Measurement of thermal expansion at low temperatures using the strain gage method

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Main goal

To meet the thermal expansion characteristic parameter needs for material selection and structural design of the cryogenic , an accurate, fast, easy to operate, low-cost method for measuring the thermal expansion characteristics and experimental setup were developed.

Innovation point

A constant rate mode, with temperature varying rate of 0.3 K/min, was adopted for a quick and accurate thermal expansion characteristic parameter measurement, requiring less than 14 h. The sensitivity coefficient of Karma foil strain gage was corrected in the temperature range of 77–293 K to ensure the accurate measurement of thermal expansion characteristic parameters at low temperature based on strain gage technology.

Major method and results

1. **The experimental setup with a PID temperature control system based on the strain gage method** to measure the thermal expansion of material at low temperatures is shown in Figs. 1 and 2.

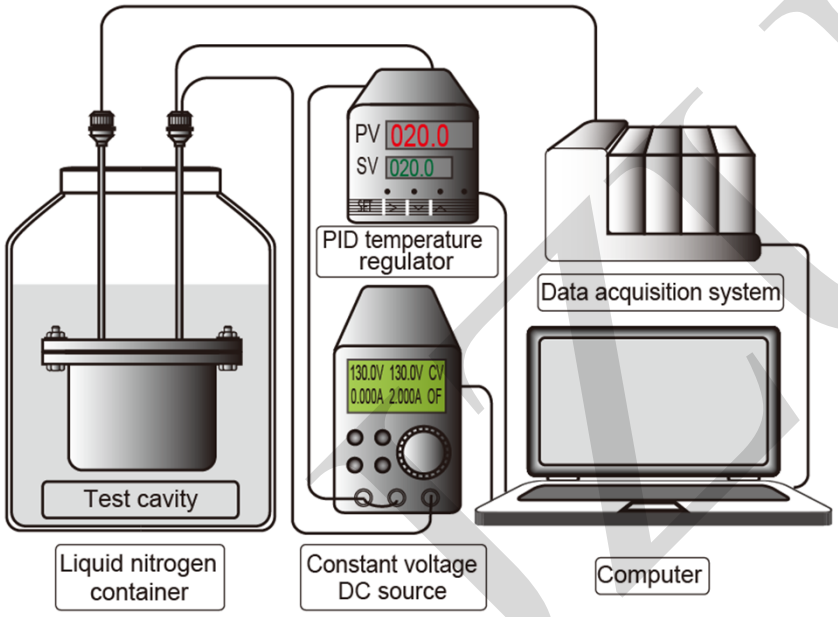

Fig. 1 Schematic of measurement system for thermal expansion of solid materials at low temperatures

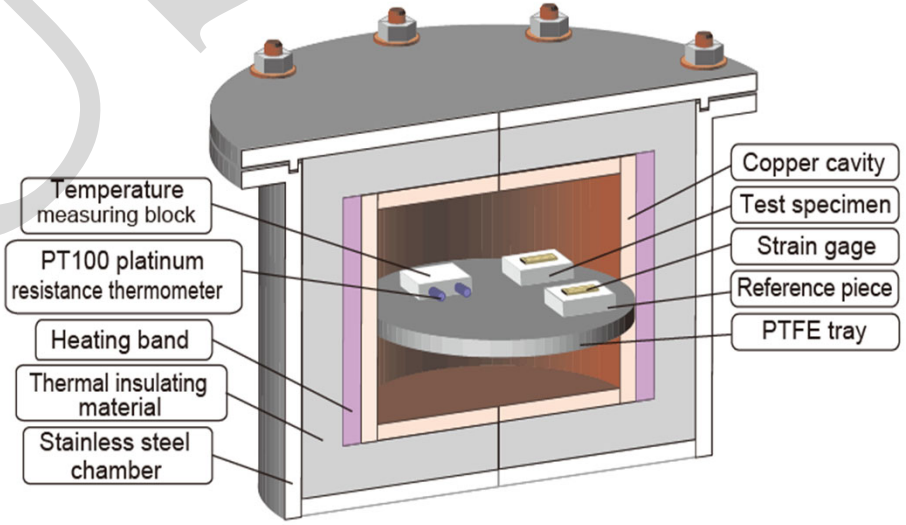

Fig. 2 Schematic of the test cavity

Major method and results

2. **The sensitivity coefficient of the Karma foil strain gages was corrected** in the temperature range of 77–293 K, by comparing the measured thermal expansion data of 304 stainless steel with the source data from NIST, as shown in Figs. 3 and 4.

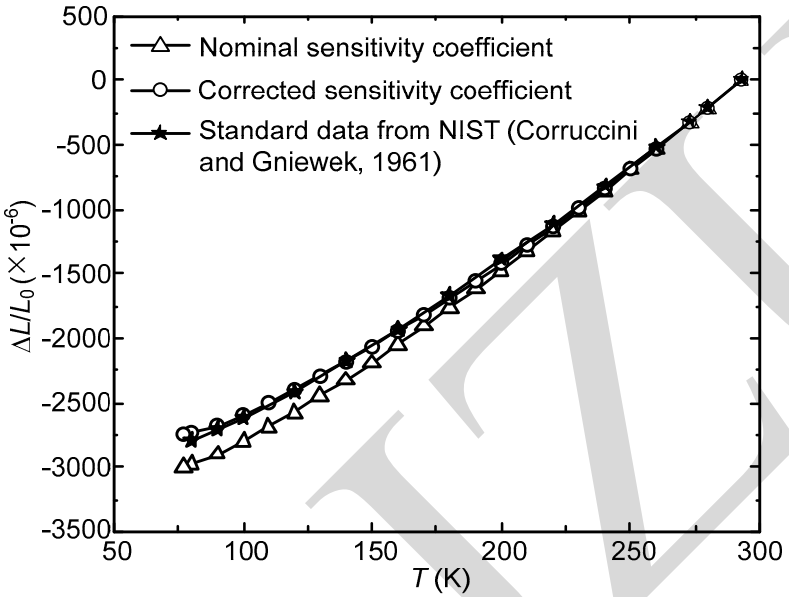

Fig. 3 Linear contractions relative to 293 K of 304 stainless steel in the range of 77–293 K

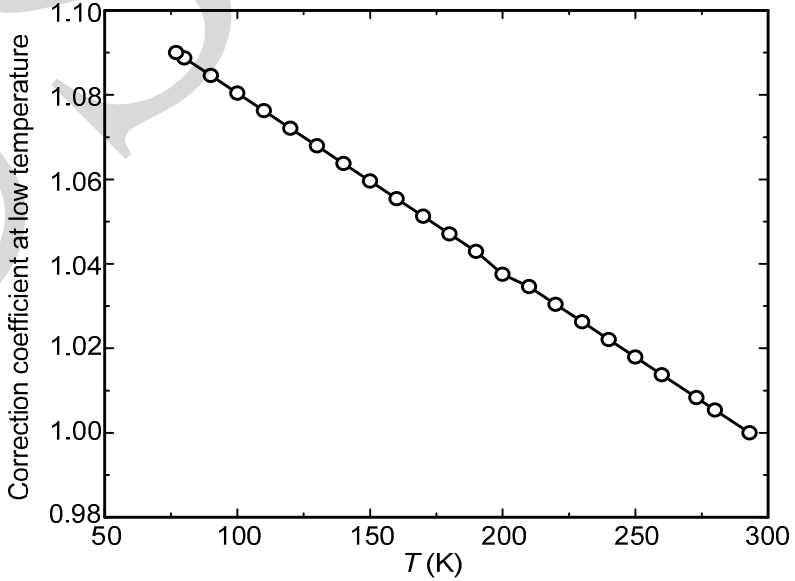

Fig. 4 Correction coefficient for the sensitivity coefficient at low temperatures

Major method and results

3. With the corrected sensitivity coefficient, the measured linear contractions of the oxygen-free copper are quite consistent to the NIST data, which indicates that **the corrected sensitivity coefficient is applicable for the linear contraction measurement of diverse solid materials in the temperature range of 77–293 K**, as shown in Fig.5 and Table 1.

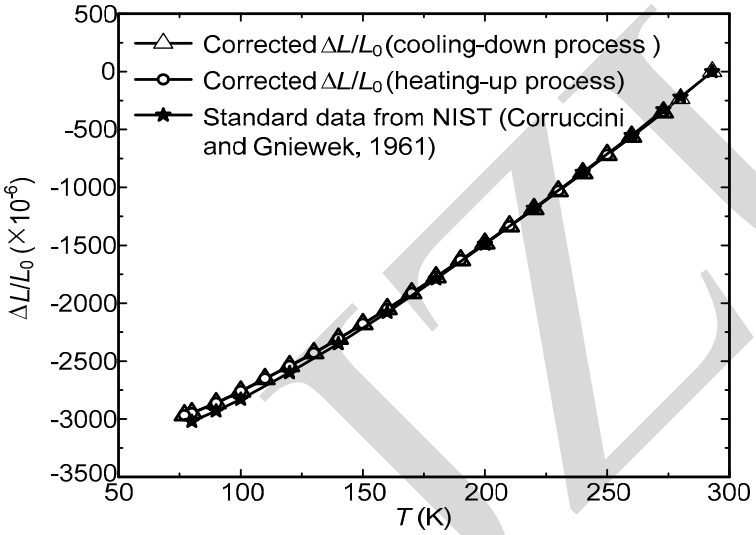

Fig. 5 Linear contractions relative to 293 K of oxygen-free copper in the range of 77–293 K

Table 1 Comparison of measured linear contractions relative to 293 K of oxygen-free copper in the cooling-down process from 293 K to 77 K with the source data from NIST (Corruccini and Gniewek, 1961)

Temperature (K)	Experiment data (10^{-6})	NIST data(10^{-6})	Relative deviation (%)
293~280	-232.9	-220	5.85
293~273	-350.4	-330	6.18
293~260	-562.1	-550	2.20
293~240	-876.4	-870	0.73
293~220	-1185.6	-1180	0.48
293~200	-1485.3	-1490	0.32
293~180	-1775.0	-1790	0.84
293~160	-2050.9	-2080	1.40
293~140	-2370.3	-2350	1.82
293~120	-2541.7	-2600	2.24
293~100	-2762.5	-2830	2.38
293~90	-2863.4	-2930	2.27
293~80	-2948.4	-3020	2.37
293~77	-2968.2	-	-
293~70	-	-3100	-