National Institute of Advanced Industrial Science and Technology

National Metrology Institute of Japan

Reference Material Certificate

NMIJ CRM 5805-a
No. +++

High-purity copper for Thermal Expansivity Measurements

This certified reference material (CRM) was produced in accordance with the NMIJ’s management system, and in compliance with ISO GUIDE 34:2009 and ISO/IEC 17025:2005. This CRM is intended for use in calibrating push-rod dilatometers and thermomechanical analyzers or as a reference specimen in thermal expansion measurements.

Certified Values

The certified values of thermal expansivity \( \alpha \) and their expanded uncertainties \( U \) in this CRM are given from the following equations. The value of \( \alpha \) is the linear thermal expansivity based on a specimen length at 20 \(^\circ\)C (\( L_0 \)). The value of \( U \) given by the equation is the half-width of the expanded uncertainty interval calculated using a coverage factor (\( k \)) of 2, which gives a level of confidence of approximately 95 \%.

at 20 K \( \leq T < 31 \)K,
\[
\alpha/\left(10^{-6} \text{K}^{-1}\right) = -1.559444 \times 10^{-4} \cdot (T / K)^2 + 4.133681 \times 10^{-5} \cdot (T / K)^3 + 1.663047 \times 10^{-7} \cdot (T / K)^4 - 4.939234 \times 10^{-9} \cdot (T / K)^5
\]

at 31 K \( \leq T < 100 \)K,
\[
\alpha/\left(10^{-6} \text{K}^{-1}\right) = 3.716863 - 3.917249 \times 10^{-2} \cdot (T / K)^2 - 1.753929 \times 10^{-4} \cdot (T / K)^3 + 9.827042 \times 10^{-7} \cdot (T / K)^4 - 2.157414 \times 10^{-9} \cdot (T / K)^5
\]

at 100 K \( \leq T < 170 \)K,
\[
\alpha/\left(10^{-6} \text{K}^{-1}\right) = -1.631489 \times 10^{-1} + 6.048822 \times 10^{-3} \cdot (T / K) - 5.705181 \times 10^{-3} \cdot (T / K)^2 + 3.203064 \times 10^{-5} \cdot (T / K)^3 - 9.990485 \times 10^{-8} \cdot (T / K)^4 + 1.324350 \times 10^{-10} \cdot (T / K)^5
\]

at 170 K \( \leq T < 300 \)K,
\[
\alpha/\left(10^{-6} \text{K}^{-1}\right) = -1.281768 - 1.845905 \times 10^{-1} \cdot (T / K) - 7.519537 \times 10^{-4} \cdot (T / K)^2 + 1.279893 \times 10^{-6} \cdot (T / K)^3 - 1.157627 \times 10^{-10} \cdot (T / K)^4 - 1.368713 \times 10^{-12} \cdot (T / K)^5
\]

at 20 K \( \leq T < 300 \)K,
\[
U/\left(10^{-6} \text{K}^{-1}\right) = 5.80 \times 10^{-2} - 3.80 \times 10^{-4} \cdot (T / K) + 1.55 \times 10^{-6} \cdot (T / K)^2 - 1.86 \times 10^{-9} \cdot (T / K)^3
\]

The calculated results from above equations at typical temperature points are shown in the table below. The value of \( U \) is rounded up to the third decimal place.

<table>
<thead>
<tr>
<th>( T / K )</th>
<th>( \alpha/\left(10^{-6} \text{K}^{-1}\right) )</th>
<th>( U/\left(10^{-6} \text{K}^{-1}\right) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.279</td>
<td>0.052</td>
</tr>
<tr>
<td>40</td>
<td>2.260</td>
<td>0.046</td>
</tr>
<tr>
<td>60</td>
<td>5.457</td>
<td>0.041</td>
</tr>
<tr>
<td>80</td>
<td>8.328</td>
<td>0.037</td>
</tr>
<tr>
<td>100</td>
<td>10.486</td>
<td>0.034</td>
</tr>
<tr>
<td>120</td>
<td>12.044</td>
<td>0.032</td>
</tr>
<tr>
<td>140</td>
<td>13.182</td>
<td>0.031</td>
</tr>
<tr>
<td>160</td>
<td>14.024</td>
<td>0.030</td>
</tr>
</tbody>
</table>
Analysis
Each certified value was determined by the following measurement methods:
(1) The thermal expansion measurement was conducted by a laser interferometric dilatometer, and the determination of specimen length at 20 °C was carried out by a digital linear scale.
(2) The certified values were determined as a function of temperature by a least square method under restrictive conditions with the weight of the measurement uncertainty.

Metrological Traceability
Each certified value was determined from the measurement results in a change of specimen temperature (ΔT), a change of specimen length (ΔL) and a specimen length at 20 °C (L0). The value of ΔT, ΔL, and L0 were measured by instruments calibrated by reference standards which were an Iodine stabilized He-Ne laser, a Platinum resistance thermometer, a standard resistance and a block gauge, respectively. In the results, the certified value is traceable to the International System of Units (SI).

Expiration of Certification
This certificate is valid until March 31, 2019, provided that the material remains unopened and is stored in accordance with the instructions given in this certificate.

Sample Form
This CRM is in the form of a rectangular block with a base of 10 mm × 10 mm and a length of 30 mm, kept in a plastic case.

Homogeneity
The homogeneity of the CRM was determined by analyzing the measurement results on 4 specimens (20 mm × 20 mm × 8 mm) which were cut from different positions of an ingot of copper. The homogeneity of thermal expansivity is reflected in the uncertainty of the certified value.

Instructions for Storage
This CRM should be kept at 25 °C or below, and under a nitrogen gas atmosphere.

Instructions for Use
・ Do not use this CRM for any purpose other than the calibration of a dilatometer.
・ The certificated value denotes the value of the thermal expansivity along the 30 mm length direction of the distributed shape of the CRM.
・ Cautions with respect to thermal cycles.
  ・ Avoid a thermal shock which causes cracks in the CRM.
  ・ Avoid heating above 315 K.
・ Processing of specimen
  ・ Customers can cut and polish the CRM to adjust to their dilatometer.
  ・ When processing, note that the certificated value denotes the value of the thermal expansivity along the 30 mm length direction of the distributed shape of the CRM.
  ・ Avoid generating cracks and plastic deformation in the specimen in consideration of thermal and mechanical stress in processing.
  ・ When cracks are generated in the specimen, do not use the specimen.

Precautions for Handling
Handling of the CRM is similar to that of the solid of copper. Refer to the safety data sheet (SDS) on this CRM before use.

Preparation Method
This CRM was made from a high-purity copper ingot with the purity of 99.999 at% or more. The CRM was cut in a rectangular block with a base of 10 mm × 10 mm and a length of 30 mm by electrical discharge machining.
NMIJ Analysts
The technical and production manager for this CRM is N. Yamada and the analyst is N. Yamada.

Technical Information
Customer registration on the NMIJ Website (given below) will facilitate notification of any revision of the information given above. Technical reports regarding this CRM can be obtained from the contact details given below.

Reproduction of Certificate
In reproducing this certificate, it should be clearly indicated that the document is a copy.

If you have any questions about this CRM, please contact
National Institute of Advanced Industrial Science and Technology,
National Metrology Institute of Japan,
Center for Quality Management of Metrology, Reference Materials Office,
1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, Japan
Phone: +81-29-861-4059; Fax: +81-29-861-4009; https://www.nmij.jp/english/service/C/

Revision history
April 1, 2015: “Metrology Management Center” was renamed to “Center for Quality Management of Metrology.”