in quantum Hall resistance measurements."

Acknowledgement:

VSL is the National Metrology Institute (NMI) of the Netherlands and is responsible for developing and maintaining the highest level of measurement standards in the Netherlands. A significant part of this task is to provide measurement services for the Dutch industry and research institutes in the area of electrical

measurements, which covers the very wide range from electrical quantum standards to radiofrequency and microwave measurements.
http://www.vsl.nl/

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