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Deliverable D41.12: High Dose Experiments at 750°C & 950°C - Full PIE of INNOGRAPH-IB and INNOGRAPH-2B

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Summary

This document contains the results from the Graphite Irradiation programme, part of the RAPHAEL-IP, for the medium to high dose level in which the irradiation behaviour of modern graphite grades is investigated at two irradiation temperatures, 750°C and 950°C. Following up on the screening Post-Irradiation Examination (PIE) performed in the RAPHAEL project, and issued under Deliverable D41-11 a full PIE was performed in the ARCHER project. This report describes the screening PIE and full PIE of the high dose experiments at 750°C (INNOGRAPH-1B) and 950°C (INNOGRAPH-2B).

Approval

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D41.12: High dose experiments at 750°C and 950°C

Full PIE of INNOGRAPH-1B and INNOGRAPH-2B

Under the contract of Euratom
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Contents

Summary

In the European graphite irradiation programme, part of the RAPHAEL-IP, the irradiation behaviour of modern graphite grades is investigated at two irradiation temperatures, 750°C and 950°C. Following up on the screening Post-Irradiation Examination (PIE) performed in the RAPHAEL project, a full PIE was performed in the ARCHER project. This report describes the screening PIE and full PIE of the high dose experiments at 750°C (INNOGRAPH-1B) and 950°C (INNOGRAPH-2B).
The work described was performed with financial support from the European Union and the Dutch Ministry of Economic Affairs, Agriculture, and Innovation. The views expressed in this report are those of the authors and do not necessarily represent those of the European Union, nor those of the Dutch government.

1 Introduction

Graphite is a suitable material to be used as a neutron moderator and reflector in nuclear reactors. Graphite has been used in Advanced Gas-Cooled Reactors, Magnox reactors, RBMK's (a Russian acronym meaning "reactor cooled by water and moderated by graphite"), Research Reactors, Materials Test Reactors and High Temperature Reactors (HTR's). Recently, there has been a renewed interest in HTR's. Two prototypes, one in Japan (HTTR) and one in China (HTR-10) are operated. The Pebble Bed Modular Reactor (PBMR) in South Africa and Next Generation Nuclear Plant NGNP in the US are in development. The European Commission is also supporting research projects for the development of HTR technology with the aim to determine the technological requirements for designing and constructing an HTR in Europe.

Much research has been done on the behaviour of graphite grades in a nuclear reactor environment, because graphite is already being used in reactors for decades. However, these graphite grades are no longer commercially available since the raw materials no longer exist. In addition, most data from the past are from low temperature experiments (<550°C), whereas for HTR's the graphite temperatures will generally be higher than 550°C. In order to be able to design a European HTR, it is decided by the European commission to create a database that contains data of the materials behaviour of available graphite grades under neutron irradiation at temperatures relevant for the HTR's. This will allow the 'best' graphite(s) to be chosen, and provide the necessary data to allow the core design to be carried out.

Within the RAPHAEL-IP framework, graphite irradiation experiments were performed at 750°C and 950°C in the High Flux Reactor (HFR) in Petten. These were named INNOGRAPH-1B (750°C, high dose), INNOGRAPH-2A (950°C, medium dose) and INNOGRAPH-2B (950°C, high dose). In every experiment a few graphites were also irradiated at lower temperatures of 650°C (in the 1B) and 850°C (in the 2A and 2B). Figure 1.1 shows schematically the expected volume change of graphite with neutron fluence at the two main irradiation temperatures. The boxes on the curves indicate the four different irradiation experiments. Box 1A indicates the low dose irradiation at 750°C named INNOGRAPH-1A. This has been performed within HTR-M1 in the 5th Framework Programme and had a target dose of 8 dpa [1]. Box 1B indicates INNOGRAPH-1B, the high dose (up to ~25 dpa) experiment at the same temperature. Boxes 2A and 2B indicate the medium and high dose experiments at 950°C, INNOGRAPH-2A and INNOGRAPH-2B respectively. In order to reach the target dose in as short a time as possible, the high dose experiments (INNOGRAPH-1B/2B) partly contain specimens that have been irradiated in the

low dose experiments. These two high dose experiments had to be built in a hot-cell because of the radioactivity of the samples. The capability to do this delicate work with manipulators is essential to carry out this irradiation programme [2, 3].

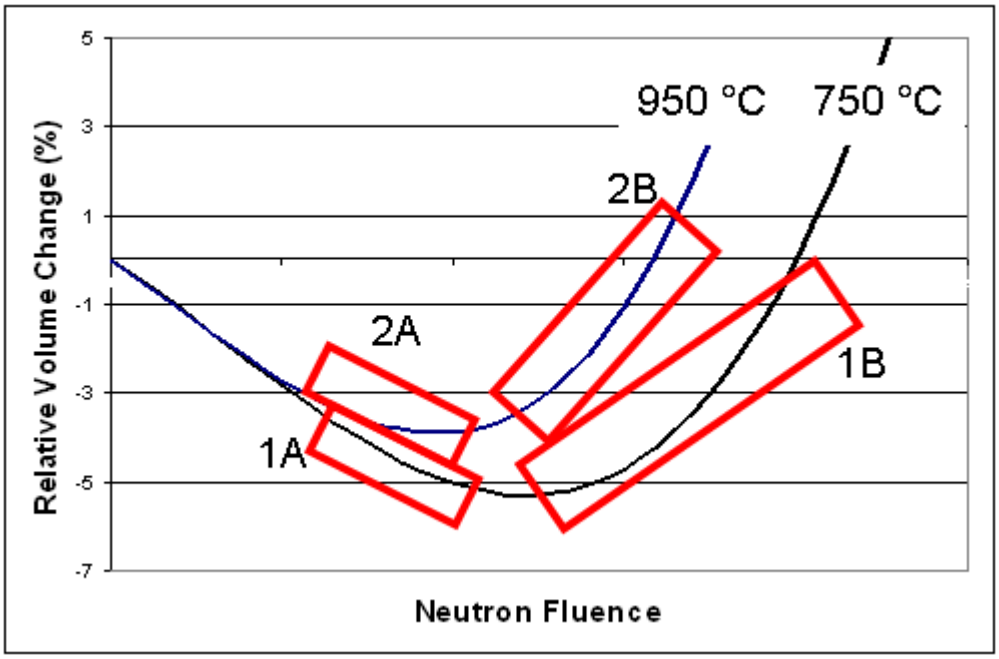

Figure 1-1 Schematic overview of the four INNOGRAPH irradiation experiments

Four graphite grades have been selected as major grades by the project partners in the 5th and 6th Framework projects; two produced by SGL Carbon and two by Graftech. In addition, minor graphite grades are included in the experiments with fewer samples. These also include graphite grades produced by Toyo Tanso.

The following properties were measured and compared before and after irradiation: specimen dimensions, mass, dynamic Young's modulus, coefficient of thermal expansion and thermal diffusivity. Density and thermal conductivity were calculated from the measurements. A full PIE has been performed on the INNOGRAPH-1A and -2A in the HTR-M1 and RAPHAEL projects [4, 5]. Screening PIEs have been performed for the INNOGRAPH-1B and 2B irradiations [6, 7].

This report presents the results of the screening Post-Irradiation Examinations and the full Post-Irradiation Examinations of INNOGRAPH-1B and INNOGRAPH-2B experiments. With this report, ARCHER deliverable D41.12 is fulfilled.

2 Experiments and measurement techniques

2.1 Test matrices

2.1.1 Grades

The selection of the graphite grades for the RAPHAEL programme is based on several factors such as thermal and mechanical properties, impurity levels and availability [2]. The four major grades, produced by SGL Carbon and Graftech are chosen in such a way that the graphites cover a variety of microstructures. This is achieved by selecting grades based on different raw materials, i.e. coal tar pitch coke or petroleum coke, and different manufacturing methods, i.e. extrusion, isostatic-moulding or fibro-moulding.

The minor grades include graphites from three different manufacturers, SGL Carbon, Graftech and Toyo Tanso. The minor grades include iso-moulded graphites and graphites based on needle coke. The graphites used in the experiments are listed in Table 2.1 and Table 2.2.

The list of major and minor grades is slightly different compared to the list in the 5th framework programme [1], due to the fact that in the four year period between the two lists new insights and grades became available.

Table 2.1 Selected major graphite grades

Grade	Manufacturer	Coke	Process
PCEA	Graftech	Petroleum	Extrusion
PPEA	Graftech	Pitch	Extrusion
NGB-10	SGL	Pitch	Extrusion
NBG-18	SGL	Pitch	Fibro-moulding

Table 2.2 Selected minor graphite grades

Grade	Manufacturer	Coke	Process
PCIB-SFG	Graftech	Petroleum	Iso-moulding
LPEB/BAN	Graftech	Needle	Extrusion
LPIB	Graftech	Needle	Iso-moulding
NBG-20	SGL	Petroleum	Extrusion
NBG-25	SGL	Petroleum	Iso-moulding
NBG-17	SGL	Pitch	Fibro-moulding
IG-110	Toyo Tanso	Petroleum	Iso-moulding
IG-430	Toyo Tanso	Pitch	Iso-moulding

2.1.2 Specimen types

All specimens are cylindrical. The diameter of all specimens is 8 mm and the length is either 6 mm or 12 mm. Specimens of these sizes are small enough to allow a sufficient number of specimens in the irradiation rig, and large enough to perform reasonably accurate measurements. The specimens with a length of 6 mm are suitable for all type of measurements (dimensional changes, dynamic Young's modulus, coefficient of thermal expansion and thermal diffusivity). The specimens with a length of 12 mm are suitable for measuring dimensional changes, dynamic Young's modulus, and coefficient of thermal expansion (CTE). The thermal diffusivity measurements cannot be performed on these specimens because a length of 12 mm is too long for a laser flash measurement. These 12 mm samples are included to have some data points with higher measurement accuracy for the dimensional change measurements. Specimens of 12 mm were not included in the INNOGRAPH 2B experiment as CTE measurements on 6 mm length specimens were found sufficiently accurate in previous experiments.

The sample machining of the samples from the graphite blocks is described in [8]. The cylindrically shaped specimens are flattened by milling a plane with a width of 3 mm along the length. Figure 2-1 schematically shows the flattening. Producing a plane with a width of 3 mm mills only 1% of the volume of the cylinders. The benefits of this plane are threefold. The first benefit is the possibility to indicate the z-direction from the original graphite blocks in the specimen. The plane is milled perpendicular to the *z*-direction if the axial direction of the cylinder is parallel to the *xy*-direction, and therefore the *z*-direction in the specimen is known after fabrication. The plane is milled on an arbitrary position if the axial direction of the cylinders is parallel to the *z*-direction, because in that case the *z*-direction is already indicated by the axial direction.

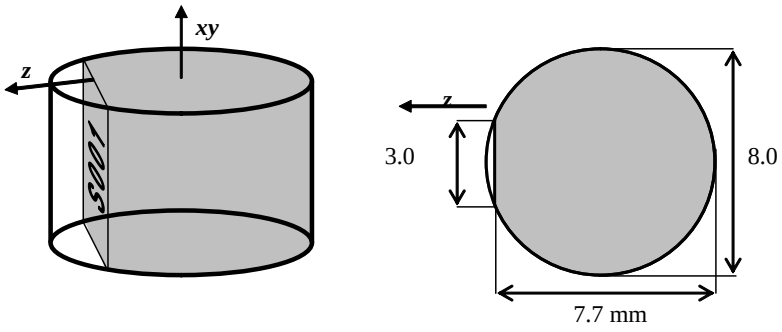

Figure 2-1 Flattening of the specimens. The figure on the left-hand side exaggeratedly shows the flatting of the cylinder. The figure on the right-hand side is a top-view of the specimen

The second benefit of the plane is that it gives an area to engrave the specimen with a unique code. This code is necessary to easily identify a specimen. The code consists of four characters. The first character is

a letter that indicates the graphite manufacturer (S= SGL, U= UCAR (Graftech) and T= Toyo Tanso). The last three characters are numbers.

A third benefit is that the milled plane can act as a marking that defines the measuring positions during the dimensional measurements before and after irradiation.

2.1.3 Test matrices

Table 2.3 and Table 2.4 give the test matrices of the INNOGRAPH-1B and INNOGRAPH-2B irradiation experiments respectively. Samples are machined from the centre or edge of the original graphite blocks to allow studying effects of variation within the blocks. Samples are taken in two directions: with the axial direction of the sample parallel to the With Grain (WG) direction in the graphite or parallel to the against grain direction (AG) in the graphite to analyse the anisotropy in irradiation behaviour of graphite. The focus lies with the major grades. Therefore, the number of major grade samples in the experiments typically is larger than the number of minor grade samples.

Table 2.3 Test matrix for the INNOGRAPH-1B experiment

Grade	No. of specimens		Centre		Edge		Irradiated	Unirradiated
	6 mm	12 mm	WG	AG	WG	AG		
NBG-10	31	0	7	7	9	8	17	14
NBG-17	14	0	4	4	3	3	0	14
NBG-18	14	0	3	3	4	4	0	14
NBG-20	4	0	2	2	0	0	4	0
NBG-25	12	0	4	5	2	1	6	6
PCEA	29	0	7	7	7	8	16	13
PCIB	13	0	6	4	1	2	7	6
PPEA	25	3	9	10	5	4	11	17
IG-110	12	0	3	4	2	3	6	6
IG-430	12	0	4	3	2	3	6	6
LPEB	6	0	2	2	1	1	0	6
LPIB[1]	2	0	1	1	0	0	0	2

[1] For the LPIB grade, whether the specimen comes from the edge or the centre is undefined.

Table 2.4 Test matrix for the INNOGRAPH-2B experiment

Grade	No. of specimens	Centre		Edge		Irradiated	Unirradiated
		WG	AG	WG	AG		
NBG-10	31	8	7	9	7	13	18
NBG-17	19	7	7	3	2	7	12
NBG-18	34	8	9	8	9	16	18
NBG-25	11	2	2	4	3	5	6
PCEA	34	9	9	8	8	16	18
PCIB	11	2	3	4	2	5	6
PPEA	30	8	8	7	7	10	20
IG-110	2	0	0	1	1	2	0
IG-430	6	2	4	0	0	2	4
LPEB	9	2	4	1	2	3	6
LPIB[2]	2	1	1	0	0	2	0

2.2 Irradiation experiments

2.2.1 INNOGRAPH-1B

The INNOGRAPH-1B rig consists of a stack of eight TZM (0.5Ti, 0.08Zr, Mo) drums that are used as specimen-holders. The rig contained seven drums with a height of 60 mm and one drum with a height of 30 mm. In each drum, three channels are present to contain the samples. In between drums, a thin graphite foil is placed to prevent specimens moving axially into the drum below. The high density of TZM makes it possible to reach the required nominal temperature of 750°C. Because of the relatively low neutron flux in the top drum, this drum cannot reach the 750°C. However, this drum is still usable to irradiate graphite specimens at a slightly lower temperature. The top drum is separated from the drums below by a thermal barrier and is designed to have a temperature of 650°C. For the rest of the rig the design temperature is 750°C.

The capsule is instrumented with 24 thermocouples that are placed on different radial and axial positions to monitor the temperature during irradiation. Temperature was controlled by changing the He/Ne gas mixture in the second containment and the vertical displacement of the experiment in the reactor core.

[2] For the LPIB grade, whether the specimen comes from the edge or the centre is undefined.

The temperature was controlled for the 750°C drums; the temperature for the top drum at 650°C is not controlled.
In the centre of each drum a hole was drilled to place neutron fluence detector sets. Five fluence detector sets were distributed axially over the rig with TZM fillers in between. Four fluence detector sets are distributed radially in two drums to monitor the radial gradients. The detector sets are analysed after the experiment to determine the neutron fluence.

2.2.2 INNOGRAPH-2B

The INNOGRAPH-2B rig consisted of a stack of eight Densimet drums (Tungsten alloy). This was different compared to the other INNOGRAPH experiments (1A, 1B and 2A) where Molybdenum was used. The higher density of Densimet was needed to generate enough gamma heating to reach 950ºC. In INNOGRAPH-2A the density of Molybdenum was high enough. However, the diameter of the sample stacks is larger in INNOGRAPH-2B to allow swelling during this high dose experiment. As a result, less material was available for gamma heating in the INNOGRAPH-2B rig than in INNOGRAPH-2A, and Densimet was required.
Each drum had three channels for sample stacks. INNOGRAPH-2B has six drums of 60 mm in height and one drum of 30 mm in height targeted at 950ºC (Figure 2-2). An extra drum of 60 mm was placed on top. The position of this extra drum with respect to the centre of the HFR core is too large for an accurate thermal design at 950 ºC. However there are still neutrons that will induce gamma heating. Therefore, this drum is targeted at a lower temperature, at 850ºC. The two temperature zones are separated by a thermal barrier.
The capsule was instrumented with 24 thermocouples, placed on different axial and radial positions, to monitor the irradiation temperature. The temperature was controlled by changing the He/Ne gas mixture in the second containment and vertical displacement of the experiment in the reactor core. The temperature was controlled for the 950°C drums.
For purposes of neutron metrology nine activation monitor sets were prepared. Five monitor sets were placed in the central channel of the specimen holder at various vertical levels. The remaining monitor sets were placed in the northern (2), eastern (1) and southern (1) channels, useful for an indication of the radial gradients and the orientation of the experiment. The neutron fluence was measured after the experiment.
It is important to keep the level of radioactivity of the graphite samples as low as reasonably possible, to make the handling of the samples more practical after the irradiation experiment (post irradiation examinations) of the samples. Aside from extra purification steps that were made by the manufacturers, some measures are taken in the design in the experiment. Contact between the metal drum and graphite

samples was avoided by placing a graphite foil between them. Therefore contamination of the graphite samples by the drum material was not possible. For the same reason, the inner containment is purged with high purity Helium.

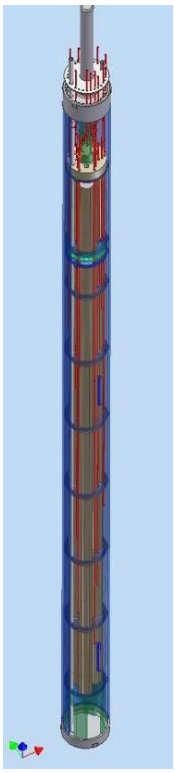

Figure 2-2 Drawing of INNOGRAPH-2B. The upper drum (8) is separated from the other 7 drums (1-7) by a thermal barrier. Red lines are thermocouple wires

2.3 Measurement techniques

2.3.1 Dimensions

The dimensions of the samples are measured by inductive probes (Mahr, Type P 2104 MB) with a measurement range of 4 mm and accuracy of 0.1 um. The measurement is a comparison of the dimension of the sample and the dimension of a well-known caliber. The length (*l*) is measured at 5 positions at both sides of the sample (10 measurements in total). The diameter (*d*) is measured at three positions at every 90º (12 measurements in total). The size of the sample perpendicular to the flat side (*x*) is measured at three positions. The average values of *l*, *d* and *x* are reported.

2.3.2 Mass

The mass (m) is measured with a Mettler AT261 balance with an accuracy of 0.01 mg. The measurement is repeated three times and the average value is reported. Measurements are performed in-box or in-cell, depending on the activity of the sample; the type of balance is the same for both.

2.3.3 Dynamic Young's Modulus

The Dynamic Young's Modulus (DYM) is determined by measuring the velocity of sound in a sample. A 1 MHz wave packet is generated by Krautkrämer USM 25 controller box. This box is connected by two Krautkrämer (MK1S) acoustical transducers, one acting as the transmitter and one as the receiver. The input and output signals are analysed and digitally stored by using an oscilloscope. The velocity of sound is determined by measuring the time difference between input and output.

The DYM can be calculated by multiplying the density and the velocity of sound squared. A true measure of the Young's Modulus is obtained by taking into account the Poisson's ratio. This results in a correction factor. For example, the Young's modulus is reduced by 10 per cent for a Poisson ration of 0.2. However, because the Poisson ratios of the irradiated samples are not known, the correction factor is not taken into account in this work.

The measurement set-up of the DYM of the post irradiation examination was slightly different compared to the measurements that were performed before irradiation (in 2006). The frequency was lowered to 1 MHz, compared to 5 MHZ and the reading of the signal was performed by an oscilloscope instead of the controller box. To be sure the measurements can be directly compared with the previous measurements, both set-ups are used. The differences in results are very small and there is no clear trend in this difference. Therefore, the results of the DYM measurements of both set-ups can be compared. An example of such a comparison is given in [9].

2.3.4 Coefficient of Thermal Expansion

The coefficient of thermal expansion (CTE) is measured in a Netzsch dilatometer DIL402C using an alumina sample holder. The furnace is purged with He to prevent oxidation during heating. The measurement consists of three temperature cycles up to the irradiation temperature of 750°C and 950ºC for INNOGRAPH-1B and -2B samples respectively. The first cycle is for setting the system and the second and third cycle are considered as the measurements. The heating rate during the measurement cycles is 5 K/min. The average of the result of the second and third heat-up cycle is reported as the CTE value. Measurements are repeated in case of a difference between second and third heat-up cycle larger than 0.1×10^{-6} K^{-1}.

2.3.5 Thermal diffusivity and thermal conductivity

The coefficient of thermal diffusivity is measured by laser flash method with a LFA 457 MicroFlash from Netzsch. The Microflash uses a laser to give the heat input. The transmitted heat is detected using an IR-pyrometer. Three samples can be placed at the same time in the furnace by using a carrousel. Measurements can be performed in vacuum or in a helium atmosphere; the PIE measurements were performed in a helium atmosphere. The temperature of the furnace can be controlled from room

temperature to a maximum of 1100ºC. The maximum measurement temperature is limited to either the irradiation temperature (to avoid annealing during the measurements) or the maximum temperature of the equipment (1100ºC). At each defined measurement temperature, the samples were measured three times. The average result of these three measurements is taken as the final result. The thermal diffusivity was measured at intervals of 100°C as a compromise between number of data points to get a curve and the measuring time to finish the measurement.

The coefficient of thermal conductivity is calculated from the measured coefficient of thermal diffusivity by multiplying this value with the specific heat (tabulated in ASTM 781-96) and the density. It is assumed that the specific heat is not changed due to neutron irradiation.

3 Results & Discussions

3.1 Irradiation experiment

3.1.1 INNOGRAPH-1B

Irradiation

The specimen holder 352-12 (INNOGRAPH-1B) was irradiated in two HFR core positions (i.e. C3 and C7) during twenty-one reactor cycles. The specimen holder was first loaded in channel 02 of a standard reloadable TRIO facility located in core position C3 and after a reactor outage reloaded in channel 02 of a standard, reloadable QUATTRO-129 irradiation facility placed in core position C7. The orientation of the QUATTRO facility was a standard one for HFR core position C7. During the second irradiation interval of INNOGRAPH-1B the QUATTRO channels 01, 03 and 04 were occupied with experiments 364-01, 352-22 (INNOGRAPH-2B) and 365-01 respectively.

The irradiation campaign of INNOGRAPH-1B performed during the period from August 22nd 2007 to February 19th 2010 (HFR cycles 2007-07 up to and including 2010-01) was interrupted during the second half of 2008 caused by a reactor outage. The duration of the irradiation was twenty-one HFR cycles, corresponding to 577 full power days (at 45 MW).

The nominal temperature during operation inside the specimen holder was 750 °C.

Dosimetry

During the dismantling procedure after irradiation the nine monitor sets were recovered in rather good condition, so all sets were usable for the neutron dosimetry evaluation procedure.

Analogous to the evaluation procedure used for earlier INNOGRAPH irradiation campaigns a combination of Monte Carlo calculations and the measurement results from the nine monitor sets provided the opportunity to derive reliable nuclear parameters for all specimens loaded inside the specimen holder. The measured and calculated reaction rates valid for the monitor set positions show an acceptable match. Therefore, the calculations were considered as satisfactory.

The results at the monitor set positions are summarized in Table 3.1 and plotted in Figure 3-1 [10]. Based on the results of the measurements and Monte Carlo calculations individual specimen doses have been obtained, valid for the positions of the specimens in the stacks. The dpa values range from 6.2 to 13.7 dpa, depending on the position in the holder. The average number of dpa's reached in the specimen holder is 11.3, the cumulative position-averaged (±200 mm) dpa value calculated after twenty-one HFR-cycles was 12.0 dpa (target was 12-13 dpa).

Table 3.1 Results of neutron metrology evaluations for monitor set locations inside the INNOGRAPH-1B (352-12) specimen holder; bold indicated data are based on measurements

distance to C_L spec. holder (mm)	TZM drum code	monitor set code	fluences values (10^{25} m^{-2}) thermal fluence Φ_{Co}	fluence E>0.1 MeV	fluence E>1.0 MeV	fluence Φ_{EDN}	dpa
+214	**8**	**09**	**2.9**	**10.3**	**4.6**	**5.9**	**7.4**
+110	**6**	**08**	**4.8**	**16.2**	**7.0**	**9.2**	**11.5**
+48	**5**	**07**	**5.4**	**17.5**	**7.7**	**9.9**	**12.4**
+48	**5**	**06**	**5.5**	**18.9**	**8.4**	**10.8**	**13.5**
+48	**5**	**05**	**5.7**	**18.5**	**8.1**	**10.5**	**13.2**
-77	**3**	**04**	**5.7**	**18.1**	**7.9**	**10.3**	**12.9**
-201	**1**	**03**	**4.3**	**12.2**	**5.5**	**6.9**	**8.7**
-201	**1**	**02**	**4.4**	**13.4**	**5.9**	**7.6**	**9.6**
-201	**1**	**01**	**4.6**	**16.4**	**7.1**	**9.3**	**11.7**

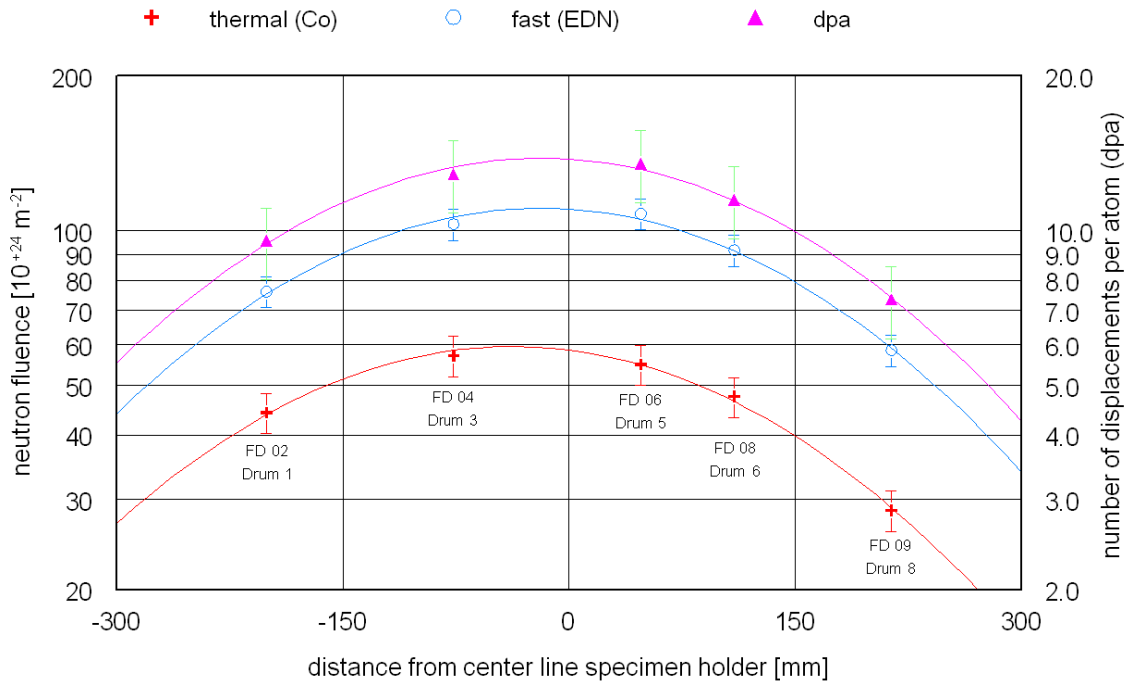

Figure 3-1 Vertical fluence and dpa distributions in specimen holder INNOGRAPH-1B (352-12)

3.1.2 INNOGRAPH-2B

Irradiation

INNOGRAPH-2B has been irradiated for 12 cycles, corresponding to 323 full power days at 45 MW [10]. The irradiation started in June 2008, after being successfully assembled in a hot-cell. The specimen holder was irradiated in two HFR core positions (i.e. the first cycle in C3, the rest in C7). The irradiation is interrupted from August 2008-February 2009 due to temporary shutdown of the HFR. Irradiation continued in February 2009 and was finished in February 2010.The nominal temperature inside the specimen holder during operation was 950°C.

Dosimetry

The monitor sets used for the INNOGRAPH-2B irradiation were constructed of Inconel instead of the typically used stainless steel. The higher temperature resistance of the Inconel helps to reduce the damage caused by the combination of high temperature and material interactions during irradiation. Five out of nine monitor sets were recovered after the dismantling procedure of the INNOGRAPH-2B capsule. Analogous to the evaluation procedure used for the first high temperature irradiation campaign (INNOGRAPH-2A), a combination of Monte Carlo calculations and the measurement results for the monitor sets 01, 03, 05, 07 and 08 provided the opportunity to derive reliable nuclear parameters inside the specimen holder. The measured and calculated reaction rates show an acceptable match. Therefore, the calculations were considered as satisfactory. The results are summarised in

Table 3.2 and plotted in Figure 3-2 [10]. From the results of the measurements and calculations individual specimen doses have been obtained, based on the positions of the specimens in the stacks. The dpa values range from 3.3 to 7.2 dpa, depending on the position in the holder. The average number of dpa's reached in the specimen holder is 6.0, the cumulative position-averaged (±200 mm) dpa value calculated after twelve HFR-cycles was 6.6 dpa (target was 5-7 dpa).

Table 3.2 Results of neutron metrology evaluations for monitor set locations inside the INNOGRAPH-2B (352-22) specimen holder; bold indicated data are based on measurements

distance to C_L spec. holder (mm)	Densimet 176 drum code	monitor set code	fluences values (10^{25} m^{-2}) thermal fluence Φ_{Co}	fluence E>0.1 MeV	fluence E>1.0 MeV	fluence Φ_{EDN}	dpa
+214	*8*	*09*	*0.8*	*5.7*	*2.4*	*3.2*	*4.0*
+110	**6**	**08**	**1.3**	**8.3**	**3.5**	**4.7**	**5.9**
+48	**5**	**07**	**1.5**	**10.1**	**4.3**	**5.7**	**7.2**
+48	*5*	*06*	*1.4*	*9.7*	*4.1*	*5.5*	*6.9*
+48	**5**	**05**	**1.5**	**8.7**	**3.7**	**4.9**	**6.1**
-77	*3*	*04*	*1.5*	*9. 7*	*4.2*	*5.5*	*6.9*
-201	**1**	**03**	**1.2**	**7.4**	**3.3**	**4.2**	**5.3**
-201	*1*	*02*	*1.1*	*7.0*	*3.9*	*4.0*	*5.0*
-201	**1**	**01**	**1.2**	**6.4**	**2.8**	**3.6**	**4. 6**

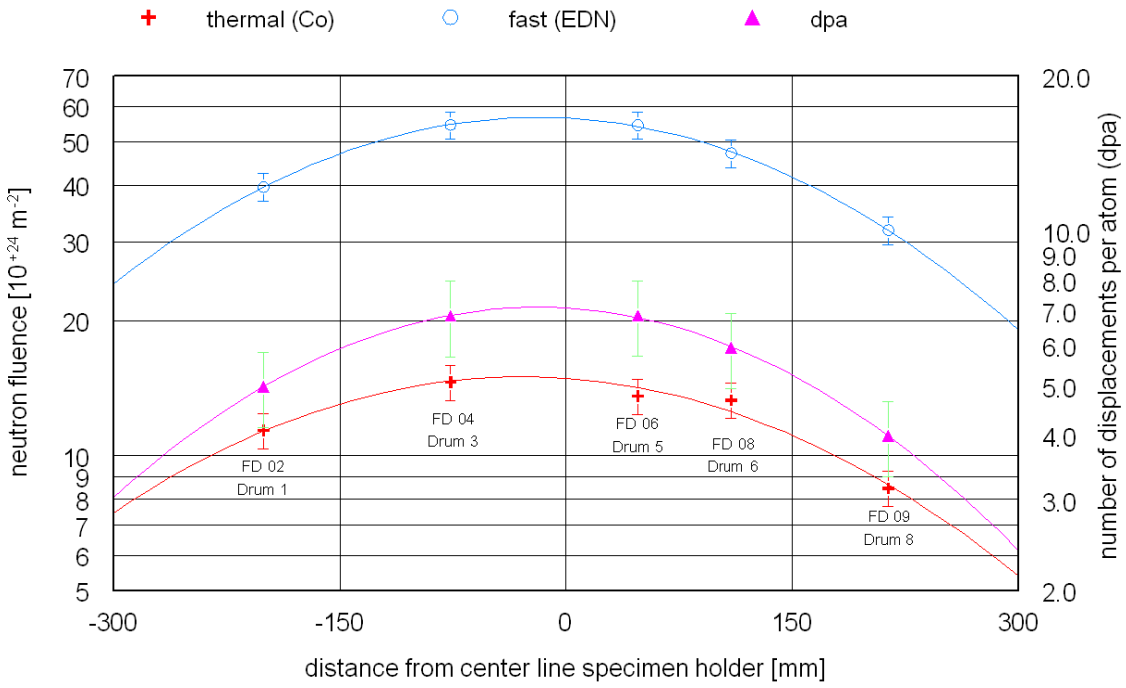

Figure 3-2 Vertical fluence and dpa distributions in specimen holder INNOGRAPH-2B (352-22)

3.2 Post-Irradiation Examination

In this section, the results of the post-irradiation examination of the irradiation experiments at 750°C and 950°C, INNOGRAPH-1B and INNOGRAPH-2B, are presented. These results include the data from the screening PIE that was performed in 2010 for these experiments [6, 7]. Next to that, PIE data from the INNOGRAPH-1A and -2A irradiations is included in the graphs to give a complete set of data. The PIE data of the "B" irradiation experiments are presented in tables in Appendix B through Appendix D. Although the PIE for the high dose 750°C and 950°C experiments is called "full", not all measurements are performed for all specimens. The reason for this is on the one hand financial, on the other hand technical. Financially, the project budget does not allow for all measurements to be performed, specifically the time consuming measurements like CTE and thermal diffusivity. Technically, a number of specimens were either too much swollen or too active to be measured in the LFA set-up. Nonetheless, samples were chosen such to give as good coverage of the dpa range of the irradiation as possible.

3.2.1 Dimensions

The volumetric changes ($\Delta V/V_0$) for an irradiation temperature of 750°C are presented in Figure 3-3 to Figure 3-5, grouped by graphite manufacturer. The volumetric changes ($\Delta V/V_0$) for an irradiation temperature of 950°C are presented in Figure 3-5 to Figure 3-7. In these graphs, the INNOGRAPH-1A and -2A data is presented by solid symbols. The 1B and 2B data is presented by open symbols. The shrinking and swelling behaviour of the graphite is strongly influenced by irradiation temperature. For all grades the point of turn around in volumetric behaviour occurs at a lower dose for 950°C compared to 750°C. Also, in general the maximum shrinkage is lower for the specimens irradiated at 950°C compared to those irradiated at 750°C.

The length changes ($\Delta L/L_0$) are presented in Figure 3-8 to Figure 3-12, also grouped by manufacturer and irradiation temperature and using the same system of open and closed symbols. For the length changes, the data in the graphs is specified by grain orientation ("against grain" and "with grain"). The length change for a graphite grade can differ significantly with grain direction. Examples for which this is significant are NBG-25 and PCEA. Others show little difference, for instance PCIB and NBG-18.

Data for volume and length change at 650°C and 850°C are presented in Table A.1 and Table A.2 in Appendix A.

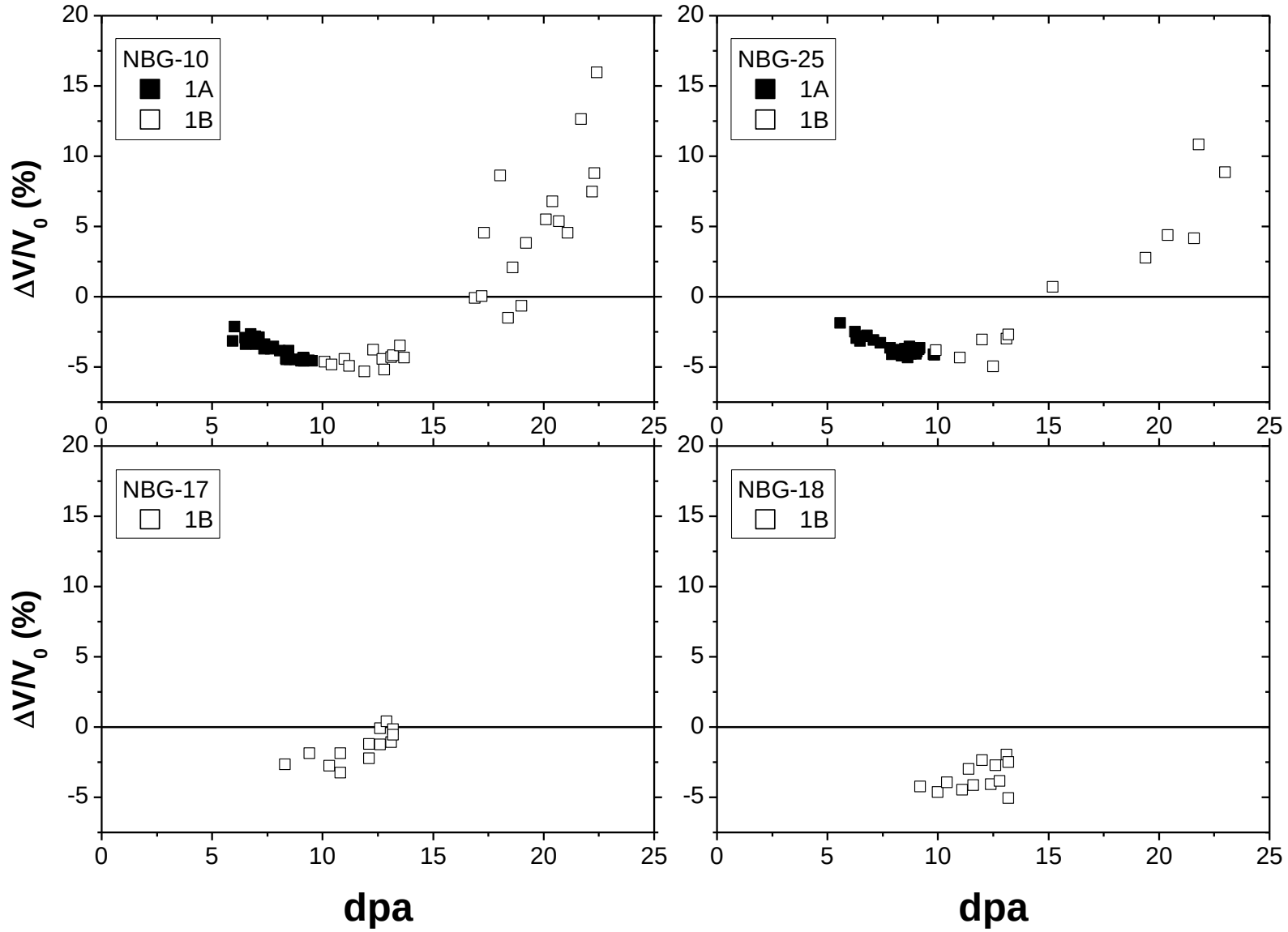

Figure 3-3 Volume change for SGL graphite grades irradiated at 750°C

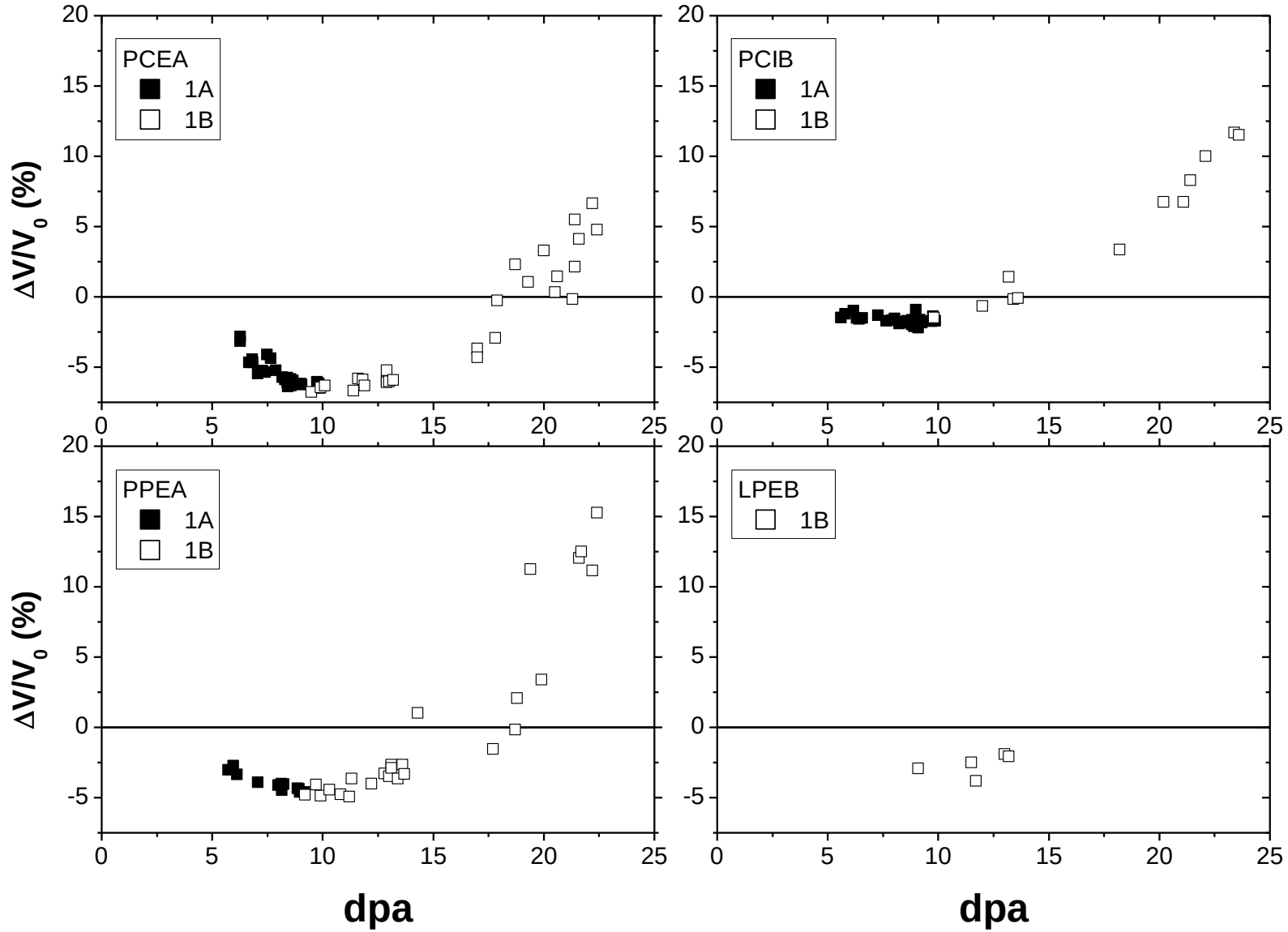

Figure 3-4 Volume change for Graftech graphite grades irradiated at 750°C

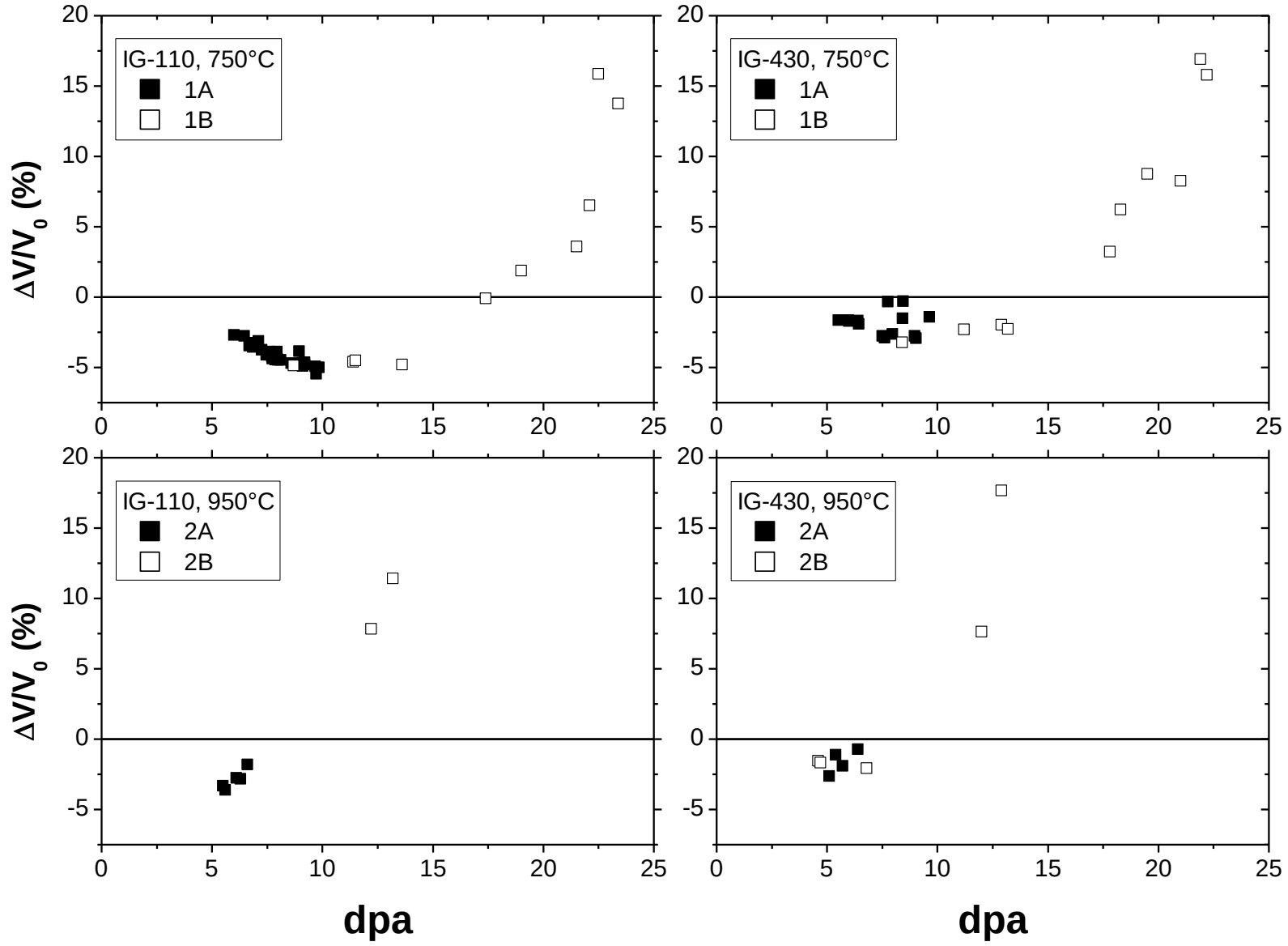

Figure 3-5 Volume change for Toyo Tanso graphite grades irradiated at 750°C (top) and 950°C (bottom)

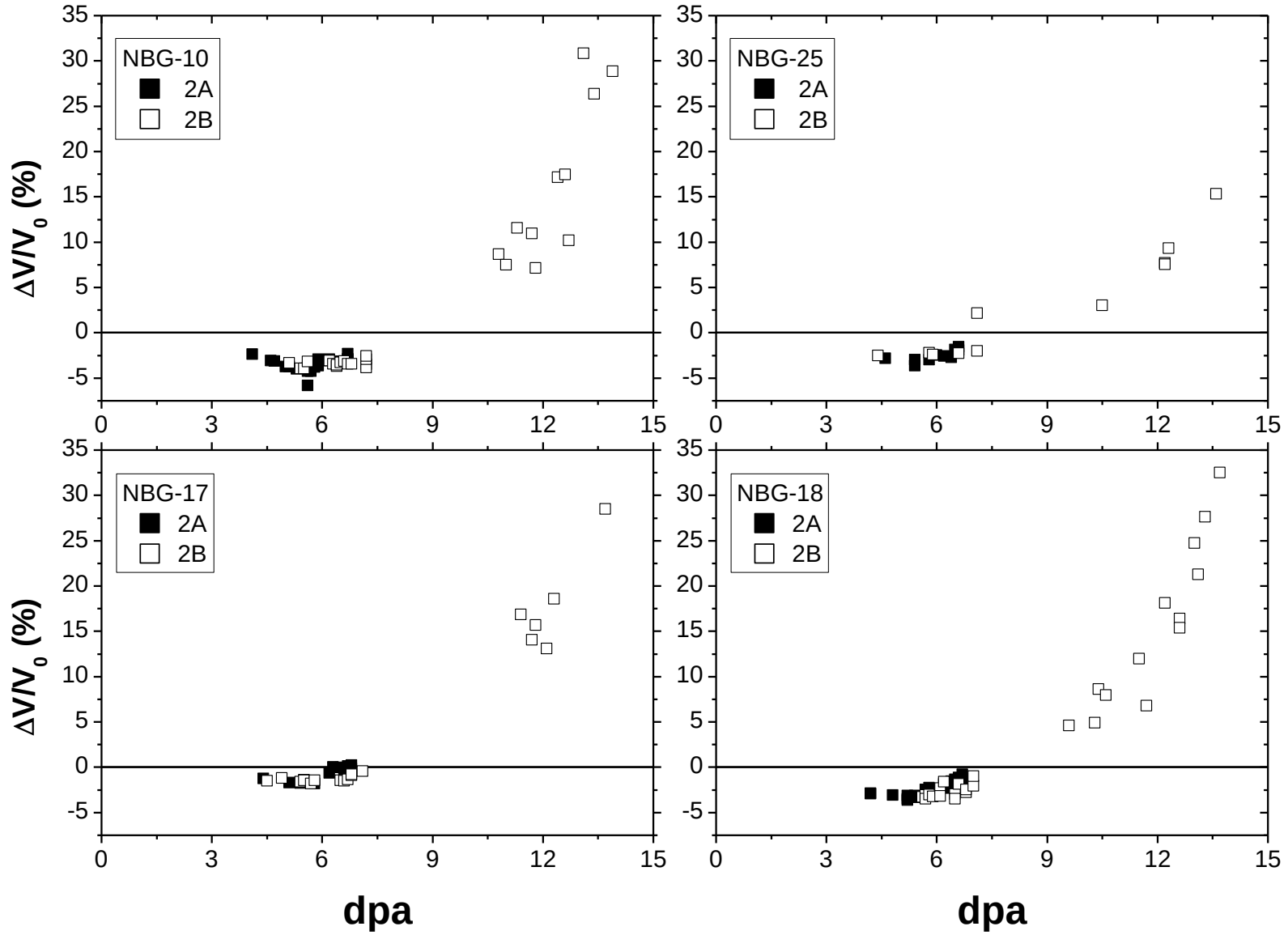

Figure 3-6 Volume change for SGL graphite grades irradiated at 950°C

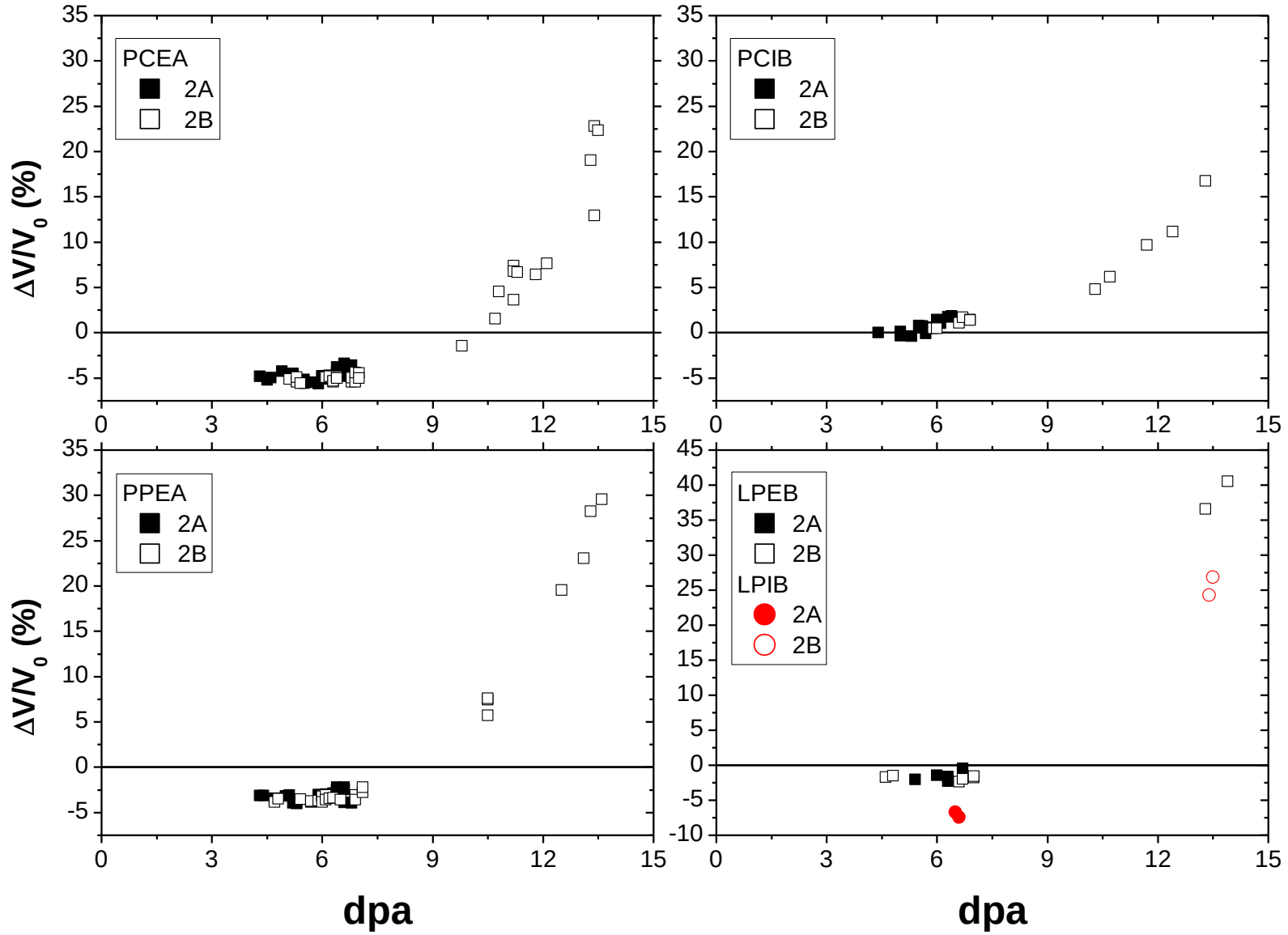

Figure 3-7 Volume change for Graftech graphite grades irradiated at 950°C. Note that the vertical scale of the LPEB & LPIB graph is different

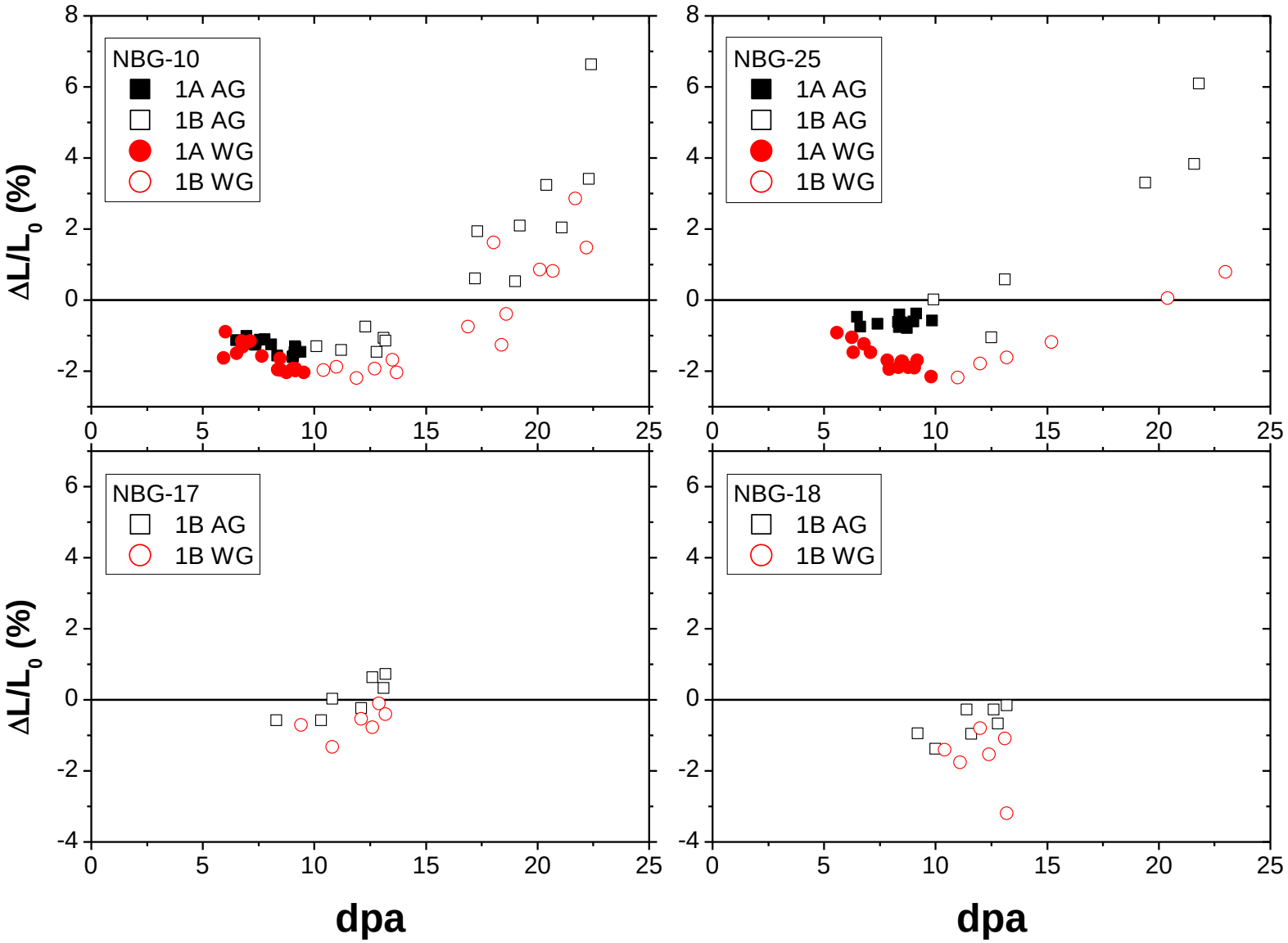

Figure 3-8 Length change for SGL graphite grades irradiated at 750°C, specifying "against grain" (AG) and "with grain" (WG) direction. Note that the bottom panels have the same scale as the top panels but with a different off-set

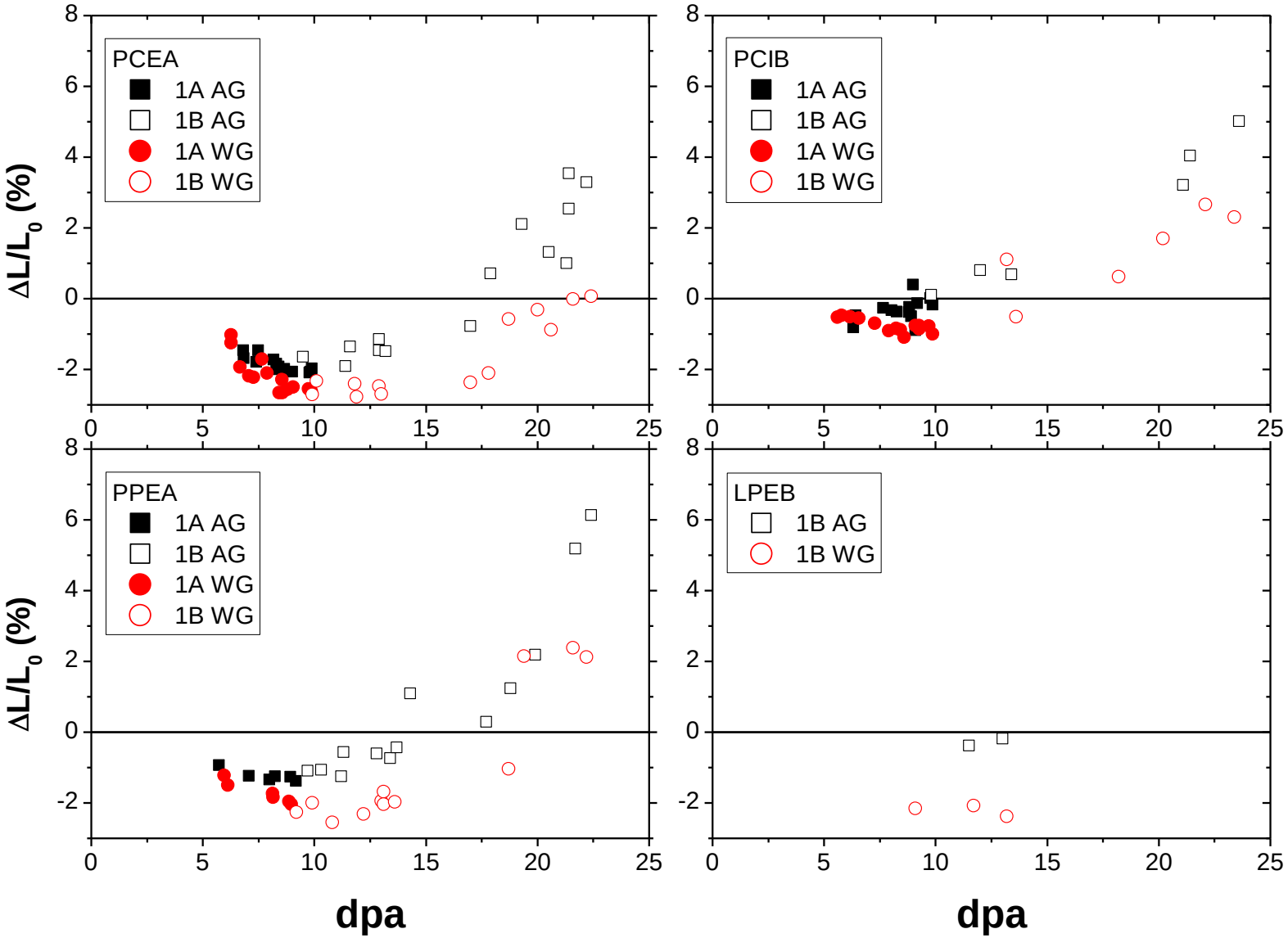

Figure 3-9 Length change for Graftech graphite grades irradiated at 750°C, specifying “against grain” (AG) and “with grain” (WG) direction

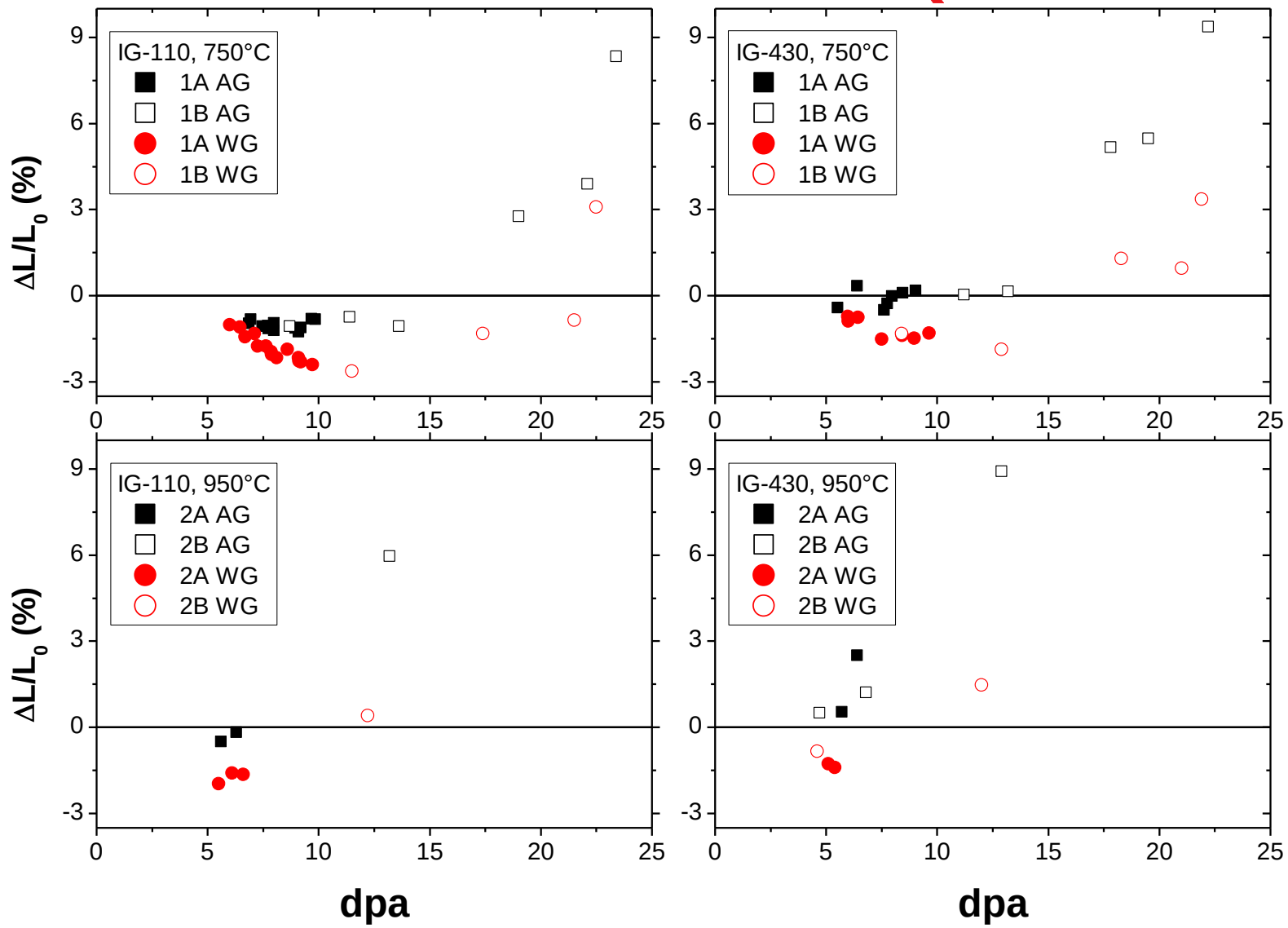

Figure 3-10 Length change for Toyo Tanso graphite grades irradiated at 750°C (top) and 950°C (bottom), specifying "against grain" (AG) and "with grain" (WG) direction

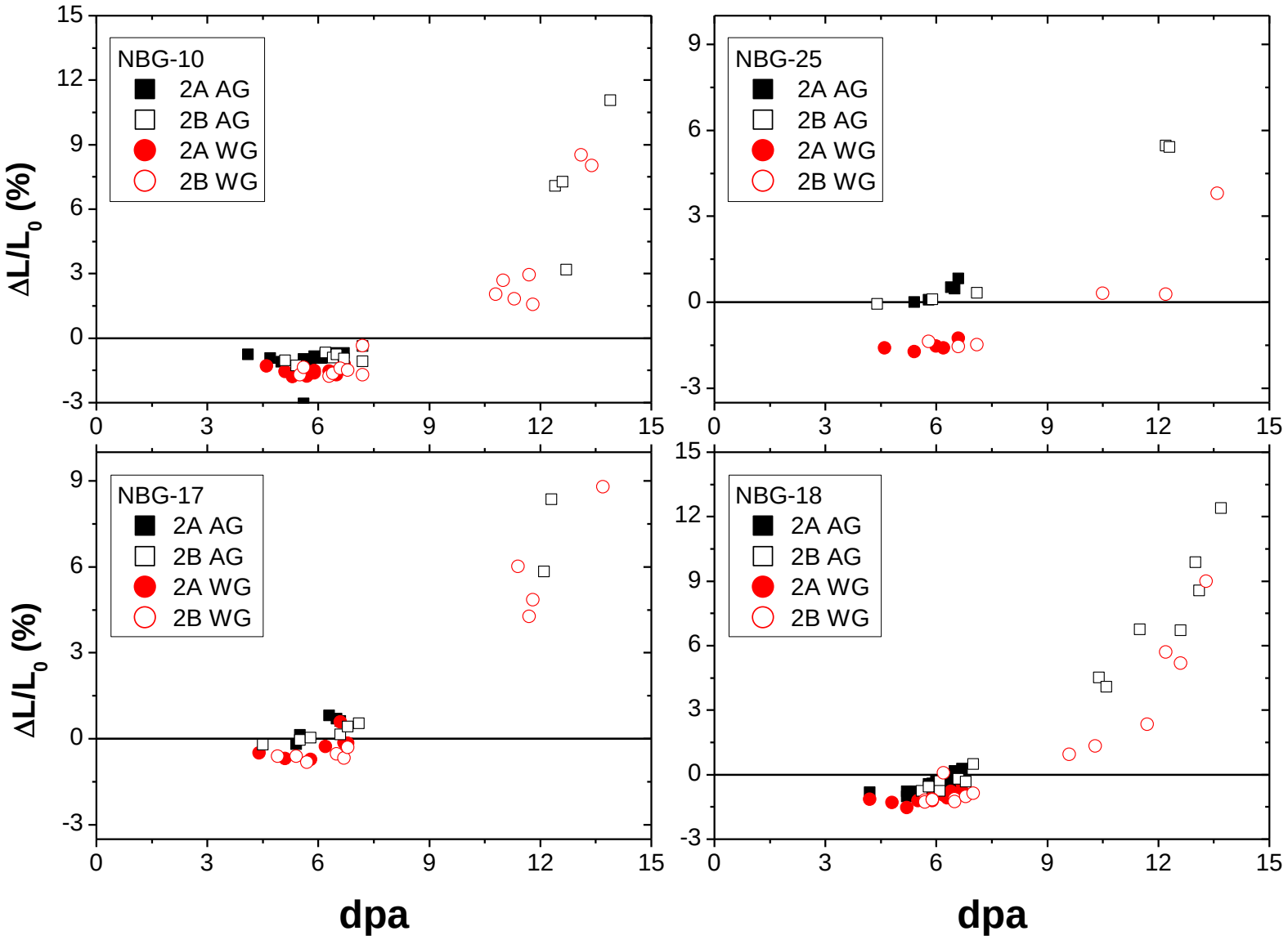

Figure 3-11 Length change for SGL graphite grades irradiated at 950°C, specifying "against grain" (AG) and "with grain" (WG) direction. Note that the vertical scales of the NBG-10 and NBG-18 graphs are different from the scales of the NBG-17 and NBG-25 graphs

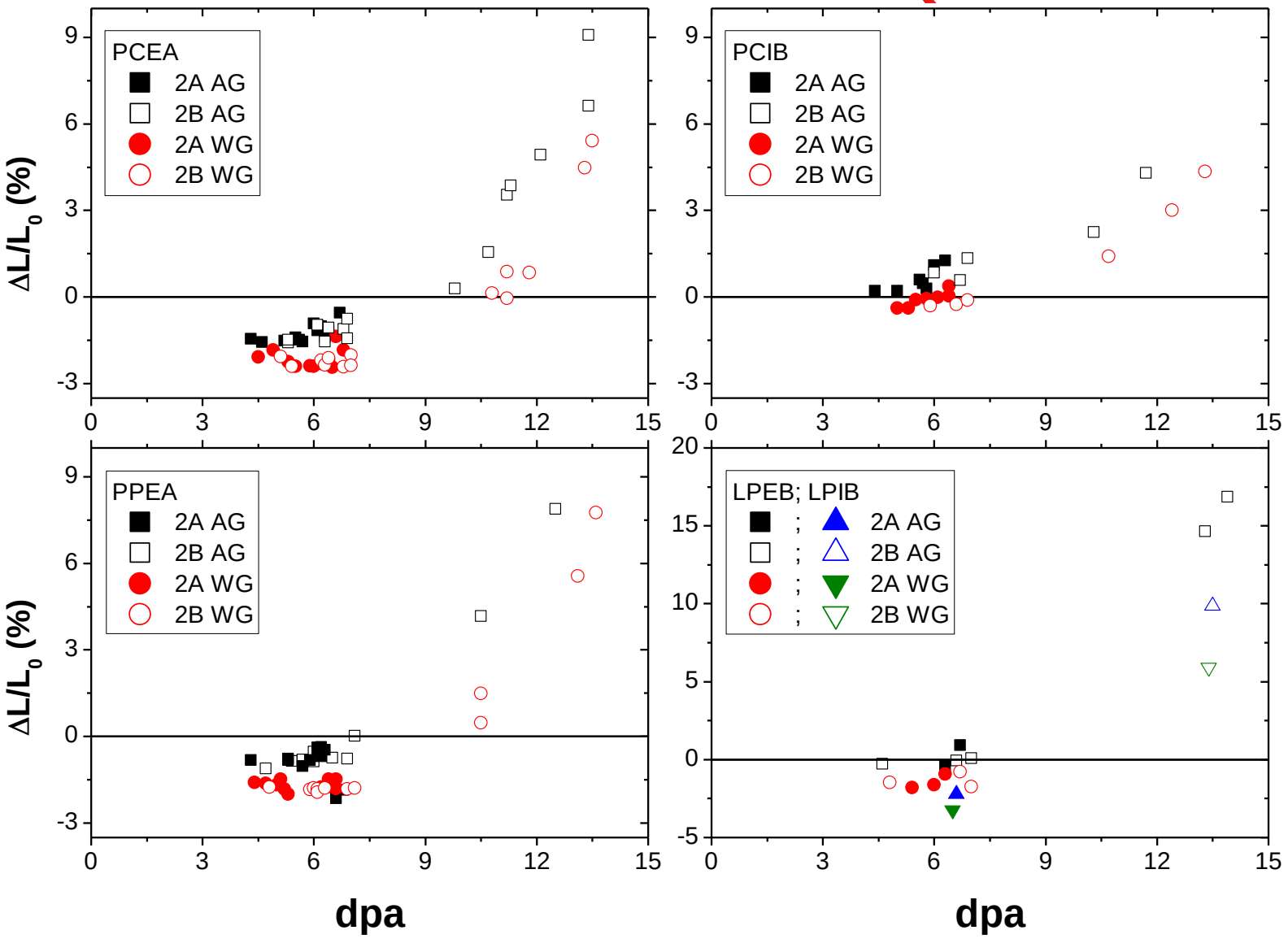

Figure 3-12 Length change for Graftech graphite grades irradiated at 950°C, specifying “against grain” (AG) and “with grain” (WG) direction. Note that the vertical scale of the LPEB & LPIB graph is different

3.2.2 Dynamic Young's Modulus

The Dynamic Young's Modulus (DYM) was measured for 105 out of 177 samples for the INNOGRAPH-1B irradiation and 94 out of 189 samples for the INNOGRAPH-2B irradiation. The ratio of the DYM after irradiation to the DYM before irradiation (E/E_0) is plotted in Figure 3-13 to Figure 3-17. The graphs are ordered by irradiation temperature, manufacturer, and graphites grades. The data in the graphs is specified by "A" and "B" irradiation and by "against grain" and "with grain" orientation. In general, the changes in DYM are not grain direction dependent. The typical trend is an increase in DYM ratio at medium dose, a plateau at medium to high dose, and a decrease at high dose. Especially at high dose and high temperature, the ratio E/E_0 can return to 1 or even below.

DYM data for samples irradiated at 650°C and 850°C is presented in Table A.1 and Table A.2 in Appendix A.

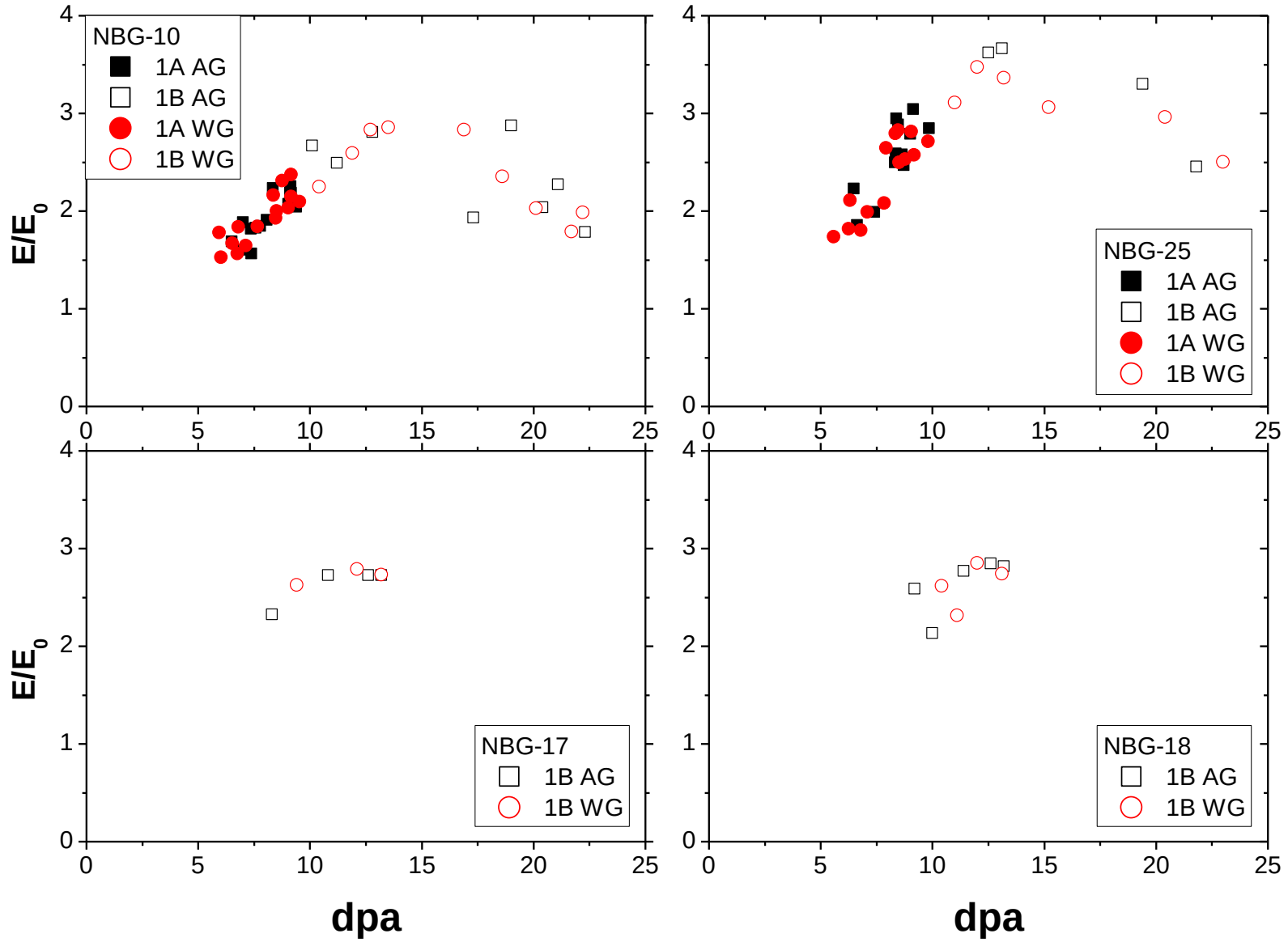

Figure 3-13 DYM change for SGL graphite grades irradiated at 750°C

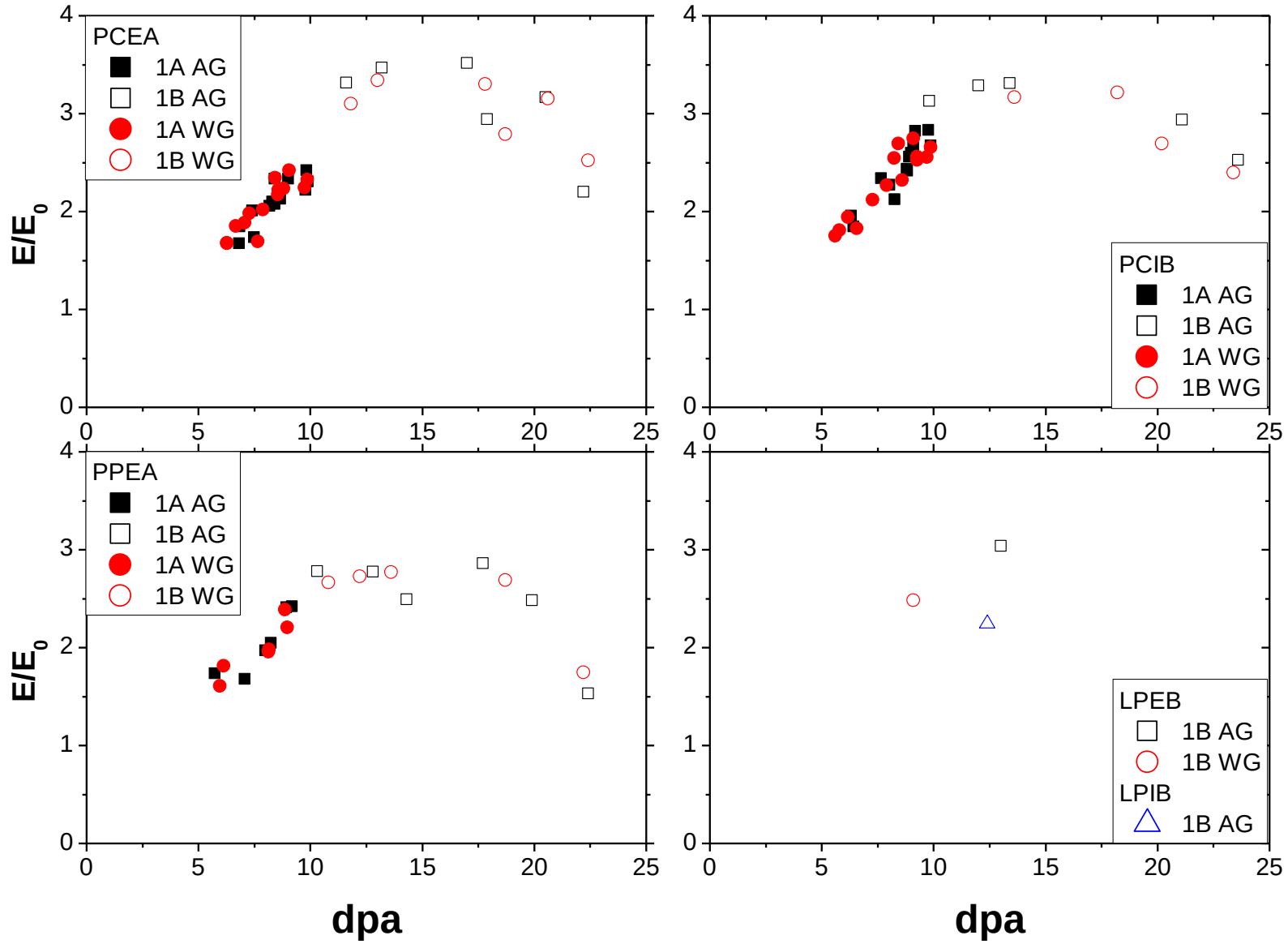

Figure 3-14 DYM change for Graftech graphite grades irradiated at 750°C

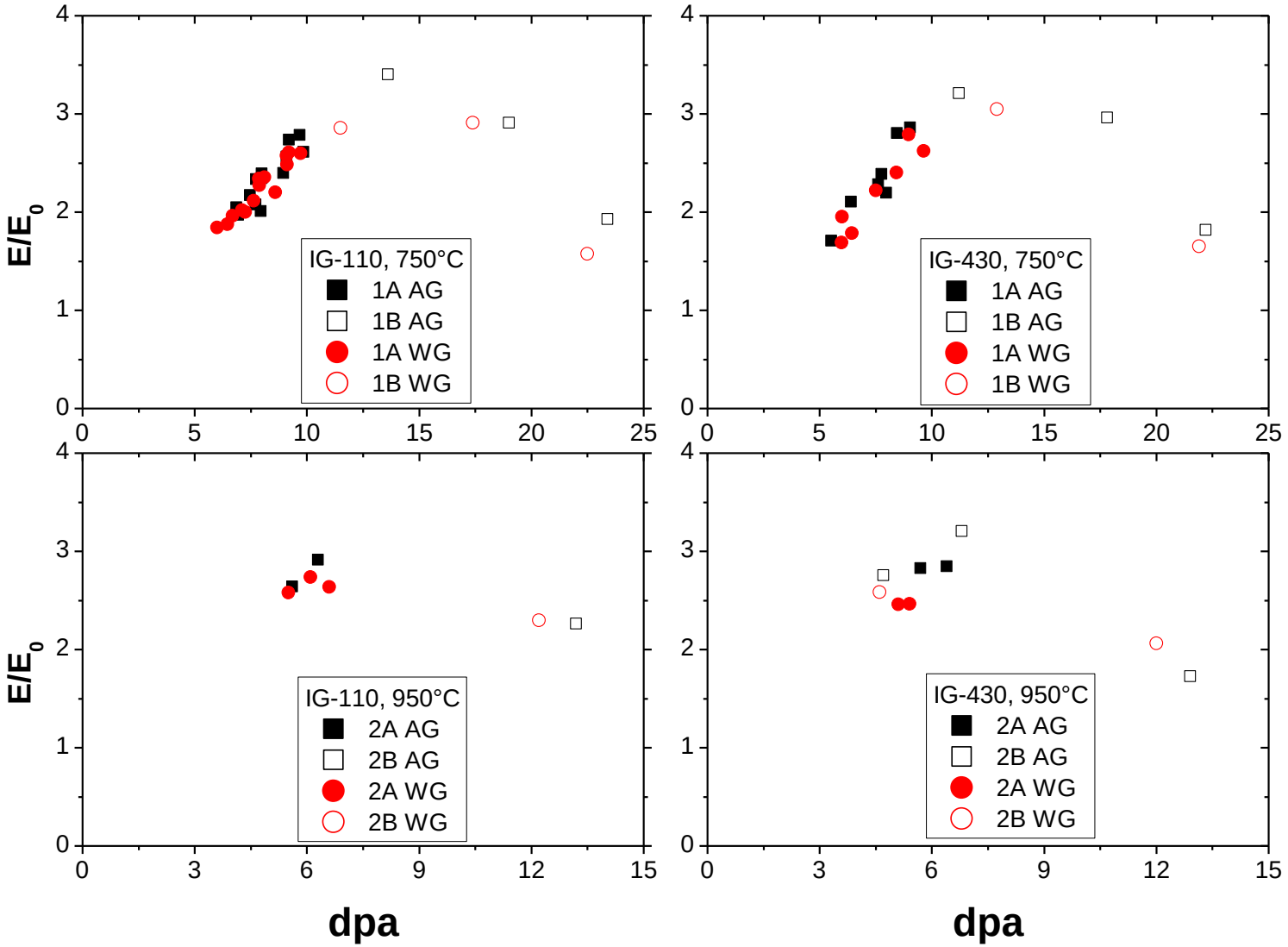

Figure 3-15 DYM change for Toyo Tanso graphite grades irradiated at 750°C (top) and 950°C (bottom). Note that the horizontal scale for the bottom panels is different from the top panels

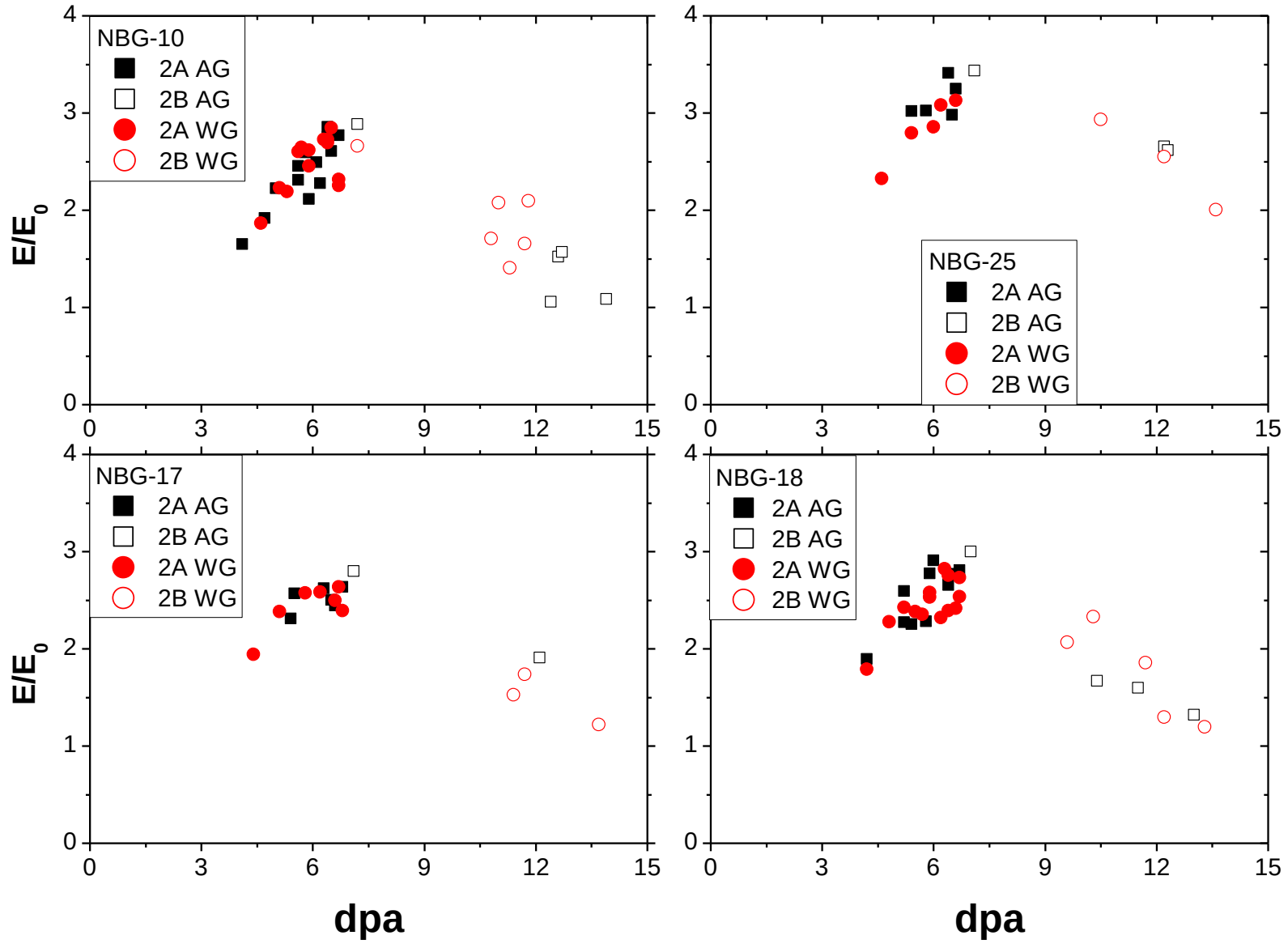

Figure 3-16 DYM change for SGL graphite grades irradiated at 950°C

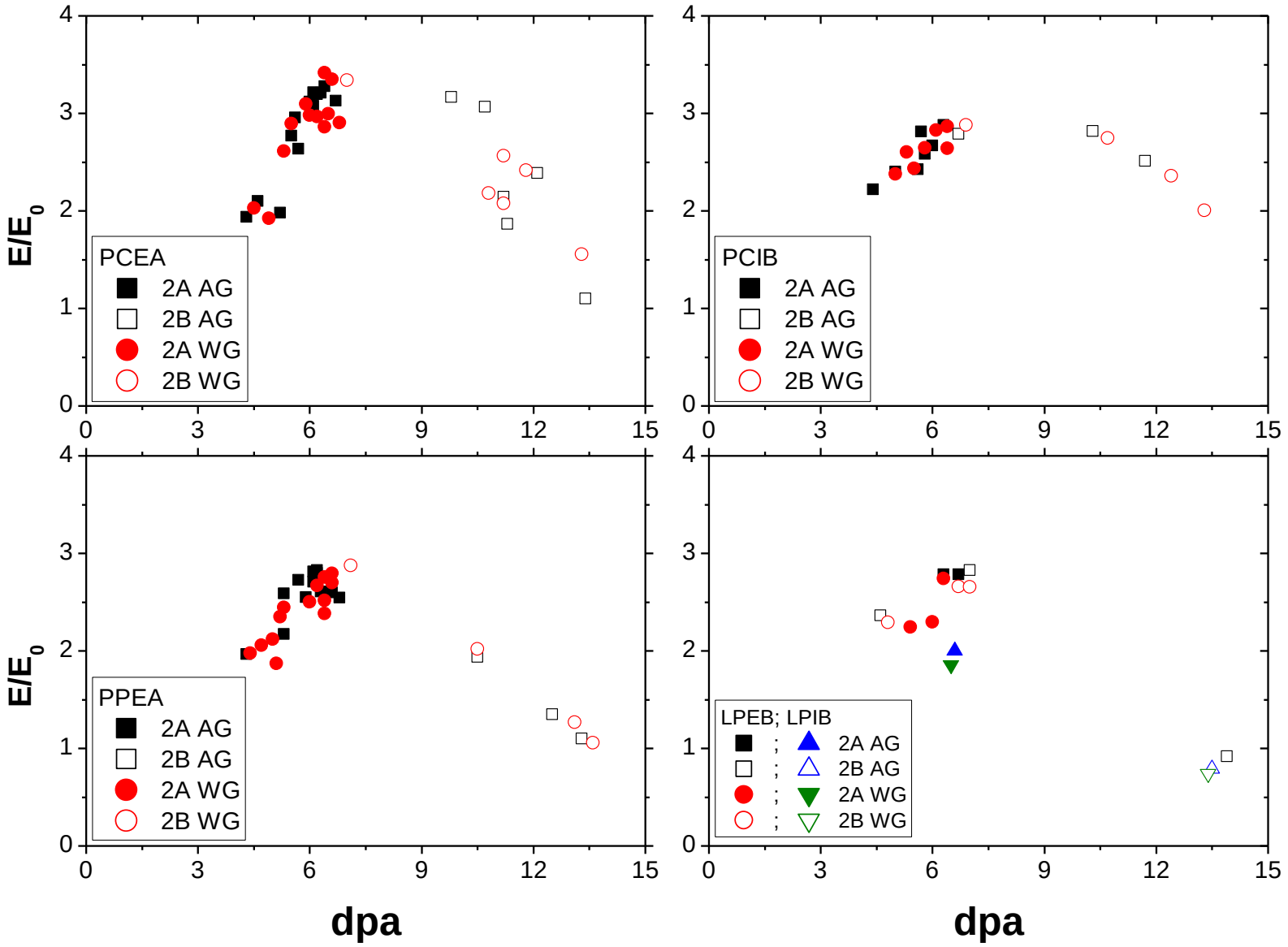

Figure 3-17 DYM change for Graftech graphite grades irradiated at 950°C

3.2.3 Coefficient of Thermal Expansion

The coefficient of thermal expansion (CTE) as function of neutron irradiation damage is presented in Figure 3-18 to Figure 3-22, arranged by manufacturer, grade, and irradiation experiment. For reference, the CTEs of unirradiated graphite grades are included. Presented is the technical coefficient of thermal expansion over the range of 30°C to 750°C. This range is also selected for the results of the 950°C experiment to be able to compare the CTEs with those of the 750°C experiment. The CTE data for other intervals are presented in Appendix C. These intervals are 30°C-120°C, 30°C-200°C, and 30°C-950°C (for the 950°C specimens). Also for the specimens irradiated at 650°C and 850°C, the coefficients of thermal expansion are presented in Appendix C.

No difference is noticed in the irradiation behaviour of the coefficient of thermal expansion with respect to grain direction. The general trend is a drop in CTE at medium dose followed by a stable plateau at medium to high dose. The plateaux start approximately at volume change turn-around. Some grades irradiated at 950°C show a slight increase in CTE at high dose, for instance PCEA and NBG-10.

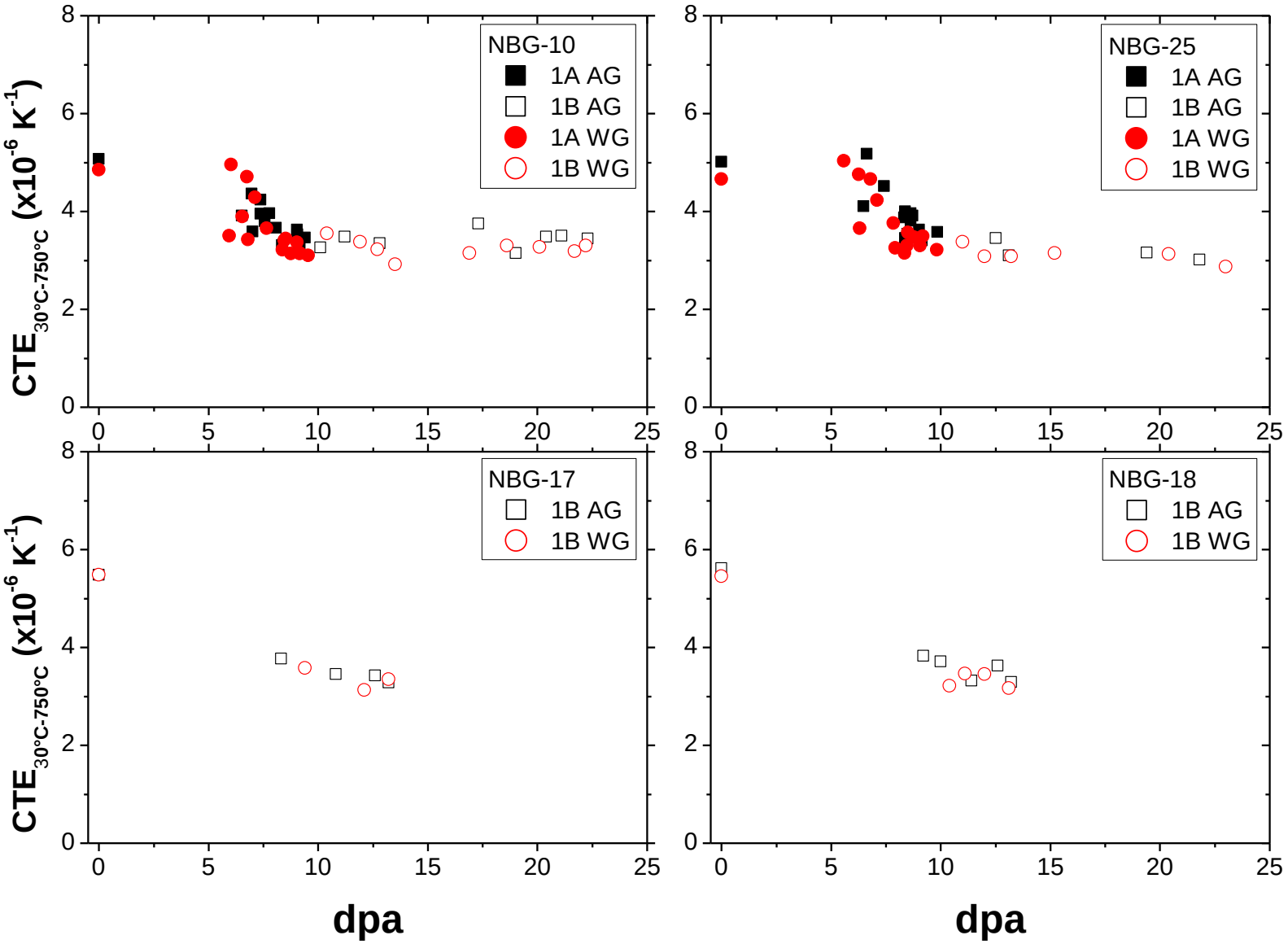

Figure 3-18 Coefficient of thermal expansion over the range of 30°C to 750°C for SGL graphite grades irradiated at 750°C

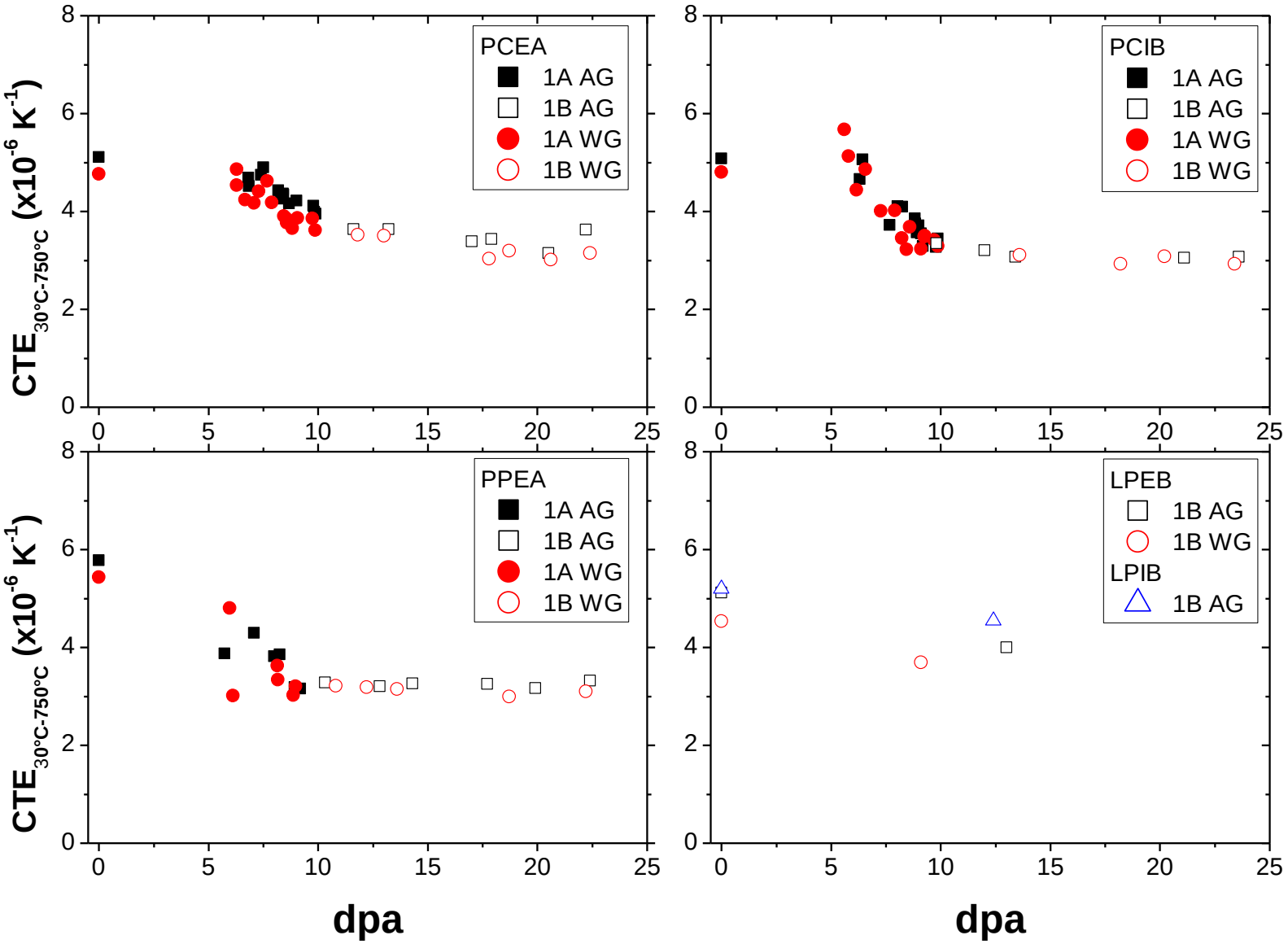

Figure 3-19 Coefficient of thermal expansion over the range of 30°C to 750°C for Graftech graphite grades irradiated at 750°C

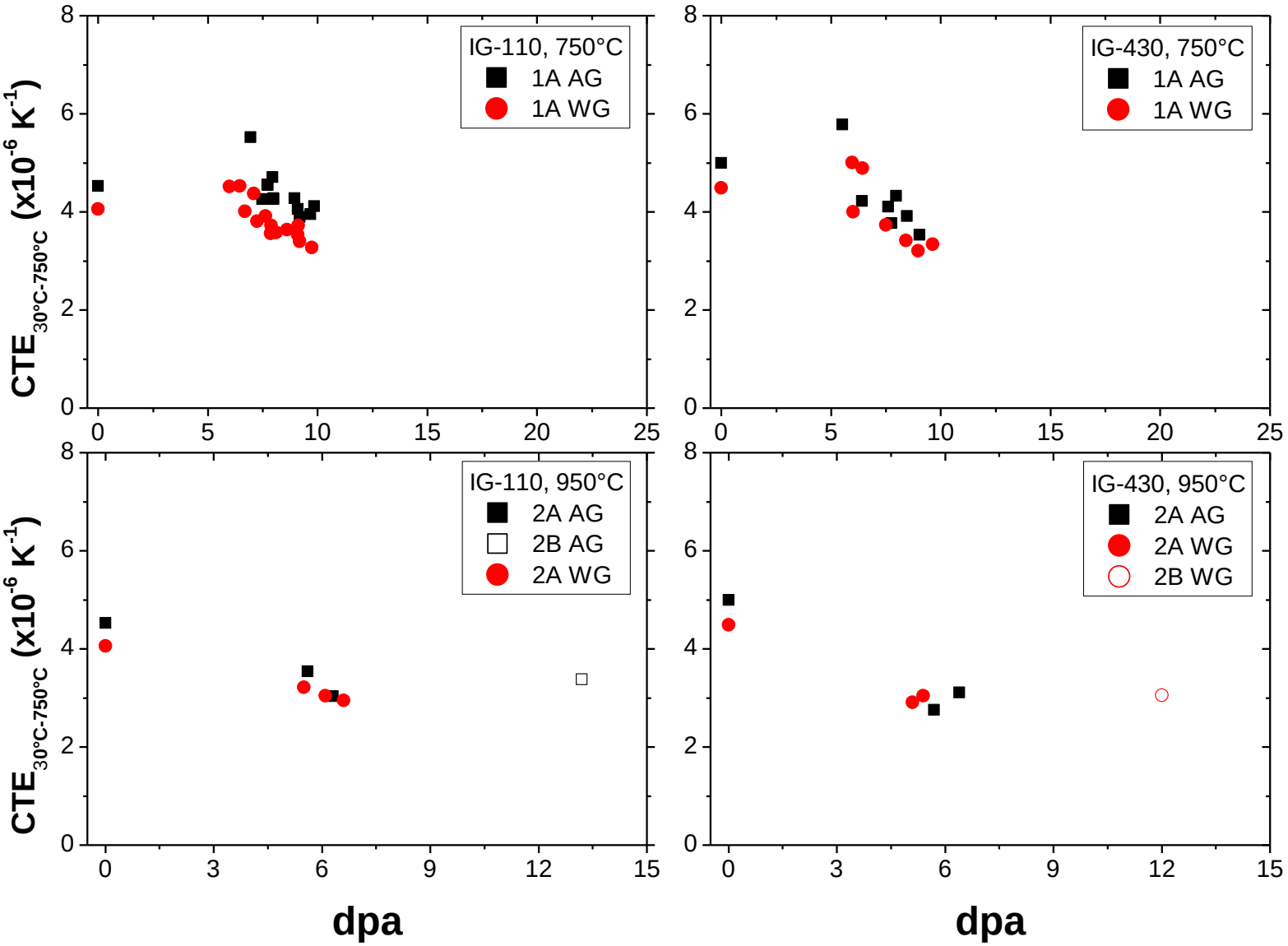

Figure 3-20 Coefficient of thermal expansion over the range of 30°C to 750°C for Toyo Tanso graphite grades irradiated at 750°C and 950°C. Note that the scale for the bottom panels is different from the top panels

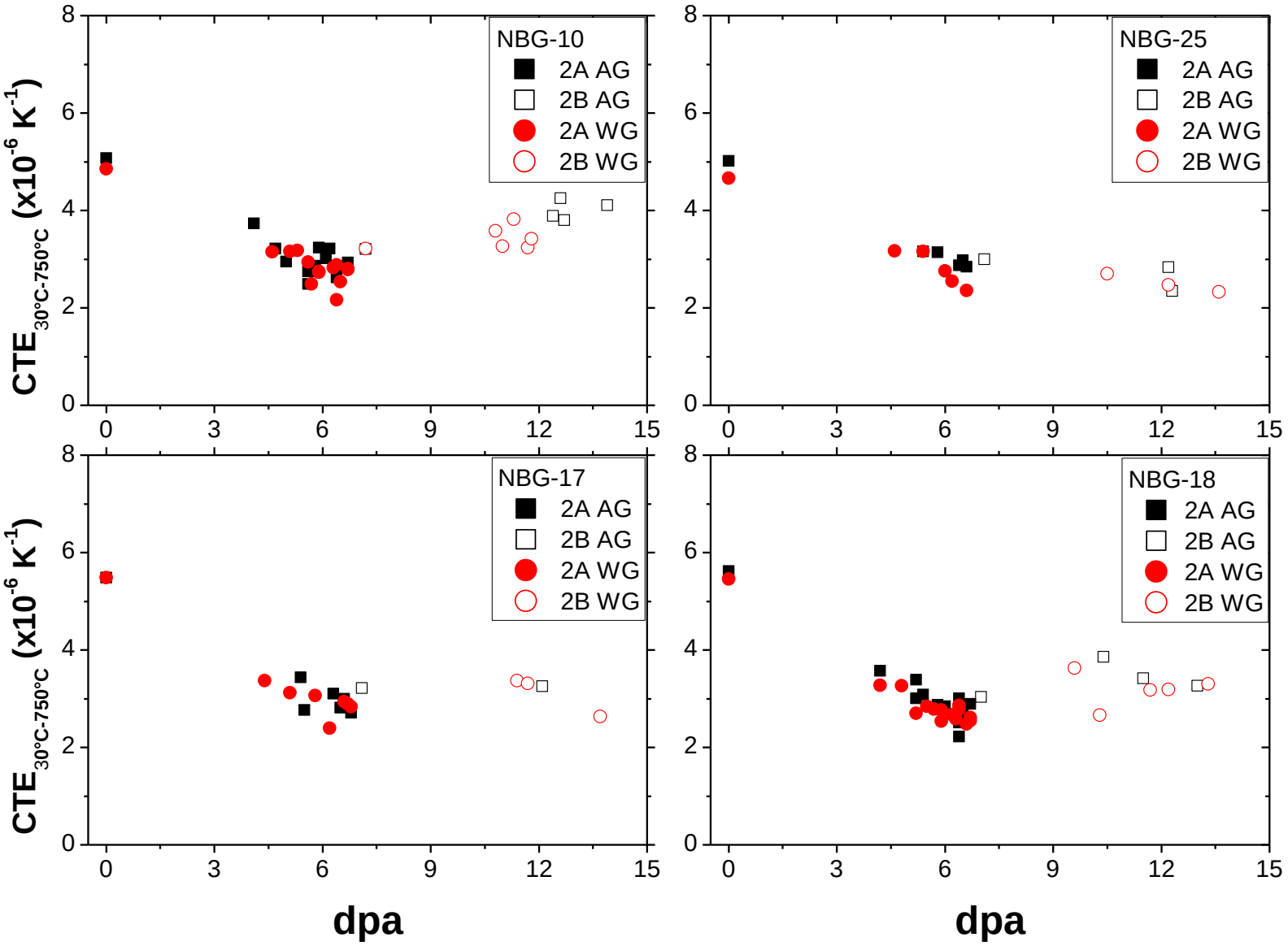

Figure 3-21 Coefficient of thermal expansion over the range of 30°C to 750°C for SGL graphite grades irradiated at 950°C

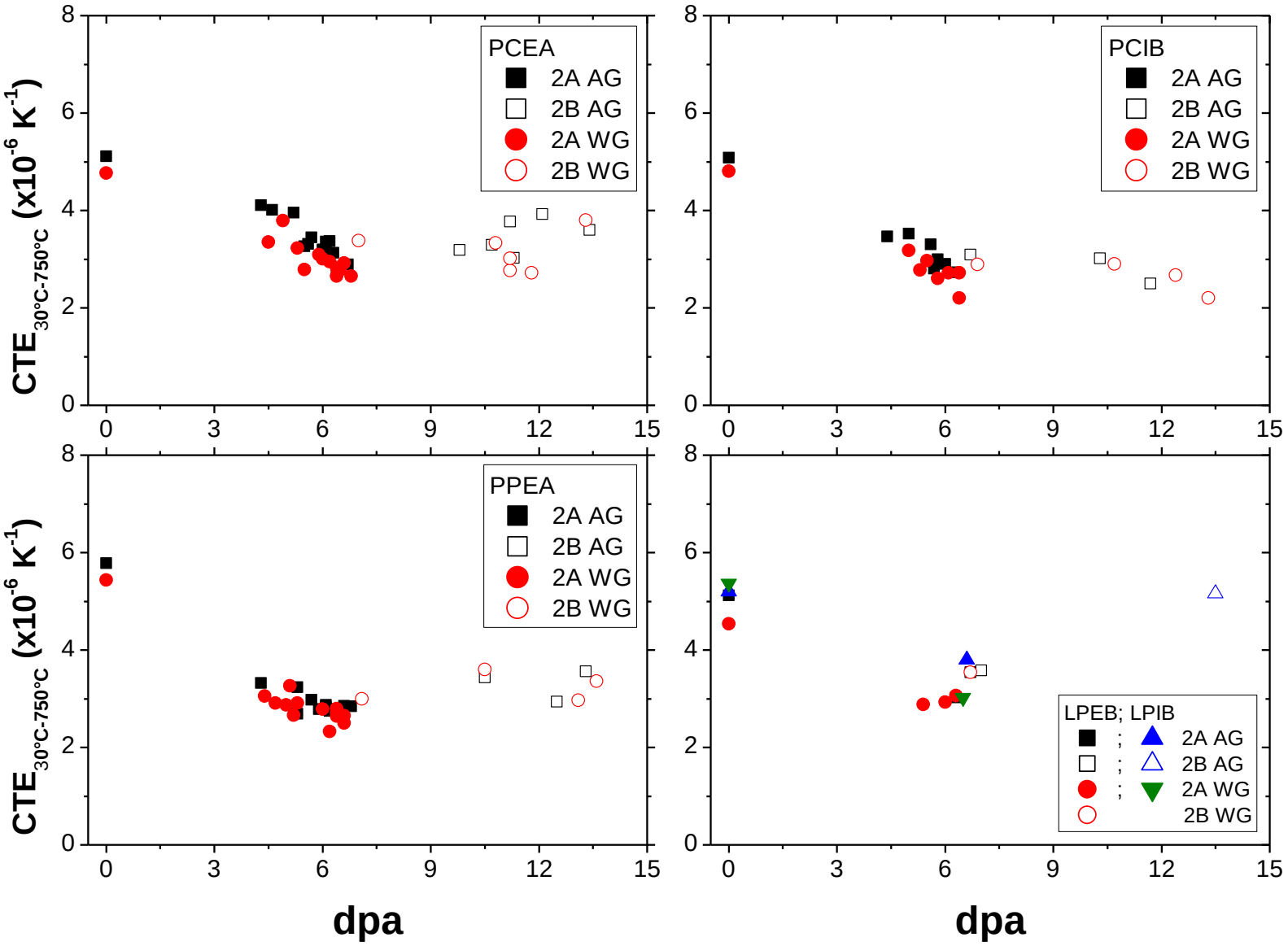

Figure 3-22 Coefficient of thermal expansion over the range of 30°C to 750°C for Graftech graphite grades irradiated at 950°C

3.2.4 Thermal diffusivity and thermal conductivity

Thermal diffusivity was measured at temperatures from room temperature up to irradiation temperature in steps of 100°C. Thermal conductivity was calculated from the measured thermal diffusivity, measured density, and tabulated specific heat (ASTM 781-96). It is assumed that the specific heat is not changed due to neutron irradiation.

Figure 3-23 to Figure 3-27 show the thermal diffusivity (α) of the Innograph-1B and -2B specimens at 700°C. Figure 3-28 to Figure 3-32 show the thermal conductivity (k) of these specimens at 700°C. Included for both are the reference values for the graphite grade at 0 dpa. The thermal diffusivity and conductivity at temperatures other than 700°C are reported in Appendix D.

The number of samples of the Innograph-2B irradiation that were available for thermal characterisation was limited. For a number of samples the contact dose rate was too high for the samples to be allowed in the glove-box of the laser flash analysis set-up. For some of these samples, low-active alternatives were found. Other samples were too much swollen to fit in the LFA sample holders. For these, alternatives cannot be found, as alternative samples at similar dpa have similar swollen diameters as a result of the neutron dose. Table 3.3 gives an overview of the samples of which the thermal diffusivity could not be measured. The limit for the LFA sample holder diameter is 8.2 mm.

Table 3.3 Overview of the Innograph-2B specimens that were originally planned for PIE LFA measurements but were either too active ("cell"), too expanded (≥8.2 mm), or both

Specimen code	Grade	dpa	Ø [mm]	Cell or box?	Specimen code	Grade	dpa	Ø [mm]	Cell or box?
S036	NBG-10	5.3	8.3	cell	S608	NBG-17	5.4	8.3	box
S062	NBG-10	5.6	8.23	box	S672	NBG-18	7	7.93	cell
S077	NBG-10	5.6	8.34	box	U375	LPIB	6.6	8.59	box
S350	NBG-10	5.7	8.25	box	T087	IG-430	5.1	8.3	box
S410	NBG-25	7.1	8.15	cell	U010	PCEA	6	8.26	box
S414	NBG-25	5.4	8.15	cell	U033	PCEA	6.4	8.54	cell
S448	NBG-25	6.2	8.25	cell	U084	PCEA	6.4	8.6	box
S462	NBG-18	6.4	8.65	box	U087	PCEA	5.5	8.22	box
S463	NBG-18	5.2	8.45	box	U175	PCIB	5.7	8.2	cell
S473	NBG-18	6	8.55	box	U201	PCIB	6.4	8.46	box
S511	NBG-18	4.2	8.12	cell	U227	PPEA	6.2	8.66	cell
S519	NBG-18	6.4	8.23	box	U241	PPEA	5.7	8.47	cell
S552	NBG-17	6.2	8.43	box	U368	LPEB	7	7.91	cell
S598	NBG-17	5.8	8.38	cell					

The thermal diffusivity, and therefore thermal conductivity, shows a decreasing trend as a function of irradiation damage. The largest change occurs at low dose for which no data is available. Starting at

medium dose, the decrease is more gradual for the 750°C experiment. For 950°C, the trend appears more linear staring from 0 dpa. For the 950°C however, fewer data points are available as discussed before. For all grades, no difference can be noticed in diffusivity or conductivity for different grain orientations.

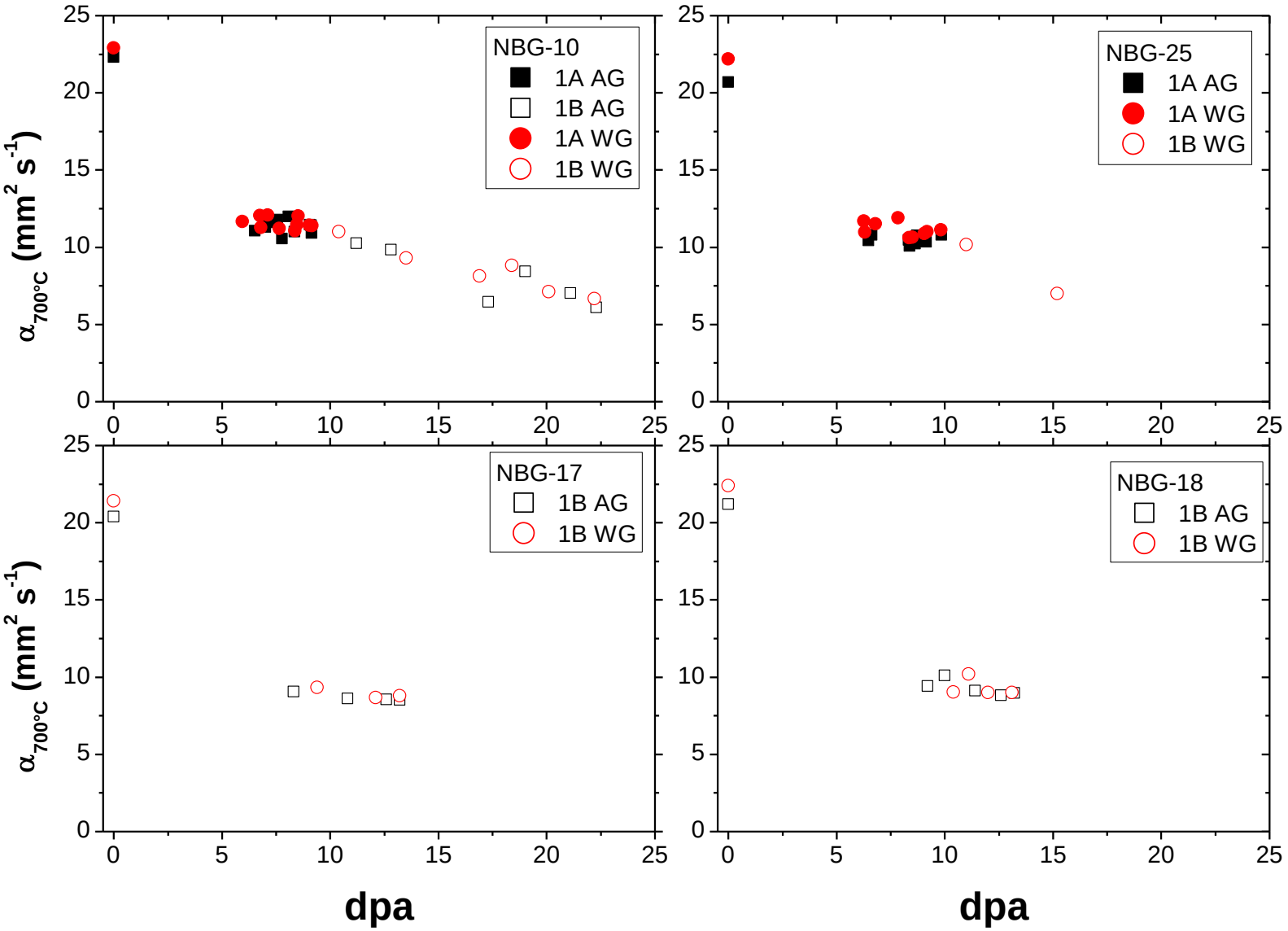

Figure 3-23 Thermal diffusivity at 700°C for SGL graphite grades irradiated at 750°C

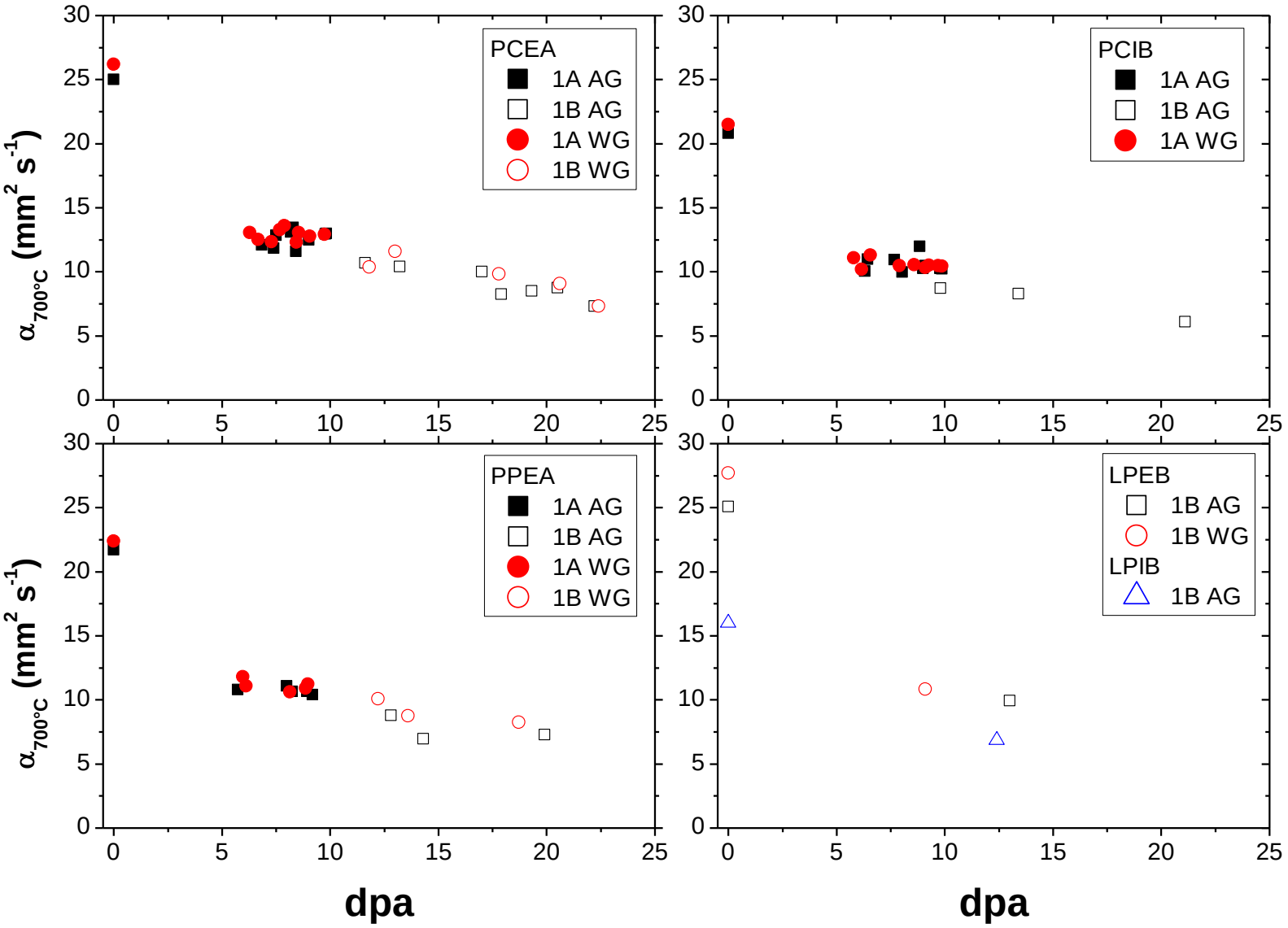

Figure 3-24 Thermal diffusivity at 700°C for Graftech graphite grades irradiated at 750°C

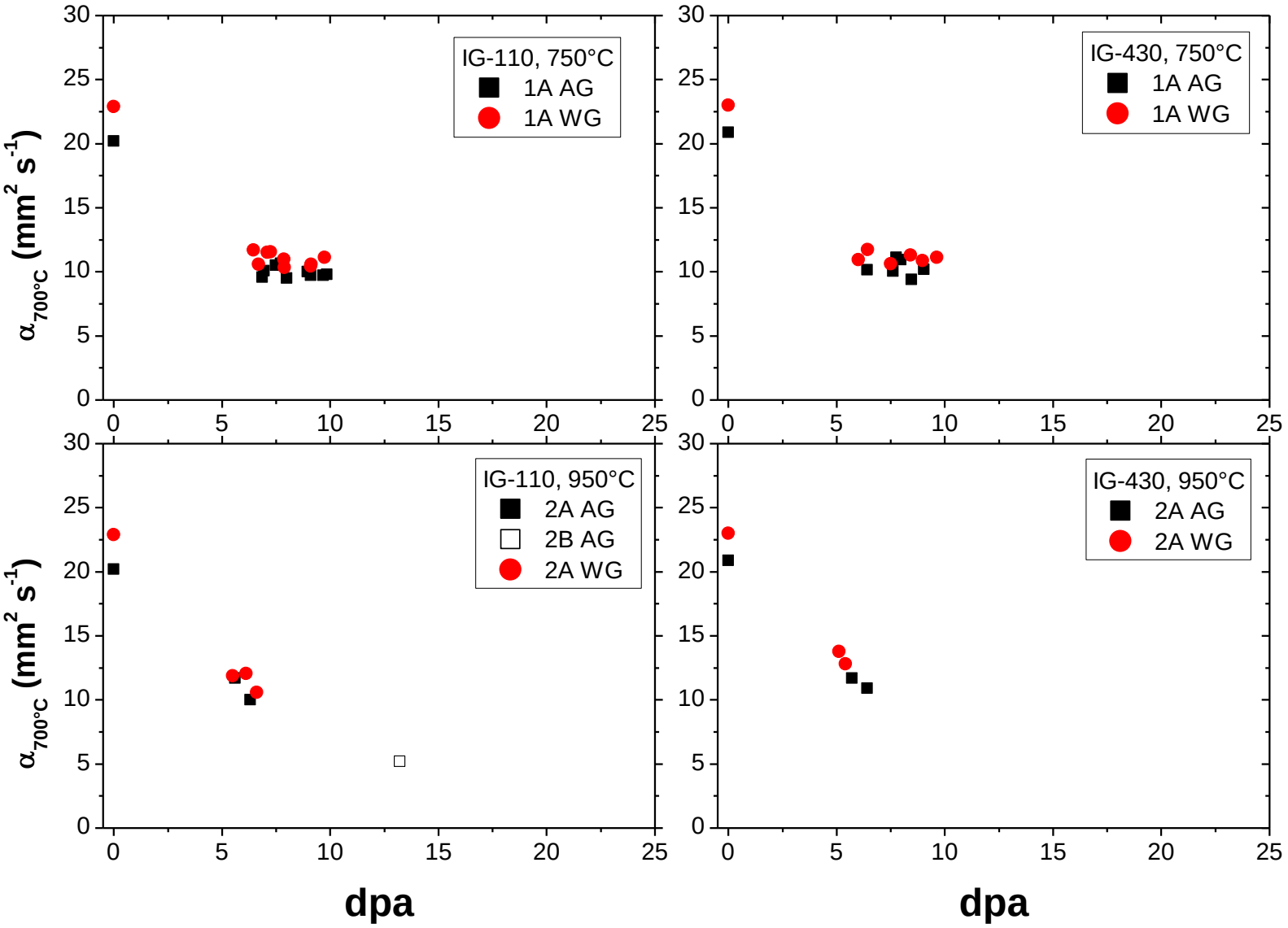

Figure 3-25 Thermal diffusivity at 700°C for Toyo Tanso graphite grades irradiated at 750°C (top) and 950°C (bottom)

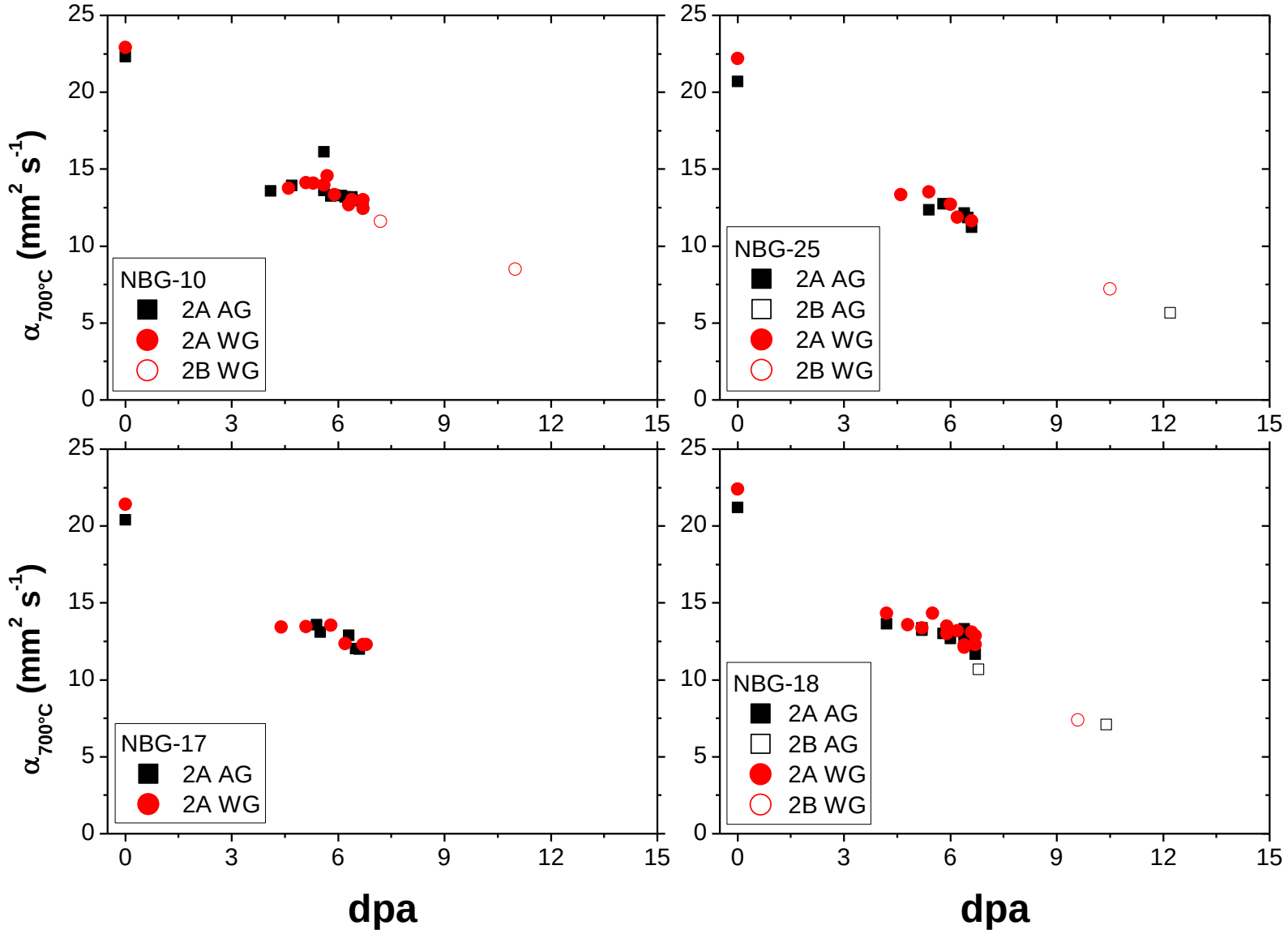

Figure 3-26 Thermal diffusivity at 700°C for SGL graphite grades irradiated at 950°C

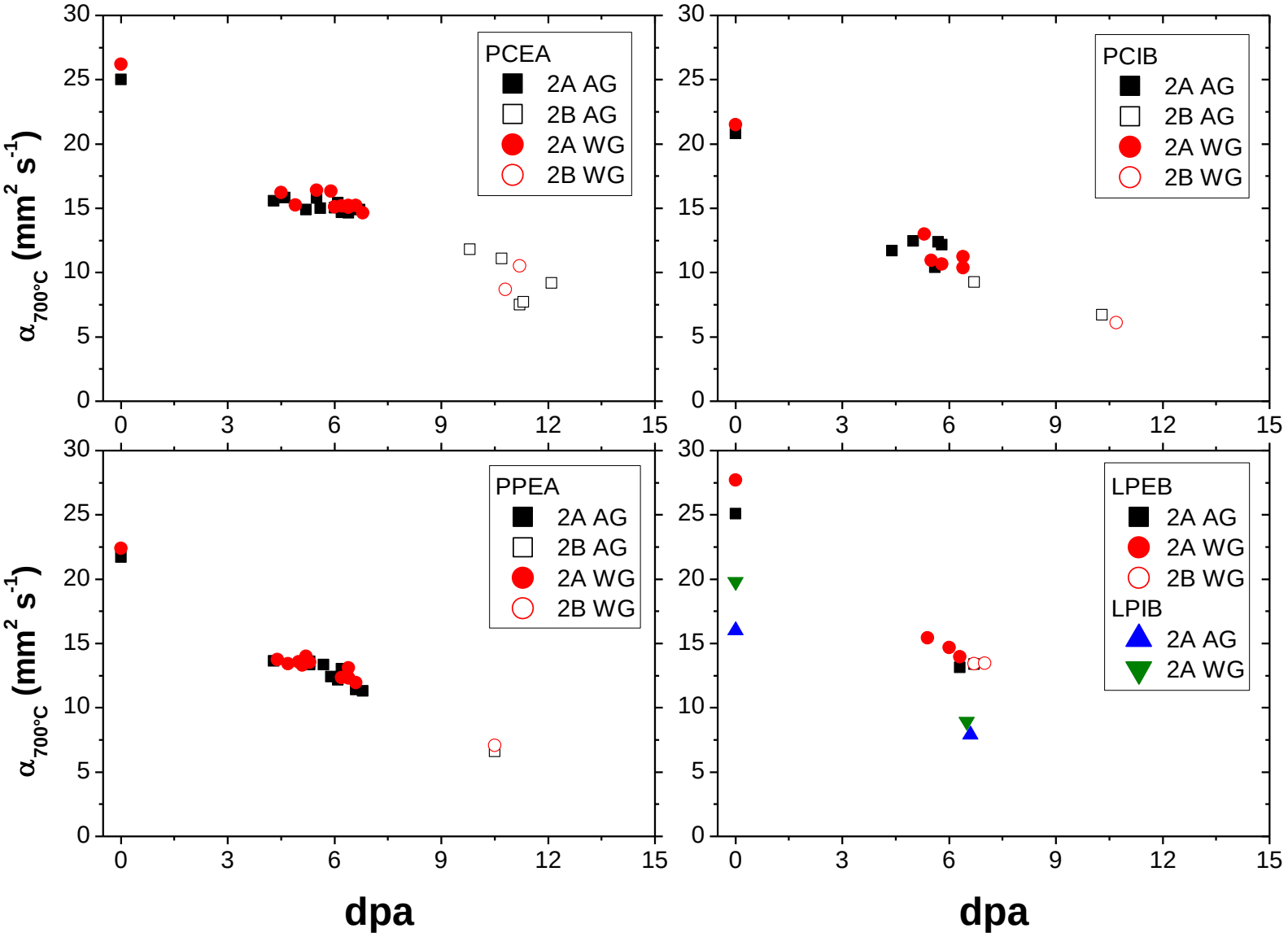

Figure 3-27 Thermal diffusivity at 700°C for Graftech graphite grades irradiated at 950°C

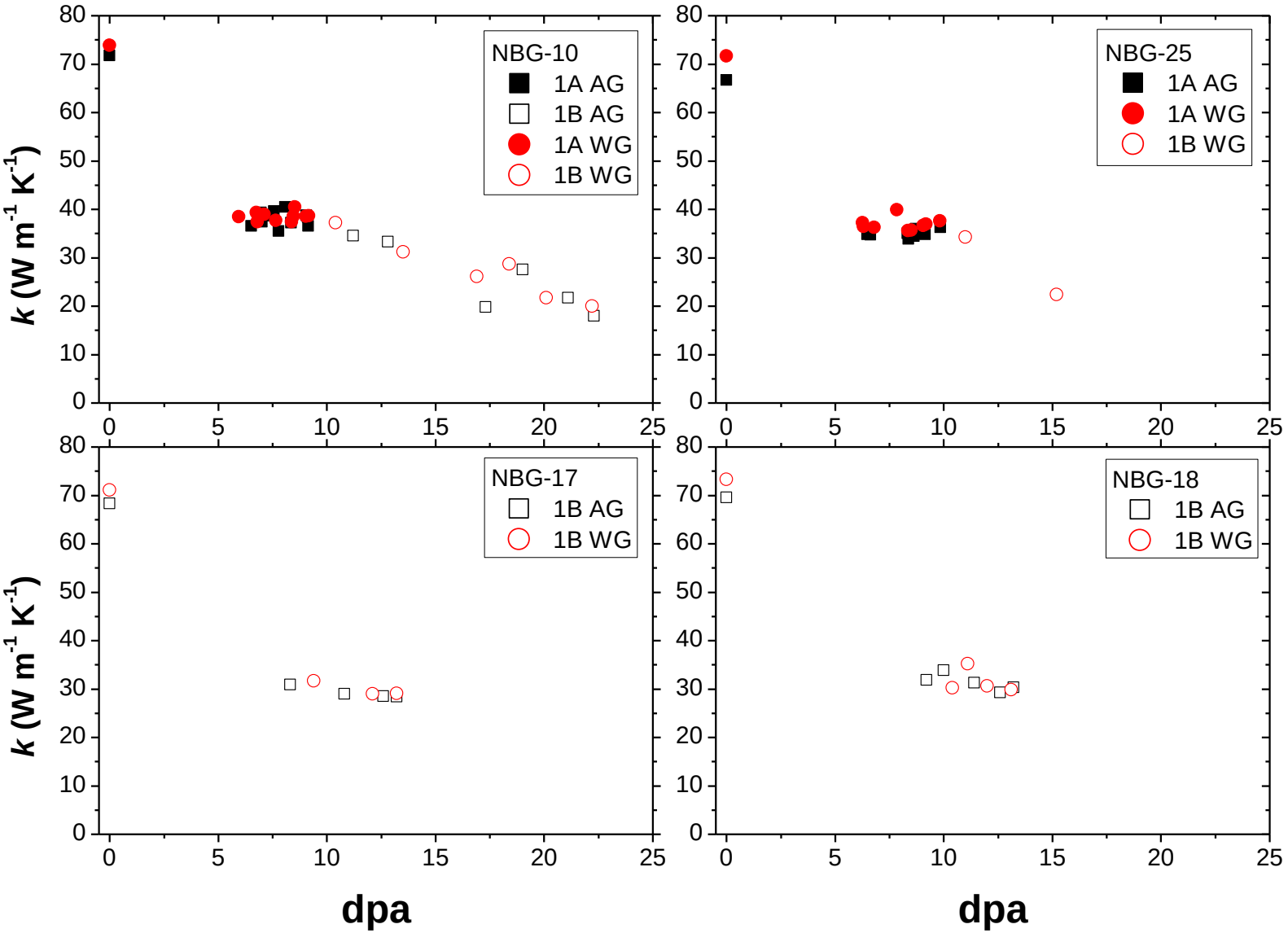

Figure 3-28 Thermal conductivity measured at 700°C for SGL graphite grades irradiated at 750°C

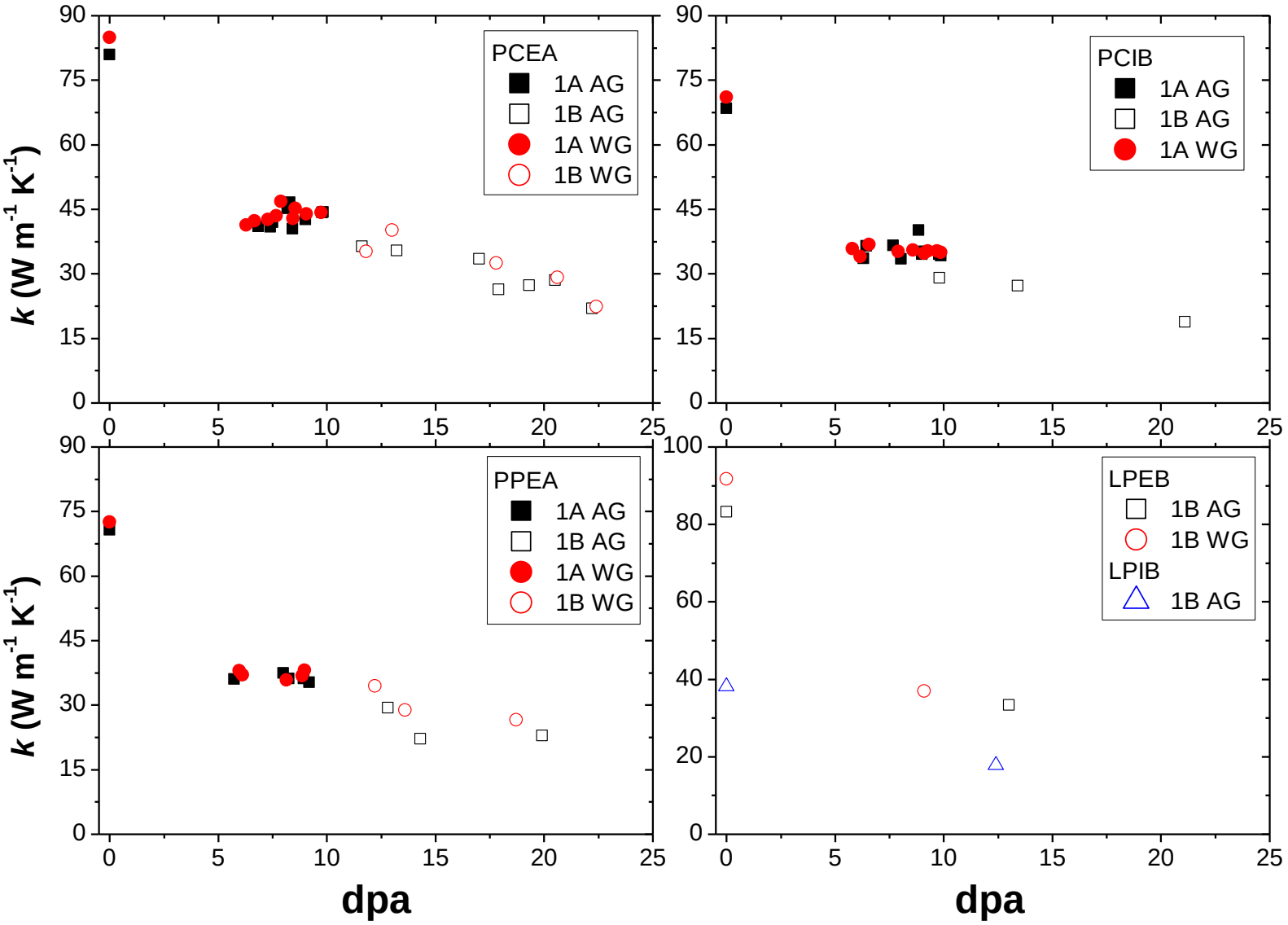

Figure 3-29 Thermal conductivity measured at 700°C for Graftech graphite grades irradiated at 750°C. Note that the graph for LPEB and LPIB has a different vertical scale

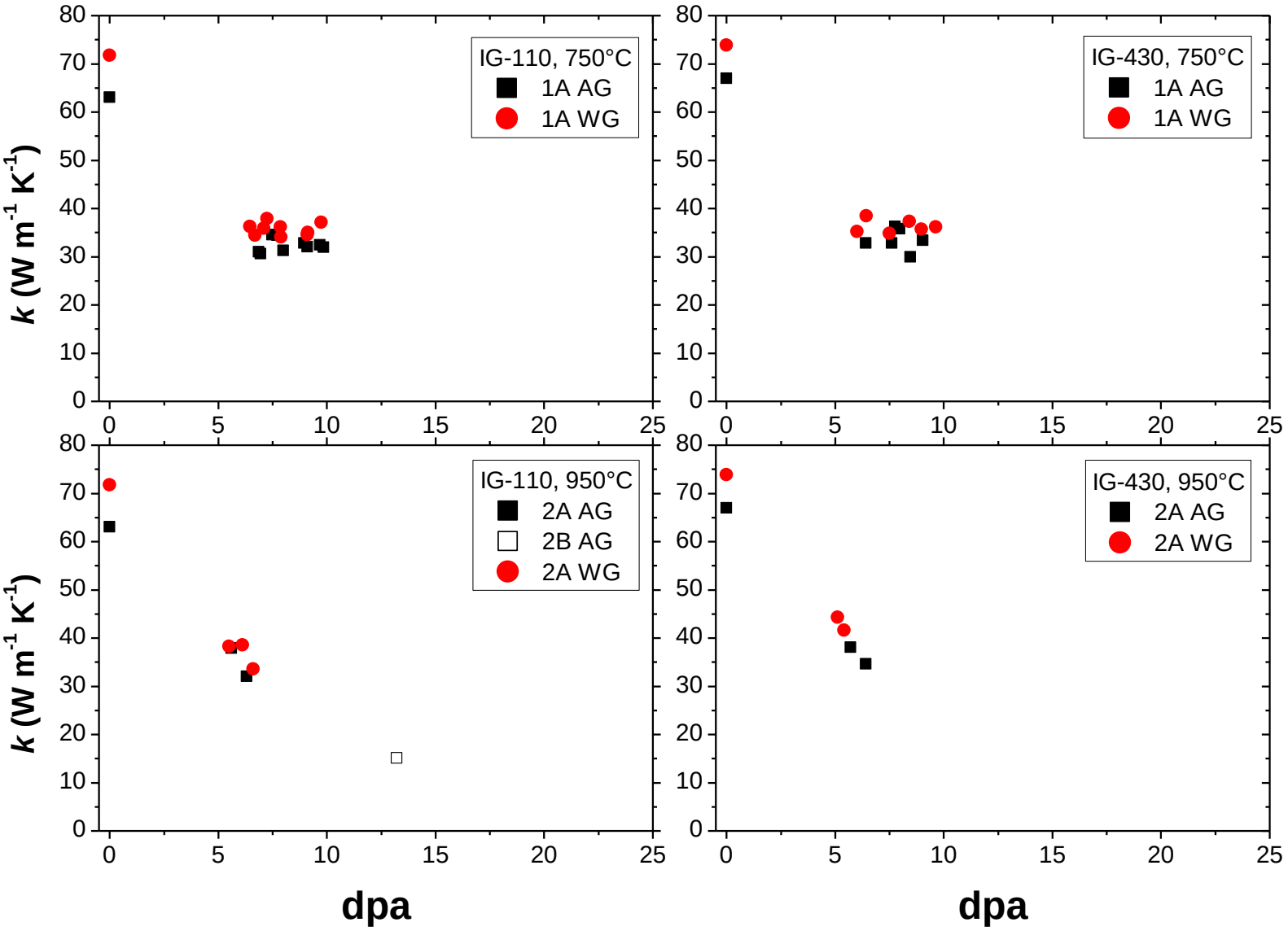

Figure 3-30 Thermal conductivity measured at 700°C for Toyo Tanso graphite grades irradiated at 750°C (top) and 950°C (bottom)

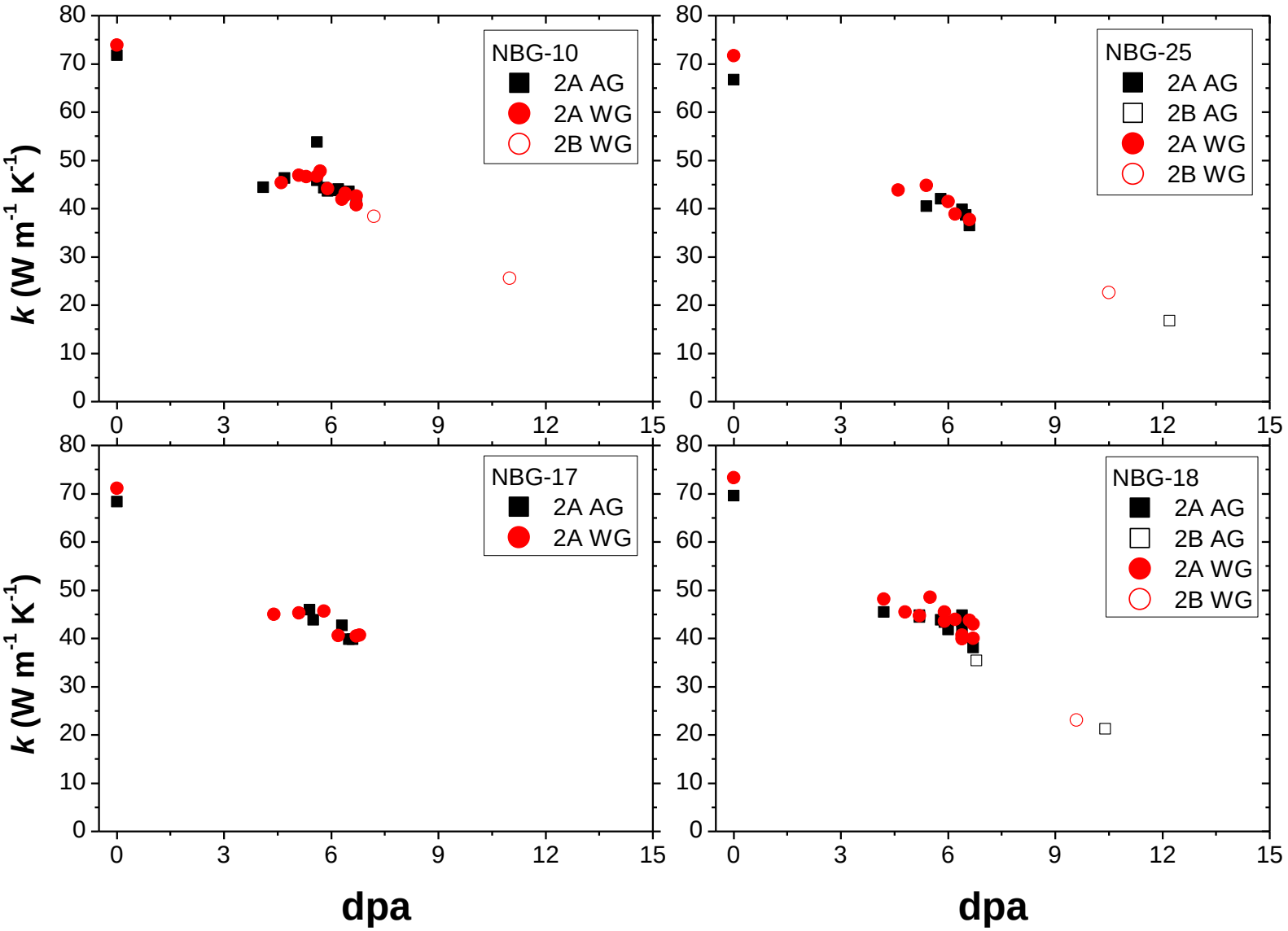

Figure 3-31 Thermal conductivity measured at 700°C for SGL graphite grades irradiated at 950°C

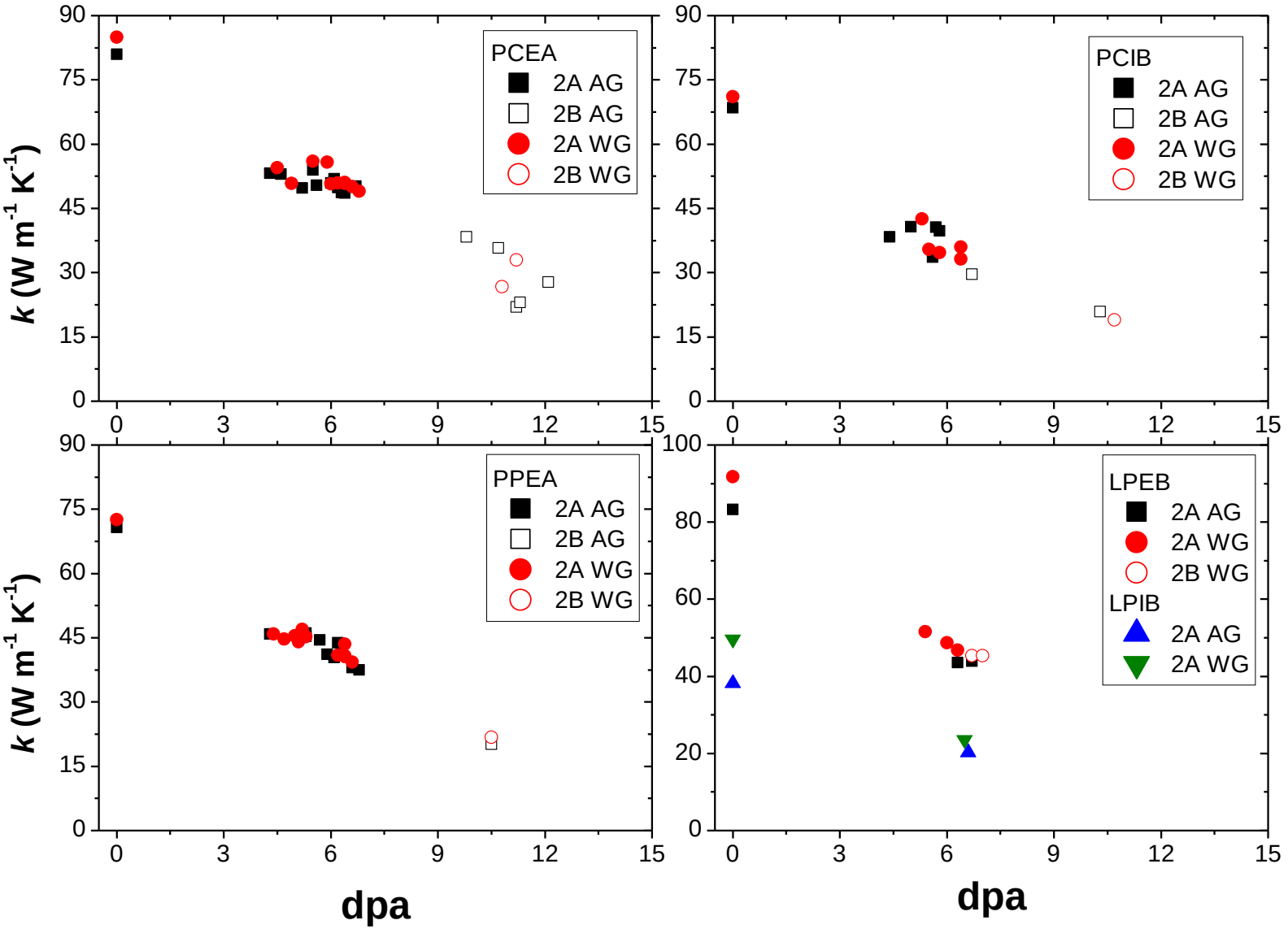

Figure 3-32 Thermal conductivity measured at 700°C for Graftech graphite grades irradiated at 950°C. Note that the vertical scale of the LPEB & LPIB graph is different

4 Conclusions

Following the screening PIE of the 1B and 2B experiments within the 6th Framework project RAPHAEL, a "full" PIE was conducted within the 7th Framework project ARCHER. The results of these PIEs are presented in this report.

The INNOGRAPH-1B irradiation with a nominal temperature of 750°C and INNOGRAPH-2B with a nominal temperature of 950°C were successfully completed. Both experiments contained unirradiated and irradiated specimens to give a range of 10 to 24 dpa and 4.5 to 13.5 dpa for the 750°C and 950°C experiment respectively.

Results on dimensional change show that for both temperatures the experiments provide samples well beyond "turn around". For the 2B experiment, the neutron dose was such that a gap in the curves exists around cross-over.

The results on Dynamic Young's Modulus measurements show a trend for an increase at medium dose to a decrease at high dose. The coefficient of thermal expansion was found to in general decrease and reach a stable plateau at dimensional change turn-around.

Thermal diffusivity and conductivity typically continuously and gradually drop starting from medium dose; at low dose a larger drop should occur but no data is available as present at these spa values. The number of INNOGRAPH-2B specimen for which thermal diffusivity and conductivity were measured was strongly reduced by specimen activity and by the level of swelling of samples.

References

[1] F. Schmalz *et al.*, Preliminary irradiation testing of selected graphite grades for HTR, *Final report on HTR-M1 WP3*, 20787/05.71179/P, 19 December 2005

[2] J.A. Vreeling *et al.*, Designing loading and assembling an irradiation experiment with radioactive samples, *DLM 3.1: Progress on continuation of 750°C graphite irradiation test*, 21457/06.77295/P, 26 October 2006

[3] J.A. Vreeling, *DML3.8 Continuation of 950°C graphite irradiation, Status March* 2009, NRG-21457/09.94517, 18 March 2009

[4] J.A. Vreeling, B. Sakintuna, *DML3.13: Full PIE INNOGRAPH-1A and description INNOGRAPH-1B*, NRG-21457/10.101850, 14 April 2010.

[5] J.A. Vreeling, B. Sakintuna, Post Irradiation Examinations of experiment at 950°C, *DML 3.16 Full PIE of INNOGRAPH-2A*, NRG-21457/10.101644, 14 April 2010

[6] J.A. Vreeling, *Screening PIE results of INNOGRAPH-1B*, 22188/11.106188 I&D/AV/LD, 21 January 2011

[7] J.A. Vreeling, B. Sakintuna, High dose graphite irradiation experiment at 950°C, *DML 3.15 Screening PIE of INNOGRAPH-2B*, NRG-21457/10.101992, 14 April 2010

[8] O. Wouters, J.A. Vreeling, INNOGRAPH-1B and INNOGRAPH-2A specimen manufacture and pre-characterisation, *DML3.3: Graphite material procurement & characterisation*, 21457/06.77300/P, 23 October 2006

[9] J.A. Vreeling, DML 3.9 Heat-up experiments on irradiated graphite, NRG-21457/09.94732/P, 28 March 2009

[10] D.J. Ketema, INNOGRAPH-12 and 22, *Neutron Metrology Results*, NRG, 6 December 2010

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Appendix A PIE results for specimens irradiated at 650°C and 850°C.

Table A.1 Volume change, length change, and DYM change for samples irradiated at 650°C. The samples are ordered per graphite grade and increasing dpa

Specimen code	Grade	Location	Orientation	INNO	dpa	$\Delta V/V_0$ [%]	$\Delta L/L_0$ [%]		E/E_0	
							AG	WG	AG	WG
T035	IG-110	Edge	AG	1A	3.68	-1.51	-0.54		1.81	
T051	IG-110	Edge	WG	1A	4.80	-1.90		-0.82		1.83
T016	IG-110	Heart	AG	1B	6.2	-2.96	-0.90		1.83	
T045	IG-110	Edge	AG	1A	7.47	-2.03	-0.65		1.81	
T021	IG-110	Heart	WG	1B	7.6	-3.52		-1.49		1.90
T062	IG-430	Heart	AG	1A	4.17	-1.16	-0.31		1.72	
T089	IG-430	Heart	WG	1A	4.50	-1.36		-0.57		1.72
T106	IG-430	Edge	WG	1A	5.19	-1.61		-0.69		1.70
T101	IG-430	Edge	AG	1A	5.60	-1.34	-0.34		1.74	
T072	IG-430	Heart	AG	1B	6.3	-2.33	-0.52		1.64	
T086	IG-430	Heart	WG	1B	6.6	-2.46		-0.92		1.63
U366	LPEB	Heart	AG	1B	6.6	-2.18	-0.67		1.64	
S086	NBG-10	Edge	AG	1A	2.92	-1.01	-0.42		1.58	
S075	NBG-10	Edge	AG	1A	4.52	-1.87	-0.70		1.58	
S035	NBG-10	Heart	WG	1B	7.3	-4.76		-2.69		1.50
S045	NBG-10	Heart	AG	1B	8.2	-4.09	-1.35		1.55	
S034	NBG-10	Heart	WG	1B	14.7	-5.65		-2.33		2.62
S604	NBG-17	Heart	WG	1B	7.2	-2.69		-1.17		1.61
S466	NBG-18	Edge	WG	1B	7.0	-3.20		-1.28		1.49
S171	NBG-20	Heart	AG	1A	4.88	-2.02	-0.83		1.54	
S126	NBG-25	Edge	AG	1A	3.41	-1.36	-0.38		1.76	
S136	NBG-25	Edge	AG	1A	4.18	-1.85	-0.52		1.72	
S142	NBG-25	Edge	WG	1A	4.39	-1.89		-0.74		1.68
U068	PCEA	Edge	AG	1A	3.16	-1.49	-0.51		1.67	
U082	PCEA	Edge	AG	1A	4.54	-2.00	-0.71		1.66	
U073	PCEA	Edge	WG	1A	4.77	-1.91		-0.74		1.69
U093	PCEA	Edge	AG	1B	7.9	-4.61	-1.61		1.57	
U007	PCEA	Heart	WG	1B	15.2	-7.06		-3.11		2.87
U178	PCIB	Edge	AG	1A	3.17	-1.14	-0.34		1.75	
U200	PCIB	Edge	AG	1A	5.13	-1.20	-0.30		1.77	
U195	PCIB	Edge	WG	1A	5.37	-1.10		-0.53		1.76
U133	PCIB	Heart	WG	1B	8.2	-2.27		-1.06		1.86
U242	PPEA	Heart	AG	1A	3.85	-1.70	-0.57		1.51	
U223	PPEA	Heart	WG	1A	4.18	-1.73		-0.67		1.54
U242	PPEA	Heart	AG	1B	11.0	-5.39	-1.74		2.06	
U223	PPEA	Heart	WG	1B	12.1	-5.67		-2.38		2.20
U280	PPEA	Heart	WG	1B	13.9	-5.58		-2.53		2.40

Table A.2 Volume change, length change, and DYM change for samples irradiated at 850°C. The samples are ordered per graphite grade and increasing dpa

Specimen code	Grade	Location	Orientation	INNO	dpa	$\Delta V/V_0$ [%]	$\Delta L/L_0$ [%]		E/E_0	
							AG	WG	AG	WG
T035	IG-110	Edge	AG	1A	3.68	-1.51	-0.54		1.81	
T051	IG-110	Edge	WG	1A	4.80	-1.90		-0.82		1.83
T016	IG-110	Heart	AG	1B	6.2	-2.96	-0.90		2.03	
T045	IG-110	Edge	AG	1A	7.47	-2.03	-0.65		1.81	
T021	IG-110	Heart	WG	1B	7.6	-3.52		-1.49		2.11
T062	IG-430	Heart	AG	1A	4.17	-1.16	-0.31		1.72	
T089	IG-430	Heart	WG	1A	4.50	-1.36		-0.57		1.72
T106	IG-430	Edge	WG	1A	5.19	-1.61		-0.69		1.70
T101	IG-430	Edge	AG	1A	5.60	-1.34	-0.34		1.74	
T072	IG-430	Heart	AG	1B	6.3	-2.33	-0.52		1.82	
T086	IG-430	Heart	WG	1B	6.6	-2.46		-0.92		1.81
U366	LPEB	Heart	AG	1B	6.6	-2.18	-0.67		1.82	
S086	NBG-10	Edge	AG	1A	2.92	-1.01	-0.42		1.58	
S075	NBG-10	Edge	AG	1A	4.52	-1.87	-0.70		1.58	
S035	NBG-10	Heart	WG	1B	7.3	-4.76		-2.69		1.66
S045	NBG-10	Heart	AG	1B	8.2	-4.09	-1.35		1.72	
S034	NBG-10	Heart	WG	1B	14.7	-5.65		-2.33		2.91
S604	NBG-17	Heart	WG	1B	7.2	-2.69		-1.17		1.78
S466	NBG-18	Edge	WG	1B	7.0	-3.20		-1.28		1.66
S171	NBG-20	Heart	AG	1A	4.88	-2.02	-0.83		1.54	
S126	NBG-25	Edge	AG	1A	3.41	-1.36	-0.38		1.76	
S136	NBG-25	Edge	AG	1A	4.18	-1.85	-0.52		1.72	
S142	NBG-25	Edge	WG	1A	4.39	-1.89		-0.74		1.68
U068	PCEA	Edge	AG	1A	3.16	-1.49	-0.51		1.67	
U082	PCEA	Edge	AG	1A	4.54	-2.00	-0.71		1.66	
U073	PCEA	Edge	WG	1A	4.77	-1.91		-0.74		1.69
U093	PCEA	Edge	AG	1B	7.9	-4.61	-1.61		1.74	
U007	PCEA	Heart	WG	1B	15.2	-7.06		-3.11		3.19
U178	PCIB	Edge	AG	1A	3.17	-1.14	-0.34		1.75	
U200	PCIB	Edge	AG	1A	5.13	-1.20	-0.30		1.77	
U195	PCIB	Edge	WG	1A	5.37	-1.10		-0.53		1.76
U133	PCIB	Heart	WG	1B	8.2	-2.27		-1.06		2.06
U242	PPEA	Heart	AG	1A	3.85	-1.70	-0.57		1.51	
U223	PPEA	Heart	WG	1A	4.18	-1.73		-0.67		1.54
U242	PPEA	Heart	AG	1B	11.0	-5.39	-1.74		2.29	
U223	PPEA	Heart	WG	1B	12.1	-5.67		-2.38		2.45
U280	PPEA	Heart	WG	1B	13.9	-5.58		-2.53		2.66

Appendix B Dimensional and DYM data of INNOGRAPH-1B and INNOGRAPH-2B

Table B.1 Measurement results of dimensions, mass, volume, density, and DYM for SGL graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation							Pre irradiation						
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	x	d	l	m	V	ρ	E	x	d	l	m	V	ρ	E
						[mm]	[mm]	[mm]	[g]	[mm^3]	[g/cm^3]	[GPa]	[mm]	[mm]	[mm]	[g]	[mm^3]	[g/cm^3]	[GPa]
S030	NBG-10	Centre	WG	750	20.1	7.850	8.179	6.145	0.5465	318.5	1.716	27.9	7.703	7.988	6.093	0.5486	301.9	1.817	13.7
S031	NBG-10	Centre	WG	750	16.9	7.714	8.026	6.002	0.5416	299.7	1.807	35.8	7.707	7.994	6.047	0.5435	300.0	1.812	12.6
S033	NBG-10	Centre	WG	750	22.2	7.895	8.237	6.114	0.5404	321.2	1.682	26.0	7.704	7.994	6.025	0.5418	298.9	1.813	13.1
S034	NBG-10	Centre	WG	650	14.7	7.585	7.854	5.875	0.5389	281.6	1.914	37.1	7.716	7.991	6.015	0.5402	298.5	1.810	12.8
S035	NBG-10	Centre	WG	650	7.3	7.624	7.922	5.880	0.5326	286.3	1.860	22.5	7.708	8.008	6.042	0.5331	300.6	1.774	13.6
S038	NBG-10	Centre	WG	750	11.9	7.594	7.868	5.867	0.5368	282.2	1.902	34.3	7.706	8.001	5.999	0.5373	298.0	1.803	13.2
S039	NBG-10	Centre	WG	750	13.7	7.616	7.914	5.871		285.2			7.705	8.009	5.993	0.5367	298.2	1.800	13.6
S041	NBG-10	Centre	AG	750	21.1	7.743	8.113	6.164	0.5451	313.4	1.739	28.7	7.710	7.996	6.041	0.5449	299.9	1.817	12.6
S042	NBG-10	Centre	AG	750	22.3	7.835	8.193	6.291	0.5403	326.6	1.654	22.0	7.698	7.969	6.084	0.5426	300.2	1.807	12.3
S043	NBG-10	Centre	AG	750	17.3	7.740	8.121	6.060	0.5333	308.5	1.729	24.2	7.709	7.996	5.945	0.5378	295.1	1.822	12.5
S045	NBG-10	Centre	AG	650	8.2	7.609	7.905	5.920	0.5352	287.0	1.865	22.6	7.716	8.018	6.001	0.5356	299.2	1.790	13.2
S051	NBG-10	Centre	AG	750	12.8	7.562	7.848	5.984	0.5444	286.1	1.903	37.2	7.712	8.000	6.073	0.5449	301.7	1.806	13.2
S052	NBG-10	Centre	AG	750	19.2	7.709	8.068	6.183		311.1			7.704	7.981	6.057	0.5415	299.7	1.807	12.2
S053	NBG-10	Centre	AG	750	13.2	7.578	7.883	5.916	0.5357	285.1	1.879		7.706	8.003	5.985	0.5359	297.5	1.802	13.0
S063	NBG-10	Edge	WG	750	20.7	7.849	8.165	6.155		318.2			7.699	7.980	6.105	0.5489	301.9	1.818	13.4
S064	NBG-10	Edge	WG	750	10.4	7.547	7.865	5.868	0.5352	281.2	1.903	31.3	7.643	7.987	5.986	0.5379	295.5	1.821	13.9
S065	NBG-10	Edge	WG	750	21.7	8.026	8.356	6.031	0.5287	326.4	1.620	23.5	7.696	7.977	5.864	0.5291	289.8	1.826	13.2
S066	NBG-10	Edge	WG	750	12.7	7.551	7.878	5.876	0.5361	282.4	1.899	39.9	7.627	7.987	5.992	0.5370	295.4	1.818	14.1
S067	NBG-10	Edge	WG	750	18.6	7.780	8.092	6.095	0.5460	309.4	1.765	31.6	7.695	7.991	6.119	0.5478	303.2	1.807	13.5
S068	NBG-10	Edge	WG	750	13.5	7.580	7.925	5.904	0.5407	286.8	1.885	41.0	7.641	8.003	6.005	0.5425	297.2	1.826	14.4
S069	NBG-10	Edge	WG	750	18.4	7.699	7.980	5.954	0.5392	294.5	1.831		7.704	7.992	6.031	0.5446	299.0	1.821	13.2
S070	NBG-10	Edge	WG	750	11.0	7.540	7.895	5.899		284.2			7.627	8.005	6.012	0.5399	297.4	1.816	14.0
S071	NBG-10	Edge	WG	750	18.0	7.946	8.272	6.123		324.7			7.704	7.995	6.026	0.5421	299.0	1.813	13.5
S072	NBG-10	Edge	AG	750	17.2	7.641	7.980	6.150		303.1			7.711	7.987	6.113	0.5532	303.0	1.826	12.5
S073	NBG-10	Edge	AG	750	22.4	7.942	8.373	6.483		350.0			7.710	7.996	6.080	0.5438	301.8	1.802	12.5
S074	NBG-10	Edge	AG	750	19.0	7.621	7.948	6.147	0.5516	300.7	1.835	36.2	7.704	7.983	6.115	0.5533	302.7	1.828	12.6
S076	NBG-10	Edge	AG	750	20.4	7.766	8.135	6.179	0.5379	316.0	1.702	26.2	7.703	7.977	5.985	0.5389	295.9	1.821	12.8
S078	NBG-10	Edge	AG	750	11.2	7.499	7.853	5.908	0.5346	281.5	1.899	32.2	7.632	7.999	5.992	0.5357	296.2	1.809	12.9
S079	NBG-10	Edge	AG	750	13.1	7.511	7.864	5.970		285.4			7.630	7.998	6.035	0.5412	298.2	1.815	13.3
S080	NBG-10	Edge	AG	750	12.3	7.531	7.886	5.965		286.7			7.655	8.008	6.009	0.5397	298.0	1.811	12.8
S081	NBG-10	Edge	AG	750	10.1	7.529	7.866	5.919	0.5389	283.4	1.902	35.2	7.653	8.006	5.997	0.5397	297.2	1.816	13.2
S094	NBG-25	Centre	AG	750	19.4	7.668	7.965	6.188	0.5379	304.6	1.766	34.9	7.704	7.980	5.990	0.5381	296.4	1.816	10.6
S096	NBG-25	Centre	AG	750	21.6	7.694	8.003	6.125		304.2			7.700	7.985	5.899	0.5303	292.1	1.816	10.8
S099	NBG-25	Centre	AG	750	9.9	7.562	7.836	5.959		284.2			7.698	7.993	5.958	0.5359	295.4	1.814	10.6
S101	NBG-25	Centre	AG	750	13.1	7.574	7.851	5.982	0.5335	286.3	1.863	39.1	7.703	7.997	5.947	0.5342	295.2	1.809	10.7
S103	NBG-25	Centre	AG	750	12.5	7.563	7.837	5.878	0.5274	280.4	1.881	39.4	7.704	8.002	5.941	0.5286	295.1	1.791	10.9
S107	NBG-25	Centre	WG	750	11.0	7.624	7.889	5.878	0.5382	284.3	1.893	35.8	7.636	8.001	6.009	0.5386	297.2	1.812	11.5
S108	NBG-25	Centre	WG	750	13.2	7.662	7.927	5.871	0.5372	286.7	1.873	38.8	7.629	7.995	5.967	0.5369	294.6	1.822	11.5
S111	NBG-25	Centre	WG	750	15.2	7.841	8.054	5.967	0.5427	301.8	1.798	35.7	7.710	7.995	6.038	0.5438	299.7	1.815	11.6
S115	NBG-25	Centre	WG	750	12.0	7.732	7.936	5.891	0.5384	289.3	1.861	39.5	7.713	8.007	5.998	0.5397	298.5	1.808	11.4
S130	NBG-25	Edge	AG	750	21.8	7.830	8.187	6.335	0.5402	328.4	1.645	26.1	7.706	7.995	5.971	0.5402	296.3	1.823	10.7
S139	NBG-25	Edge	WG	750	23.0	8.069	8.287	5.978	0.5360	320.1	1.674	29.6	7.713	7.988	5.932	0.5355	294.1	1.821	11.8
S140	NBG-25	Edge	WG	750	20.4	7.950	8.145	5.961	0.5360	308.7	1.737	33.6	7.712	7.995	5.959	0.5379	295.8	1.819	11.4
S160	NBG-20	Centre	WG	750	22.8	8.255	8.651	6.340		366.6			7.699	7.967	5.944	0.5145	293.2	1.755	10.4
S164	NBG-20	Centre	WG	750	18.9	7.931	8.276	5.904		313.1			7.708	7.970	5.820	0.4972	287.4	1.730	10.9
S169	NBG-20	Centre	AG	750	21.7	8.030	8.527	6.426		358.4			7.710	7.997	5.960	0.5306	296.0	1.792	11.6
S170	NBG-20	Centre	AG	750	21.6	7.759	8.198	6.166		318.7			7.708	7.974	5.925	0.5266	292.9	1.798	11.3
S466	NBG-18	Edge	WG	650	7.0	7.634	7.910	5.915	0.5411	287.5	1.882	23.1	7.699	7.992	5.991	0.5422	297.0	1.825	13.9
S467	NBG-18	Edge	WG	750	12.4	7.615	7.881	5.913		285.5			7.675	7.998	6.006	0.5458	297.6	1.834	14.0
S468	NBG-18	Edge	WG	750	13.1	7.655	7.942	5.921	0.5424	289.9	1.871	38.6	7.647	7.991	5.986	0.5440	295.7	1.839	14.1
S469	NBG-18	Edge	WG	750	10.4	7.588	7.893	5.916	0.5382	285.8	1.883	36.2	7.655	8.008	6.000	0.5405	297.5	1.817	13.8
S476	NBG-18	Edge	AG	750	10.0	7.545	7.856	5.931	0.5350	283.7	1.886	28.1	7.646	7.998	6.014	0.5368	297.5	1.804	13.2
S477	NBG-18	Edge	AG	750	12.8	7.548	7.858	5.952		284.9			7.651	7.995	5.993	0.5439	296.3	1.835	13.6
S478	NBG-18	Edge	AG	750	12.6	7.574	7.903	5.968	0.5396	288.6	1.870	38.2	7.651	8.009	5.985	0.5413	296.7	1.825	13.4
S479	NBG-18	Edge	AG	750	9.2	7.536	7.855	5.920	0.5394	283.0	1.906	34.5	7.646	7.995	5.977	0.5420	295.5	1.834	13.3
S512	NBG-18	Centre	WG	750	11.1	7.617	7.877	5.881	0.5505	283.7	1.940	35.4	7.691	7.998	5.986	0.5522	296.9	1.860	15.3
S513	NBG-18	Centre	WG	750	13.2	7.655	7.908	5.750		279.7			7.698	7.996	5.940	0.5395	294.7	1.831	15.3
S514	NBG-18	Centre	WG	750	12.0	7.624	7.923	5.958	0.5545	290.1	1.911	43.7	7.651	7.997	6.006	0.5555	297.1	1.870	15.3
S522	NBG-18	Centre	AG	750	11.6	7.546	7.870	5.914		283.6			7.643	8.009	5.971	0.5508	295.9	1.862	14.3
S523	NBG-18	Centre	AG	750	13.2	7.572	7.897	5.977	0.5497	288.6	1.905	40.8	7.642	7.999	5.986	0.5516	296.1	1.863	14.5
S524	NBG-18	Centre	AG	750	11.4	7.557	7.874	5.969	0.5527	286.7	1.928	40.4	7.644	7.989	5.985	0.5540	295.5	1.875	14.6
S553	NBG-17	Edge	WG	750	10.8	7.579	7.919	5.934		287.9			7.616	8.012	6.014	0.5517	297.6	1.853	14.0
S563	NBG-17	Edge	AG	750	12.1	7.571	7.923	5.996		291.0			7.665	7.998	6.010	0.5514	297.6	1.853	13.4
S568	NBG-17	Edge	AG	750	13.2	7.673	7.970	6.036	0.5581	297.5	1.876	38.4	7.715	8.002	5.993	0.5610	298.0	1.883	14.1
S571	NBG-17	Edge	AG	750	10.8	7.633	7.916	6.010	0.5536	292.5	1.893	36.5	7.707	7.992	6.009	0.5552	298.0	1.863	13.4
S579	NBG-17	Edge	WG	750	13.2	7.719	8.017	5.972	0.5557	297.8	1.866	38.1	7.741	8.018	5.997	0.5572	299.5	1.861	13.9
S580	NBG-17	Edge	WG	750	12.1	7.688	8.008	5.970	0.5579	296.6	1.881	38.3	7.729	8.030	6.002	0.5594	300.2	1.863	13.8
S604	NBG-17	Centre	WG	650	7.2	7.675	7.935	5.904	0.5578	289.1	1.929	26.4	7.733	7.997	5.974	0.5608	297.1	1.888	14.8
S605	NBG-17	Centre	WG	750	12.6	7.729	7.966	5.916		292.3			7.728	7.991	5.962	0.5598	296.0	1.891	14.7
S614	NBG-17	Centre	AG	750	10.3	7.642	7.907	5.976		290.4			7.721	7.997	6.011	0.5634	298.7	1.886	14.3
S615	NBG-17	Centre	AG	750	13.1	7.672	7.937	6.013		294.4			7.717	7.997	5.993	0.5614	297.7	1.886	14.1
S617	NBG-17	Centre	AG	750	12.6	7.669	7.979	6.048	0.5599	298.5	1.876	39.0	7.700	8.006	6.010	0.5621	298.8	1.881	14.3
S619	NBG-17	Centre	AG	750	8.3	7.621	7.919	5.970	0.5572	290.4	1.918	33.1	7.698	8.005	6.005	0.5606	298.4	1.878	14.2
S623	NBG-17	Centre	WG	750	12.9	7.793	7.996	6.004		299.4			7.750	7.982	6.010	0.5603	298.2	1.879	14.6
S626	NBG-17	Centre	WG	750	9.4	7.720	7.942	5.990	0.5618	294.4	1.908	38.6	7.744	7.995	6.033	0.5642	300.1	1.880	14.7

Table B.2 Measurement results of dimensions, mass, volume, density, and DYM for Graftech graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation							Pre irradiation						
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	x [mm]	d [mm]	l [mm]	m [g]	V [mm^3]	ρ [g/cm^3]	E [GPa]	x [mm]	d [mm]	l [mm]	m [g]	V [mm^3]	ρ [g/cm^3]	E [GPa]
U004	PCEA	Centre	WG	750	17.8	7.613	7.957	5.856	0.5336	286.8	1.861	36.2	7.674	7.981	5.982	0.5355	295.5	1.812	11.0
U005	PCEA	Centre	WG	750	22.4	7.820	8.185	5.956	0.5314	308.4	1.723	27.5	7.655	7.994	5.953	0.5334	294.4	1.812	10.9
U006	PCEA	Centre	WG	750	18.7	7.782	8.113	5.948	0.5358	303.2	1.767	30.8	7.669	7.999	5.982	0.5380	296.4	1.815	11.0
U007	PCEA	Centre	WG	650	15.2	7.531	7.827	5.758	0.5330	273.6	1.948	37.8	7.676	7.996	5.943	0.5342	294.4	1.814	11.8
U021	PCEA	Centre	AG	750	17.0	7.542	7.894	5.867	0.5318	282.6	1.882	38.7	7.695	7.999	5.913	0.5334	293.5	1.818	11.0
U022	PCEA	Centre	AG	750	21.3	7.598	7.973	6.011	0.5331	295.0	1.807		7.702	7.999	5.951	0.5334	295.5	1.805	10.8
U023	PCEA	Centre	AG	750	22.2	7.720	8.162	6.182	0.5329	316.7	1.683	23.8	7.709	7.992	5.985	0.5359	296.9	1.805	10.8
U024	PCEA	Centre	AG	750	17.9	7.598	7.971	5.975	0.5271	293.1	1.798	31.5	7.701	7.988	5.933	0.5300	293.9	1.803	10.7
U041	PCEA	Centre	AG	750	11.4	7.454	7.805	5.878		276.7			7.639	8.004	5.992	0.5368	296.6	1.810	11.7
U042	PCEA	Centre	AG	750	13.2	7.466	7.815	5.914	0.5350	279.2	1.916	40.2	7.641	7.996	6.003	0.5367	296.7	1.809	11.6
U043	PCEA	Centre	AG	750	11.6	7.472	7.810	5.909	0.5345	278.8	1.917	38.1	7.648	7.994	5.990	0.5354	296.1	1.808	11.5
U051	PCEA	Centre	WG	750	10.1	7.527	7.816	5.861		277.9			7.667	7.987	6.001	0.5349	296.6	1.803	11.4
U052	PCEA	Centre	WG	750	12.9	7.531	7.838	5.882		280.1			7.659	7.987	6.031	0.5376	297.9	1.805	11.6
U053	PCEA	Centre	WG	750	11.8	7.542	7.835	5.883	0.5354	280.2	1.911	36.7	7.669	7.982	6.028	0.5372	297.7	1.804	11.8
U069	PCEA	Edge	WG	750	17.0	7.609	7.895	5.848		283.0			7.682	7.976	5.989	0.5440	295.7	1.840	12.0
U070	PCEA	Edge	WG	750	20.6	7.704	8.097	5.886	0.5379	297.7	1.807	38.8	7.655	7.990	5.938	0.5390	293.4	1.837	12.3
U071	PCEA	Edge	WG	750	20.0	7.796	8.147	5.972		306.7			7.671	8.000	5.991	0.5453	297.0	1.836	12.2
U072	PCEA	Edge	WG	750	21.6	7.766	8.177	5.994		308.8			7.654	7.997	5.994	0.5447	296.6	1.836	12.2
U077	PCEA	Edge	AG	750	20.5	7.641	7.954	6.078	0.5456	298.1	1.830	36.2	7.741	7.974	5.999	0.5457	297.1	1.837	11.4
U078	PCEA	Edge	AG	750	9.5	7.539	7.783	5.896	0.5436	277.8	1.957		7.735	7.996	5.994	0.5451	298.0	1.829	12.1
U079	PCEA	Edge	AG	750	21.4	7.714	8.068	6.258		315.0			7.735	7.964	6.045	0.5510	298.7	1.845	11.6
U080	PCEA	Edge	AG	750	21.4	7.599	8.000	6.133		302.5			7.665	7.997	5.981	0.5428	296.2	1.833	11.1
U081	PCEA	Edge	AG	750	19.3	7.583	7.971	6.116	0.5434	299.7	1.813		7.680	7.992	5.990	0.5445	296.6	1.836	11.2
U091	PCEA	Edge	AG	750	12.9	7.477	7.793	5.894		277.3			7.657	7.983	5.982	0.5427	295.3	1.838	12.1
U092	PCEA	Edge	AG	750	12.9	7.491	7.832	5.950		282.3			7.664	7.994	6.019	0.5465	297.9	1.835	12.0
U093	PCEA	Edge	AG	650	7.9	7.549	7.855	5.885	0.5428	281.5	1.928	21.2	7.656	7.981	5.981	0.5430	295.1	1.840	12.2
U104	PCEA	Edge	WG	750	13.0	7.543	7.860	5.824	0.5431	278.8	1.948	43.3	7.655	8.004	5.986	0.5432	296.6	1.831	13.0
U105	PCEA	Edge	WG	750	11.9	7.537	7.844	5.822		277.7			7.663	7.997	5.988	0.5433	296.5	1.833	13.1
U106	PCEA	Edge	WG	750	9.9	7.528	7.844	5.799		276.5			7.668	8.002	5.961	0.5418	295.5	1.834	13.1
U114	PCIB	Centre	AG	750	21.1	7.777	8.137	6.110	0.5452	312.8	1.743	34.8	7.680	7.989	5.920	0.5455	293.0	1.862	11.8
U123	PCIB	Centre	WG	750	18.2	7.799	8.109	5.932	0.5441	302.5	1.799	39.6	7.697	8.001	5.895	0.5444	292.7	1.860	12.3
U124	PCIB	Centre	WG	750	20.2	7.876	8.205	6.047	0.5476	315.4	1.736	33.8	7.700	8.003	5.947	0.5494	295.5	1.860	12.6
U125	PCIB	Centre	WG	750	22.1	7.950	8.275	6.104		324.0			7.697	7.989	5.945	0.5482	294.5	1.861	12.5
U128	PCIB	Centre	WG	750	13.2	7.736	8.023	5.931		296.4			7.708	8.016	5.866	0.5482	292.3	1.875	12.2
U133	PCIB	Centre	WG	650	8.2	7.590	7.953	5.928	0.5471	289.7	1.889	25.7	7.619	8.008	5.991	0.5474	296.4	1.847	12.4
U148	PCIB	Centre	WG	750	13.6	7.747	8.016	5.998	0.5543	299.6	1.850	38.9	7.697	8.010	6.029	0.5548	299.9	1.850	12.3
U165	PCIB	Centre	AG	750	9.8	7.676	7.940	6.011	0.5515	294.6	1.872	36.9	7.735	8.004	6.004	0.5533	299.0	1.851	11.8
U166	PCIB	Centre	AG	750	13.4	7.707	7.967	6.029	0.5496	297.6	1.847	38.9	7.755	7.996	5.988	0.5505	298.1	1.847	11.7
U167	PCIB	Centre	AG	750	12.0	7.690	7.955	5.996	0.5472	295.0	1.855	38.2	7.733	8.017	5.949	0.5480	297.0	1.845	11.6
U191	PCIB	Edge	WG	750	23.4	8.042	8.362	6.071	0.5476	329.2	1.664	30.5	7.703	8.002	5.934	0.5473	294.8	1.857	12.7
U197	PCIB	Edge	AG	750	23.6	7.875	8.248	6.207	0.5435	326.3	1.666	30.7	7.676	7.993	5.911	0.5427	292.7	1.854	12.2
U199	PCIB	Edge	AG	750	21.4	7.801	8.160	6.190		318.7			7.682	7.986	5.950	0.5456	294.3	1.854	12.0
U223	PPEA	Centre	WG	650	12.1	7.614	7.864	11.664	1.0839	561.2	1.932	33.0	7.753	7.998	11.949	1.0849	594.9	1.824	13.5
U236	PPEA	Centre	AG	750	19.9	7.665	8.068	6.048	0.5352	303.4	1.764	31.9	7.691	7.995	5.919	0.5367	293.5	1.829	12.8
U237	PPEA	Centre	AG	750	21.7	7.834	8.314	6.246		331.2			7.693	7.994	5.939	0.5374	294.4	1.826	12.9
U238	PPEA	Centre	AG	750	22.4	7.882	8.401	6.303	0.5366	340.4	1.576	19.7	7.694	8.009	5.939	0.5386	295.3	1.824	12.9
U239	PPEA	Centre	AG	750	14.3	7.654	8.014	6.008	0.5349	298.2	1.794	32.1	7.693	8.005	5.943	0.5378	295.2	1.822	12.9
U240	PPEA	Centre	AG	750	17.7	7.591	7.945	5.917	0.5346	288.7	1.852	36.8	7.700	8.005	5.900	0.5358	293.3	1.827	12.9
U242	PPEA	Centre	AG	650	11.0	7.598	7.845	11.780	1.0861	564.0	1.926	29.4	7.761	7.989	11.989	1.0869	596.1	1.823	12.8
U252	PPEA	Centre	AG	750	18.8	7.725	8.037	12.135		607.7			7.754	7.987	11.986	1.0877	595.5	1.827	13.3
U256	PPEA	Centre	AG	750	9.7	7.510	7.861	5.962		284.8			7.636	7.980	6.028	0.5413	297.0	1.823	13.7
U257	PPEA	Centre	AG	750	13.4	7.529	7.877	5.984		287.1			7.655	7.991	6.029	0.5420	298.0	1.819	13.7
U258	PPEA	Centre	AG	750	12.8	7.535	7.874	5.969	0.5370	286.3	1.876	38.3	7.651	7.977	6.005	0.5374	296.0	1.816	13.8
U276	PPEA	Centre	WG	750	19.4	7.964	8.363	6.007		324.2			7.676	7.997	5.881	0.5298	291.4	1.818	13.6
U277	PPEA	Centre	WG	750	18.7	7.697	8.045	5.835	0.5305	292.2	1.816	36.3	7.688	8.002	5.897	0.5316	292.7	1.817	13.5
U278	PPEA	Centre	WG	750	21.6	7.988	8.379	6.166		334.3			7.677	7.995	6.023	0.5422	298.3	1.818	13.4
U279	PPEA	Centre	WG	750	22.2	7.962	8.350	6.044	0.5321	325.4	1.635	23.8	7.667	7.992	5.919	0.5333	292.8	1.822	13.6
U280	PPEA	Centre	WG	650	13.9	7.551	7.862	5.830	0.5368	279.3	1.922	35.9	7.664	7.991	5.982	0.5385	295.8	1.820	13.5
U285	PPEA	Centre	WG	750	9.9	7.548	7.874	5.878		282.2			7.649	7.996	5.998	0.5383	296.6	1.815	14.5
U286	PPEA	Centre	WG	750	13.0	7.589	7.917	5.861		284.5			7.639	7.984	5.978	0.5358	294.8	1.818	14.4
U287	PPEA	Centre	WG	750	13.1	7.621	7.952	5.908	0.5381	289.2	1.860		7.657	7.994	6.009	0.5391	297.2	1.814	14.6
U298	PPEA	Edge	WG	750	9.2	7.564	7.883	5.872	0.5402	282.6	1.911		7.648	7.993	6.008	0.5422	296.9	1.826	14.7
U299	PPEA	Edge	WG	750	13.1	7.617	7.942	5.888		287.7			7.640	7.981	6.011	0.5424	296.3	1.831	14.8
U306	PPEA	Edge	AG	750	11.2	7.496	7.837	5.914	0.5451	280.9	1.940		7.645	7.985	5.989	0.5460	295.5	1.848	14.4
U307	PPEA	Edge	AG	750	13.7	7.514	7.884	5.978		286.9			7.651	7.993	6.005	0.5476	296.8	1.845	14.5
U308	PPEA	Edge	AG	750	11.3	7.506	7.875	5.967		285.7			7.649	7.992	6.001	0.5449	296.6	1.837	14.4
U310	PPEA	Edge	WG	750	13.6	7.651	7.968	5.871	0.5359	288.9	1.855	41.2	7.681	7.995	5.990	0.5446	296.8	1.835	14.9
U314	PPEA	Edge	AG	750	10.3	7.519	7.869	5.936	0.5429	284.1	1.911	39.5	7.655	8.004	6.000	0.5441	297.3	1.830	14.2
U329	PPEA	Edge	WG	750	12.2	7.579	7.908	5.869	0.5455	284.1	1.920	40.9	7.634	7.980	6.008	0.5460	296.0	1.845	15.0
U330	PPEA	Edge	WG	750	10.8	7.582	7.896	5.867	0.5419	283.5	1.912	40.2	7.650	7.995	6.020	0.5458	297.7	1.833	15.1
U334	LPEB	Edge	WG	750	9.1	7.750	7.983	5.882	0.5612	291.9	1.922	29.7	7.799	8.010	6.011	0.5629	300.7	1.872	12.0
U344	LPEB	Edge	AG	750	11.5	7.654	7.891	6.024		292.0			7.760	7.969	6.048	0.5607	299.5	1.872	10.6
U354	LPEB	Centre	WG	750	13.2	7.775	8.028	5.870	0.5580	294.3	1.896		7.757	8.018	6.013	0.5605	300.6	1.865	11.9
U356	LPEB	Centre	WG	750	11.7	7.729	7.916	5.906		288.9			7.786	7.990	6.031	0.5573	300.3	1.856	11.3
U364	LPEB	Centre	AG	750	13.0	7.741	7.898	6.024	0.5558	293.8	1.892	31.9	7.751	7.982	6.035	0.5575	299.5	1.861	10.5
U366	LPEB	Centre	AG	650	6.6	7.690	7.924	5.980	0.5509	292.4	1.884	18.4	7.760	7.982	6.021	0.5527	298.9	1.849	10.1
U374	LPIB	--	AG	750	12.4	7.547	7.722	5.884	0.4005	274.0	1.462	8.7	7.758	7.999	6.029	0.4017	300.3	1.337	3.9
U384	LPIB	--	WG	750	13.0	7.521	7.827	5.750		273.1			7.767	8.027	6.008	0.4240	301.0	1.408	5.5

Table B.3 Measurement results of dimensions, mass, volume, density, and DYM for Toyo Tanso graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation							Pre irradiation						
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	x [mm]	d [mm]	l [mm]	m [g]	V [mm^3]	ρ [g/cm^3]	E [GPa]	x [mm]	d [mm]	l [mm]	m [g]	V [mm^3]	ρ [g/cm^3]	E [GPa]
T007	IG-110	Centre	AG	750	19.0	7.698	7.948	6.133	0.5182	301.4	1.719	26.4	7.719	7.987	5.968	0.5189	295.9	1.754	9.1
T011	IG-110	Centre	AG	750	23.4	7.917	8.182	6.514	0.5242	339.1	1.546	17.0	7.716	7.989	6.012	0.5236	298.2	1.756	8.8
T014	IG-110	Centre	AG	750	13.6	7.544	7.861	5.871	0.5146	281.1	1.831	30.8	7.728	8.003	5.934	0.5178	295.3	1.754	9.1
T016	IG-110	Centre	AG	650	6.2	7.646	7.925	5.932	0.5236	289.4	1.809	18.3	7.730	8.007	5.987	0.5249	298.2	1.760	9.0
T021	IG-110	Centre	WG	650	7.6	7.630	7.905	5.935	0.5265	288.1	1.828	21.7	7.710	7.988	6.025	0.5274	298.6	1.766	10.3
T022	IG-110	Centre	WG	750	17.4	7.690	8.027	5.850	0.5162	291.8	1.769	30.6	7.631	7.982	5.928	0.5169	292.1	1.769	10.5
T023	IG-110	Centre	WG	750	22.5	8.028	8.488	6.133	0.5199	339.7	1.530	17.0	7.636	7.984	5.948	0.5200	293.3	1.773	10.8
T038	IG-110	Edge	AG	750	8.7	7.641	7.824	5.931		283.5			7.760	7.988	5.995	0.5268	298.0	1.768	9.3
T040	IG-110	Edge	AG	750	11.4	7.660	7.828	5.946		284.7			7.763	7.997	5.990	0.5253	298.4	1.760	9.4
T041	IG-110	Edge	AG	750	22.1	7.989	8.042	6.137		311.4			7.715	7.979	5.907	0.5170	292.4	1.768	9.4
T048	IG-110	Edge	WG	750	21.5	7.878	8.167	5.844		302.7			7.706	7.991	5.895	0.5180	292.3	1.772	10.6
T052	IG-110	Edge	WG	750	11.5	7.685	7.896	5.844	0.5277	284.1	1.857	30.6	7.701	7.991	6.002	0.5287	297.5	1.777	10.7
T070	IG-430	Centre	AG	750	22.2	7.881	8.226	6.543	0.5302	342.7	1.547	18.0	7.698	7.983	5.982	0.5302	296.0	1.791	9.9
T072	IG-430	Centre	AG	650	6.3	7.701	7.898	6.001	0.5361	292.0	1.836	19.0	7.783	7.968	6.032	0.5376	299.0	1.798	10.4
T073	IG-430	Centre	AG	750	17.8	7.622	7.911	6.297	0.5300	305.9	1.732	28.5	7.701	7.984	5.987	0.5306	296.4	1.790	9.6
T081	IG-430	Centre	WG	750	21.9	8.278	8.459	6.181	0.5315	345.5	1.538	17.9	7.702	7.975	5.980	0.5314	295.6	1.798	10.9
T082	IG-430	Centre	WG	750	18.3	8.004	8.144	6.076		315.3			7.704	7.981	5.998	0.5349	296.8	1.802	11.0
T085	IG-430	Centre	WG	750	8.4	7.753	7.905	5.939		290.2			7.772	7.995	6.019	0.5379	299.8	1.794	11.1
T086	IG-430	Centre	WG	650	6.6	7.690	7.934	5.970	0.5349	292.5	1.829	19.7	7.774	7.990	6.025	0.5365	299.8	1.789	10.9
T098	IG-430	Edge	AG	750	13.2	7.575	7.905	5.983		289.5			7.675	8.001	5.974	0.5407	296.2	1.826	10.9
T099	IG-430	Edge	AG	750	19.5	7.727	8.139	6.331		323.1			7.695	7.985	6.002	0.5431	297.1	1.828	10.4
T100	IG-430	Edge	AG	750	11.2	7.578	7.920	6.019	0.5422	292.1	1.856	34.8	7.683	8.009	6.016	0.5437	298.9	1.819	10.9
T103	IG-430	Edge	WG	750	12.9	7.731	7.977	5.901	0.5448	292.2	1.864	36.6	7.640	8.011	6.013	0.5462	298.0	1.833	12.0
T104	IG-430	Edge	WG	750	21.0	8.024	8.253	6.069		322.1			7.695	7.985	6.012	0.5440	297.6	1.828	11.7

Table B.4 Measurement results of dimensions, mass, volume, density, and DYM for Toyo Tanso graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation							Pre irradiation						
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	x [mm]	d [mm]	l [mm]	m [g]	V [mm	ρ [g/cm	E [GPa]	x [mm]	d [mm]	l [mm]	m [g]	V [mm	ρ [g/cm	E [GPa]
T044	IG-110	Edge	AG	950	13.2	7.999	8.185	6.333	0.5402	331.3	1.631	20.7	7.768	7.990	5.978	0.5253	297.4	1.767	9.1
T055	IG-110	Edge	WG	950	12.2	7.860	8.258	6.013	0.5246	316.3	1.658	24.1	7.574	7.973	5.988	0.5191	293.4	1.769	10.5
T069	IG-430	Centre	AG	950	12.9	8.022	8.304	6.613	0.5431	354.4	1.532	18.4	7.767	7.976	6.072	0.5458	301.2	1.812	10.7
T074	IG-430	Centre	AG	850	3.7	7.708	7.964	6.000	0.5290	296.0	1.787	14.7	7.728	7.985	5.980	0.5299	296.6	1.787	8.9
T077	IG-430	Centre	AG	950	6.8	7.623	7.863	6.024	0.5282	289.9	1.822	28.3	7.733	7.999	5.952	0.5288	296.0	1.786	8.8
T078	IG-430	Centre	AG	950	4.7	7.682	7.876	6.063	0.5332	293.5	1.817	25.4	7.780	7.959	6.032	0.5348	298.4	1.792	9.2
T084	IG-430	Centre	WG	950	4.6	7.826	7.960	5.952	0.5375	295.1	1.821	25.9	7.786	8.004	6.002	0.5393	299.7	1.799	10.0
T087	IG-430	Centre	WG	950	12.0	7.782	8.296	6.122	0.5175	322.4	1.605	23.0	7.774	7.979	6.033	0.5339	299.6	1.782	11.2

Table B.5 Measurement results of dimensions, mass, volume, density, and DYM for SGL graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation							Pre irradiation						
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	x	d	l	m	V	ρ	E	x	d	l	m	V	ρ	E
						[mm]	[mm]	[mm]	[g]	[mm	[g/cm	[GPa]	[mm]	[mm]	[mm]	[g]	[mm	[g/cm	[GPa]
S036	NBG-10	Centre	WG	950	11.7	7.974	8.305	6.204	0.5354	331.6	1.615	21.3	7.704	7.992	6.027	0.5398	298.8	1.806	12.8
S062	NBG-10	Edge	WG	950	11.8	7.833	8.225	6.124	0.5360	319.7	1.677	28.2	7.687	7.987	6.030	0.5362	298.4	1.797	13.5
S077	NBG-10	Edge	AG	950	12.7	7.919	8.342	6.200	0.5250	332.4	1.580	20.3	7.977	7.996	6.008	0.5387	301.6	1.786	13.0
S102	NBG-25	Centre	AG	950	4.4	7.608	7.904	5.931		287.4			7.691	8.007	5.935	0.5340	294.9	1.811	9.8
S348	NBG-10	Edge	WG	950	13.4	8.258	8.670	6.474		375.6			7.687	7.997	5.994	0.5394	297.2	1.815	13.4
S350	NBG-10	Edge	WG	950	10.8	7.961	8.254	6.140	0.5290	324.8	1.629	22.4	7.700	8.004	6.016	0.5411	299.0	1.810	13.1
S352	NBG-10	Edge	WG	950	11.3	8.004	8.380	6.165	0.5311	334.6	1.587	19.1	7.691	7.990	6.055	0.5424	299.9	1.809	13.6
S354	NBG-10	Edge	WG	950	13.1	8.369	8.799	6.470		386.3			7.698	7.987	5.962	0.5355	295.3	1.814	13.3
S358	NBG-10	Edge	AG	950	12.6	7.926	8.398	6.389	0.5427	346.0	1.569	19.9	7.685	7.984	5.956	0.5470	294.5	1.857	13.1
S359	NBG-10	Edge	AG	950	12.4	7.953	8.399	6.464	0.5474	350.8	1.561	14.3	7.694	7.997	6.036	0.5543	299.4	1.851	13.5
S380	NBG-10	Centre	WG	850	7.8	7.626	7.910	5.907	0.5364	287.0	1.869	31.8	7.977	7.996	6.008	0.5387	301.6	1.786	13.1
S382	NBG-10	Centre	WG	950	11.0	7.887	8.194	6.138	0.5400	319.7	1.689	27.5	7.768	7.990	5.978	0.5253	297.4	1.767	13.2
S389	NBG-10	Centre	AG	950	13.9	8.134	8.670	6.638	0.5290	381.9	1.385	13.8	7.697	7.993	5.977	0.5375	296.3	1.814	12.7
S391	NBG-10	Centre	AG	850	7.9	7.577	7.882	5.961	0.5333	287.1	1.857	31.0	7.687	7.987	6.030	0.5362	298.4	1.797	12.3
S410	NBG-25	Edge	AG	950	7.1	7.600	8.148	6.014	0.5351	304.5	1.757	33.2	7.687	8.011	5.994	0.5375	298.0	1.804	9.7
S412	NBG-25	Edge	AG	950	5.9	7.597	7.900	6.011		291.0			7.677	8.007	6.005	0.5384	298.2	1.806	9.3
S414	NBG-25	Edge	AG	950	12.3	7.789	8.148	6.343	0.5347	325.6	1.642	27.6	7.683	7.989	6.017	0.5382	297.8	1.807	10.6
S416	NBG-25	Edge	WG	950	13.6	8.160	8.412	6.250	0.5371	344.3	1.560	23.5	7.693	7.995	6.021	0.5411	298.5	1.812	11.7
S417	NBG-25	Edge	WG	950	5.8	7.713	7.958	5.907		291.1			7.692	8.008	5.989	0.5389	297.7	1.810	10.6
S419	NBG-25	Edge	WG	950	7.1	7.746	7.966	5.893		291.4			7.704	8.006	5.982	0.5385	297.5	1.810	10.5
S420	NBG-25	Edge	WG	950	6.6	7.738	7.955	5.921	0.5391	292.1	1.846		7.703	8.002	6.014	0.5397	298.8	1.806	11.5
S438	NBG-25	Centre	AG	950	12.2	7.752	8.111	6.342	0.5387	322.6	1.670	28.0	7.783	7.992	6.014	0.5564	299.6	1.857	10.6
S446	NBG-25	Centre	WG	950	10.5	7.857	8.078	5.970	0.5366	303.6	1.767	33.1	7.702	7.986	5.952	0.5275	294.7	1.790	11.3
S448	NBG-25	Centre	WG	950	12.2	8.026	8.253	6.063	0.5361	321.8	1.666	28.8	7.688	7.986	6.046	0.5525	299.2	1.847	11.3
S462	NBG-18	Edge	WG	950	13.3	8.298	8.648	6.544	0.5467	379.2	1.442	16.0	7.691	7.983	6.005	0.5489	297.0	1.848	13.4
S463	NBG-18	Edge	WG	950	12.2	8.130	8.452	6.370	0.5417	352.9	1.535	17.4	7.687	7.997	6.027	0.5407	298.8	1.809	13.4
S464	NBG-18	Edge	WG	950	9.6	7.861	8.131	6.070	0.5462	312.0	1.751	27.6	7.696	7.997	6.013	0.5418	298.3	1.816	13.4
S470	NBG-18	Edge	AG	950	10.7	7.717	8.056	6.154	0.5398	309.1	1.746	31.1	7.639	7.979	5.982	0.5452	294.7	1.850	13.0
S472	NBG-18	Edge	AG	950	13.7	8.235	8.697	6.773		394.1			7.647	7.985	6.026	0.5481	297.4	1.843	12.5
S473	NBG-18	Edge	AG	950	13.0	8.052	8.549	6.574	0.5383	368.5	1.461	16.6	7.648	7.987	5.984	0.5370	295.4	1.818	12.6
S474	NBG-18	Edge	AG	950	10.6	7.759	8.134	6.207		317.2			7.641	7.979	5.964	0.5418	293.8	1.844	12.8
S475	NBG-18	Edge	AG	950	10.4	7.798	8.163	6.275	0.5440	323.2	1.683	21.6	7.688	7.994	6.005	0.5303	297.6	1.782	13.0
S506	NBG-18	Centre	WG	950	11.7	7.705	8.212	6.179	0.5447	318.9	1.708	27.7	7.697	7.981	6.038	0.5437	298.7	1.820	14.9
S510	NBG-18	Centre	WG	950	12.6	8.053	8.393	6.304		344.0			7.651	7.981	5.993	0.5542	295.6	1.875	15.3
S511	NBG-18	Centre	WG	950	10.3	7.847	8.115	6.059	0.5448	310.3	1.756	34.7	7.687	7.983	5.980	0.5515	295.7	1.865	14.9
S516	NBG-18	Centre	AG	950	12.6	7.921	8.304	6.380		339.8			7.639	7.978	5.978	0.5520	294.5	1.875	14.0
S517	NBG-18	Centre	AG	950	13.1	8.021	8.460	6.512		358.8			7.644	7.983	5.998	0.5527	295.8	1.868	13.8
S518	NBG-18	Centre	AG	850	7.6	7.554	7.875	5.949	0.5481	285.8	1.918	32.8	7.640	7.978	5.993	0.5514	295.2	1.868	13.9
S519	NBG-18	Centre	AG	950	11.5	7.833	8.228	6.396	0.5474	334.1	1.638	21.8	7.699	8.015	5.992	0.5621	298.3	1.884	13.6
S521	NBG-18	Centre	AG	850	7.2	7.566	7.886	5.960	0.5529	287.1	1.926	33.6	7.643	7.984	6.003	0.5554	296.1	1.876	14.3
S552	NBG-17	Edge	WG	950	11.4	8.061	8.431	6.334	0.5486	348.2	1.576	20.2	7.751	8.008	5.975	0.5614	298.0	1.884	13.2
S566	NBG-17	Edge	AG	950	6.8	7.676	7.956	6.017	0.5589	295.8	1.889		7.718	8.012	5.992	0.5604	298.5	1.877	14.1
S567	NBG-17	Edge	AG	950	6.6	7.666	7.938	6.005		294.0			7.716	8.008	5.996	0.5537	298.5	1.855	11.9
S577	NBG-17	Edge	WG	950	6.5	7.715	7.964	5.989		295.6			7.748	8.003	6.021	0.5564	300.0	1.855	12.3
S578	NBG-17	Edge	WG	950	6.7	7.701	7.990	5.988	0.5583	296.7	1.881		7.740	8.013	6.028	0.5598	300.8	1.861	14.0
S598	NBG-17	Centre	WG	950	11.7	8.104	8.381	6.244	0.5597	341.0	1.641	24.9	7.745	8.015	5.989	0.5620	299.0	1.880	14.3
S599	NBG-17	Centre	WG	950	13.7	8.389	8.716	6.464	0.5524	381.0	1.450	17.5	7.747	8.011	5.942	0.5576	296.5	1.881	14.3
S601	NBG-17	Centre	WG	950	11.8	8.168	8.410	6.288		346.4			7.745	8.015	5.997	0.5629	299.4	1.880	14.1
S606	NBG-17	Centre	WG	950	4.9	7.730	7.972	5.955		294.6			7.740	8.000	5.992	0.5601	298.2	1.878	13.4
S607	NBG-17	Centre	WG	950	6.8	7.739	7.977	6.010		297.7			7.744	8.002	6.028	0.5661	300.2	1.886	13.2
S608	NBG-17	Centre	AG	950	12.1	7.945	8.295	6.322	0.5597	336.7	1.662	26.2	7.719	8.015	5.973	0.5626	297.8	1.889	13.7
S611	NBG-17	Centre	AG	950	12.3	8.062	8.382	6.493		353.8			7.719	8.009	5.993	0.5611	298.4	1.880	13.6
S612	NBG-17	Centre	AG	850	7.4	7.659	7.949	5.994	0.5596	294.0	1.904	32.5	7.720	8.013	5.991	0.5623	298.5	1.884	13.3
S618	NBG-17	Centre	AG	950	4.5	7.645	7.961	5.979		293.7			7.697	8.013	5.992	0.5602	298.2	1.879	12.8
S620	NBG-17	Centre	AG	950	7.1	7.698	7.962	6.030	0.5583	297.2	1.879	36.1	7.728	8.004	5.997	0.5625	298.5	1.884	12.9
S621	NBG-17	Centre	AG	950	5.5	7.668	7.945	5.965		292.5			7.723	8.001	5.968	0.5581	296.8	1.880	12.6
S622	NBG-17	Centre	AG	950	5.8	7.675	7.949	5.968		293.0			7.730	8.011	5.965	0.5578	297.4	1.876	12.6
S624	NBG-17	Centre	WG	950	5.7	7.725	7.950	5.932		292.1			7.749	7.993	5.981	0.5595	297.4	1.881	13.2
S625	NBG-17	Centre	WG	950	5.4	7.730	7.949	5.960		293.5			7.748	7.994	5.996	0.5608	298.2	1.880	13.3
S644	NBG-10	Centre	WG	950	5.5	7.616	7.896	5.874		284.4			7.701	7.987	5.976	0.5343	296.0	1.805	12.1
S645	NBG-10	Centre	WG	950	6.6	7.634	7.911	5.895		286.6			7.693	7.983	5.979	0.5320	295.8	1.799	12.0
S646	NBG-10	Centre	WG	950	7.2	7.640	7.926	5.877	0.5334	286.6	1.861	35.9	7.716	7.997	5.980	0.5337	297.0	1.797	13.5
S647	NBG-10	Centre	WG	950	5.6	7.645	7.920	5.892		287.1			7.707	7.998	5.973	0.5312	296.6	1.791	12.0
S648	NBG-10	Centre	WG	950	6.8	7.635	7.917	5.901	0.5308	287.2	1.848		7.703	8.000	5.991	0.5311	297.5	1.785	13.1
S649	NBG-10	Centre	AG	950	5.4	7.593	7.885	5.917	0.5348	285.5	1.873		7.709	7.990	5.994	0.5352	297.2	1.801	13.2
S650	NBG-10	Centre	AG	950	6.5	7.582	7.891	5.948		287.1			7.706	7.985	5.994	0.5362	296.8	1.806	11.9
S651	NBG-10	Centre	AG	950	7.2	7.592	7.872	5.928	0.5359	285.3	1.878	34.3	7.710	7.980	5.994	0.5396	296.6	1.819	11.9
S652	NBG-10	Centre	AG	950	6.7	7.578	7.887	5.912	0.5358	285.1	1.879		7.707	7.978	5.970	0.5362	295.3	1.816	13.4
S653	NBG-10	Centre	AG	950	5.1	7.607	7.892	5.931		286.8			7.706	7.982	5.993	0.5319	296.6	1.793	11.9
S654	NBG-10	Edge	WG	950	6.3	7.651	7.923	5.877		286.7			7.710	7.993	5.984	0.5395	296.9	1.817	12.6
S657	NBG-10	Edge	WG	850	3.3	7.685	7.961	5.952	0.5347	293.1	1.824	18.5	7.708	7.980	5.986	0.5363	296.2	1.811	12.5
S658	NBG-10	Edge	WG	950	6.4	7.632	7.896	5.890		285.5			7.696	7.983	5.989	0.5384	296.3	1.817	12.5
S659	NBG-10	Edge	WG	950	7.2	7.583	7.891	5.955		287.4			7.700	7.989	5.975	0.5357	296.0	1.809	11.8
S660	NBG-10	Edge	AG	950	6.2	7.594	7.892	5.943		287.1			7.699	7.984	5.984	0.5402	296.2	1.824	12.1
S661	NBG-10	Edge	AG	950	7.2	7.607	7.901	5.966		289.0			7.712	7.983	5.988	0.5390	296.5	1.818	12.0
S662	NBG-10	Edge	AG	950	6.4	7.598	7.880	5.935		286.2			7.709	7.983	5.990	0.5401	296.7	1.821	12.2
S663	NBG-10	Edge	AG	850	3.5	7.664	7.957	5.965	0.5356	293.1	1.827	17.9	7.703	7.987	5.989	0.5359	296.7	1.806	11.9
S664	NBG-18	Centre	WG	950	5.7	7.611	7.905	5.921		287.1			7.694	7.978	5.993	0.5470	296.2	1.846	13.1
S665	NBG-18	Centre	WG	950	6.5	7.619	7.909	5.898		286.4			7.694	7.983	5.965	0.5408	295.1	1.833	13.0
S667	NBG-18	Centre	WG	950	6.5	7.605	7.900	5.898		285.6			7.697	7.989	5.973	0.5447	295.9	1.841	13.1
S668	NBG-18	Centre	WG	950	7.0	7.632	7.945	5.920		289.6			7.698	7.988	5.972	0.5455	295.8	1.844	13.2
S669	NBG-18	Centre	WG	850	3.6	7.651	7.953	5.950	0.5443	292.0	1.864	20.6	7.703	7.991	5.993	0.5449	297.1	1.834	13.0
S670	NBG-18	Centre	AG	950	5.6	7.595	7.876	5.950	0.5421	286.6	1.892		7.684	7.982	5.995	0.5426	296.3	1.831	14.3
S671	NBG-18	Centre	AG	950	6.6	7.659	7.900	5.974		290.2			7.683	7.978	5.985	0.5431	295.6	1.837	12.5
S672	NBG-18	Centre	AG	950	7.0	7.661	7.925	6.023	0.5409	294.1	1.839	38.1	7.704	7.990	5.994	0.5439	297.1	1.830	12.7
S673	NBG-18	Centre	AG	850	3.7	7.660	7.947	5.965	0.5450	292.4	1.864	19.0	7.700	7.991	5.991	0.5455	297.0	1.837	12.4
S674	NBG-18	Edge	WG	950	6.2	7.635	7.922	5.985		291.6			7.698	7.991	5.981	0.5429	296.4	1.831	12.6
S676	NBG-18	Edge	WG	950	5.9	7.638	7.899	5.917		287.0			7.701	7.989	5.986	0.5417	296.6	1.826	12.6
S677	NBG-18	Edge	WG	950	5.9	7.637	7.903	5.910		286.9			7.694	7.994	5.979	0.5415	296.4	1.827	12.5
S678	NBG-18	Edge	WG	950	5.7	7.633	7.898	5.906		286.4			7.693	7.994	5.983	0.5450	296.6	1.837	12.5
S679	NBG-18	Edge	WG	950	6.8	7.663	7.917	5.918		288.5			7.700	7.997	5.979	0.5446	296.7	1.835	12.9
S680	NBG-18	Edge	AG	950	6.1	7.625	7.902	5.966	0.5407	289.4	1.869		7.690	7.988	5.984	0.5421	296.2	1.830	13.3
S681	NBG-18	Edge	AG	950	6.8	7.612	7.898	5.969	0.5394	289.0	1.866		7.692	7.986	5.989	0.5400	296.4	1.822	12.1
S682	NBG-18	Edge	AG	950	5.8	7.611	7.881	5.952		287.3			7.700	7.982	5.986	0.5423	296.2	1.831	12.2
S683	NBG-18	Edge	AG	950	6.1	7.617	7.885	5.939	0.5402	286.9	1.883		7.703	7.987	5.984	0.5402	296.4	1.822	13.4

Table B.6 Measurement results of dimensions, mass, volume, density, and DYM for Graftech graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation							Pre irradiation						
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	x [mm]	d [mm]	l [mm]	m [g]	V [mm	ρ [g/cm	E [GPa]	x [mm]	d [mm]	l [mm]	m [g]	V [mm	ρ [g/cm	E [GPa]
U009	PCEA	Centre	WG	950	13.5	8.257	8.625	6.300		362.7			7.702	7.995	5.976	0.5357	296.5	1.807	11.5
U010	PCEA	Centre	WG	950	11.2	7.887	8.261	6.024	0.5313	317.7	1.672	24.5	7.698	7.988	5.972	0.5360	295.8	1.812	11.8
U011	PCEA	Centre	WG	950	10.8	7.808	8.182	5.999	0.5351	310.3	1.725	25.0	7.698	7.990	5.990	0.5378	296.8	1.812	11.5
U033	PCEA	Centre	AG	950	13.4	8.005	8.535	6.409	0.5345	357.3	1.496	12.2	7.683	7.991	5.876	0.5244	291.0	1.802	11.1
U034	PCEA	Centre	AG	950	11.2	7.710	8.164	6.211	0.5232	318.0	1.645	23.5	7.690	8.003	5.999	0.5355	297.8	1.798	11.0
U035	PCEA	Centre	AG	950	11.3	7.706	8.144	6.233	0.5359	317.9	1.686	20.7	7.700	7.999	6.002	0.5383	297.9	1.807	11.1
U036	PCEA	Centre	AG	950	9.8	7.558	7.942	6.030	0.5364	293.4	1.828	34.9	7.691	7.990	6.012	0.5381	297.8	1.807	11.0
U050	PCEA	Centre	WG	850	7.8	7.539	7.841	5.881	0.5351	280.4	1.909	28.4	7.657	7.985	6.010	0.5372	296.8	1.810	11.2
U074	PCEA	Edge	AG	950	12.1	7.697	8.123	6.302	0.5431	320.0	1.697	27.2	7.683	7.989	6.006	0.5446	297.3	1.832	11.4
U076	PCEA	Edge	AG	950	13.4	7.813	8.254	6.377		334.2			7.685	7.987	5.981	0.5431	295.9	1.835	11.6
U083	PCEA	Edge	WG	950	11.2	7.771	8.177	5.960	0.5415	307.2	1.763	32.2	7.706	8.006	5.963	0.5425	296.5	1.830	12.6
U084	PCEA	Edge	WG	950	13.3	8.025	8.600	6.233	0.5401	351.6	1.536	19.3	7.683	7.990	5.966	0.5410	295.3	1.832	12.4
U087	PCEA	Edge	WG	950	11.8	7.848	8.219	6.046	0.5436	315.7	1.722	30.6	7.707	7.977	5.996	0.5459	296.5	1.841	12.7
U089	PCEA	Edge	AG	950	10.7	7.615	8.018	6.072	0.5447	300.8	1.811	36.2	7.692	7.991	5.980	0.5460	296.3	1.843	11.8
U090	PCEA	Edge	AG	850	7.0	7.537	7.826	5.884	0.5432	279.7	1.942	28.3	7.701	7.995	5.970	0.5450	296.1	1.840	11.7
U103	PCEA	Edge	WG	850	7.8	7.540	7.864	5.811	0.5384	278.3	1.935	33.2	7.649	8.004	5.955	0.5401	294.9	1.831	12.3
U143	PCIB	Centre	WG	950	10.7	7.872	8.178	6.122	0.5543	317.7	1.745	33.7	7.678	7.996	6.038	0.5540	299.1	1.852	12.3
U146	PCIB	Centre	WG	950	12.4	7.979	8.302	6.228	0.5538	332.7	1.664	29.3	7.685	7.989	6.046	0.5552	299.3	1.855	12.4
U164	PCIB	Centre	AG	950	6.7	7.949	8.008	6.065	0.5493	305.1	1.800	33.1	7.739	8.000	6.029	0.5538	300.1	1.845	11.9
U171	PCIB	Centre	AG	950	10.3	7.745	8.097	6.141	0.5461	311.4	1.754	33.0	7.679	7.989	6.006	0.5505	297.2	1.852	11.7
U175	PCIB	Centre	AG	950	11.7	7.845	8.201	6.296	0.5505	327.5	1.681	29.8	7.687	7.985	6.036	0.5546	298.6	1.857	11.9
U183	PCIB	Edge	AG	950	6.9	7.678	8.003	6.085		301.9			7.671	8.000	6.004	0.5510	297.6	1.852	11.0
U184	PCIB	Edge	AG	950	6.0	7.672	7.993	6.068		300.4			7.686	8.008	6.017	0.5511	299.0	1.843	10.9
U189	PCIB	Edge	WG	950	5.9	7.734	8.030	5.973		298.9			7.684	8.005	5.992	0.5506	297.5	1.851	11.3
U201	PCIB	Edge	WG	950	13.3	8.120	8.457	6.215	0.5462	344.5	1.585	24.7	7.685	7.992	5.957	0.5471	295.0	1.854	12.3
U202	PCIB	Edge	WG	950	6.9	7.762	8.053	5.966	0.5462	300.3	1.819	33.1	7.675	8.002	5.972	0.5494	296.2	1.855	11.5
U203	PCIB	Edge	WG	950	6.6	7.749	8.047	5.976	0.5494	300.3	1.830		7.672	8.002	5.991	0.5493	297.1	1.849	12.6
U226	PPEA	Centre	WG	950	13.6	8.316	8.767	6.442	0.5307	381.3	1.392	14.8	7.638	7.976	5.978	0.5381	294.4	1.828	14.0
U227	PPEA	Centre	WG	950	13.1	8.147	8.655	6.328	0.5380	363.4	1.480	17.8	7.643	7.977	5.994	0.5408	295.3	1.831	14.0
U241	PPEA	Centre	AG	950	12.5	7.989	8.475	6.369	0.5292	351.1	1.507	17.4	7.697	8.010	5.904	0.5339	293.6	1.818	12.9
U248	PPEA	Centre	AG	950	13.3	8.049	8.638	6.690	0.5341	380.4	1.404	14.6	7.644	7.981	6.017	0.5418	296.6	1.827	13.3
U250	PPEA	Centre	AG	850	7.1	7.536	7.874	5.933	0.5356	284.6	1.882	31.8	7.643	7.978	5.998	0.5380	295.5	1.821	13.3
U284	PPEA	Centre	WG	950	10.5	7.847	8.222	6.076		317.4			7.641	7.985	5.987	0.5374	295.3	1.820	14.1
U295	PPEA	Edge	WG	950	10.5	7.838	8.189	6.016	0.5392	312.1	1.727	28.7	7.644	7.981	5.988	0.5412	295.2	1.833	14.2
U303	PPEA	Edge	AG	950	10.5	7.739	8.156	6.155	0.5397	315.3	1.712	27.1	7.699	7.995	5.908	0.5426	293.0	1.852	14.0
U305	PPEA	Edge	AG	850	7.7	7.573	7.877	5.905	0.5406	284.1	1.903	33.3	7.705	7.989	5.966	0.5428	295.7	1.836	13.8
U313	PPEA	Edge	WG	850	7.8	7.607	7.926	5.861	0.5409	285.3	1.896	35.4	7.676	7.995	5.980	0.5430	296.2	1.833	14.2
U338	LPEB	Edge	WG	950	4.8	7.762	7.978	5.942	0.5557	294.8	1.885	24.9	7.772	7.978	6.030	0.5576	299.3	1.863	10.9
U346	LPEB	Edge	AG	850	7.8	7.701	7.908	5.993	0.5527	292.3	1.891	25.0	7.755	7.984	6.029	0.5557	299.4	1.856	10.1
U348	LPEB	Edge	AG	950	4.6	7.658	7.927	6.011	0.5511	293.5	1.877	21.9	7.745	7.976	6.028	0.5537	298.7	1.854	9.3
U358	LPEB	Centre	WG	950	6.7	7.687	7.937	5.984	0.5574	293.3	1.901	27.9	7.781	7.974	6.030	0.5589	299.2	1.868	10.5
U359	LPEB	Centre	WG	950	7.0	7.760	8.009	5.907	0.5581	294.9	1.893	30.9	7.764	7.998	6.012	0.5597	299.5	1.869	11.6
U365	LPEB	Centre	AG	950	13.9	8.306	8.826	7.045	0.5544	420.8	1.317	9.1	7.768	7.981	6.028	0.5556	299.4	1.856	9.8
U367	LPEB	Centre	AG	950	13.3	8.461	8.715	6.908		408.6			7.761	7.981	6.026	0.5516	299.1	1.844	9.7
U368	LPEB	Centre	AG	950	7.0	7.702	7.908	6.027	0.5490	293.9	1.868	28.4	7.779	7.981	6.023	0.5506	299.3	1.840	10.1
U369	LPEB	Centre	AG	950	6.6	7.635	7.901	6.028		292.5			7.772	7.979	6.032	0.5507	299.5	1.839	8.7
U375	LPIB	--	AG	950	13.5	8.345	8.593	6.623	0.4014	380.9	1.054	3.4	7.766	7.997	6.029	0.4065	300.3	1.354	4.3
U385	LPIB	--	WG	950	13.4	8.083	8.823	6.387	0.4193	374.8	1.119	4.1	7.771	8.018	6.030	0.4227	301.7	1.401	5.6
U394	PPEA	Centre	WG	950	4.8	7.605	7.907	5.874		284.9			7.665	7.980	5.979	0.5373	295.1	1.821	13.2
U395	PPEA	Centre	WG	950	6.0	7.630	7.919	5.881	0.5364	286.2	1.874		7.672	7.978	5.988	0.5367	295.5	1.816	14.5
U396	PPEA	Centre	WG	950	6.9	7.639	7.920	5.877	0.5355	286.3	1.870		7.690	7.972	5.985	0.5356	295.4	1.813	14.5
U397	PPEA	Centre	WG	950	6.5								7.690	7.973	5.989	0.5397	295.6	1.826	13.2
U398	PPEA	Centre	WG	950	6.3	7.631	7.906	5.829		283.0			7.689	7.973	5.934	0.5343	293.0	1.824	13.2
U399	PPEA	Centre	AG	950	4.7	7.568	7.868	5.917	0.5377	284.1	1.893		7.688	7.975	5.983	0.5380	295.5	1.821	14.2
U400	PPEA	Centre	AG	950	5.7	7.563	7.866	5.941		285.0			7.690	7.982	5.989	0.5376	296.2	1.815	12.6
U401	PPEA	Centre	AG	950	6.9	7.561	7.886	5.943	0.5364	286.2	1.874		7.701	7.991	5.988	0.5365	296.8	1.807	13.8
U402	PPEA	Centre	AG	950	6.5	7.560	7.878	5.941		285.7			7.689	7.986	5.986	0.5380	296.2	1.816	12.5
U403	PPEA	Centre	AG	950	5.4	7.580	7.882	5.928		285.6			7.697	7.988	5.979	0.5380	296.1	1.817	12.4
U404	PPEA	Edge	WG	950	6.1	7.643	7.931	5.874		286.8			7.685	7.984	5.983	0.5446	295.9	1.840	13.7
U405	PPEA	Edge	WG	950	7.1	7.664	7.944	5.882	0.5403	288.3	1.874	39.1	7.694	7.986	5.989	0.5442	296.5	1.836	13.6
U406	PPEA	Edge	WG	950	6.1	7.630	7.912	5.873		285.5			7.688	7.982	5.988	0.5453	296.1	1.841	13.7
U407	PPEA	Edge	WG	850	3.4	7.669	7.959	5.944	0.5441	292.3	1.861	20.3	7.696	7.981	5.984	0.5452	296.0	1.842	13.8
U408	PPEA	Edge	WG	950	5.9	7.632	7.905	5.867		284.8			7.698	7.982	5.977	0.5435	295.7	1.838	13.5
U409	PPEA	Edge	AG	950	6.0	7.581	7.883	5.954		286.9			7.707	7.984	5.985	0.5385	296.4	1.817	12.5
U410	PPEA	Edge	AG	950	7.1	7.571	7.889	5.967		287.7			7.690	7.966	5.966	0.5369	294.2	1.825	12.6
U411	PPEA	Edge	AG	950	6.0	7.563	7.853	5.927		283.7			7.698	7.969	5.979	0.5401	295.1	1.830	13.0
U412	PPEA	Edge	AG	850	3.5	7.655	7.934	5.958	0.5421	291.3	1.861	19.5	7.705	7.971	5.981	0.5424	295.4	1.836	13.0
U413	PPEA	Edge	AG	950	6.2	7.570	7.864	5.931		284.6			7.708	7.973	5.963	0.5436	294.7	1.845	13.0
U414	PCEA	Centre	WG	950	5.4	7.584	7.848	5.827		278.9			7.708	7.980	5.970	0.5332	295.4	1.805	11.0
U415	PCEA	Centre	WG	950	6.4	7.596	7.861	5.844		280.7			7.701	7.974	5.971	0.5316	295.0	1.802	10.9
U416	PCEA	Centre	WG	950	6.8	7.586	7.833	5.834		278.5			7.702	7.956	5.978	0.5298	294.4	1.800	10.7
U417	PCEA	Centre	WG	950	5.1	7.591	7.830	5.856		279.5			7.703	7.957	5.980	0.5306	294.5	1.802	10.9
U418	PCEA	Centre	WG	950	6.3	7.588	7.829	5.842		278.7			7.700	7.958	5.983	0.5303	294.7	1.800	10.8
U419	PCEA	Centre	AG	950	5.3	7.531	7.827	5.879		279.4			7.694	7.979	5.973	0.5345	295.3	1.810	10.7
U420	PCEA	Centre	AG	950	6.4	7.534	7.815	5.908		280.1			7.688	7.977	5.971	0.5304	295.0	1.798	10.4
U421	PCEA	Centre	AG	950	6.9	7.546	7.831	5.875	0.5330	279.7	1.906		7.715	7.992	5.960	0.5332	295.7	1.803	11.7
U422	PCEA	Centre	AG	950	6.3	7.552	7.842	5.882		280.7			7.713	7.993	5.974	0.5355	296.4	1.806	10.5
U423	PCEA	Centre	AG	950	5.3	7.570	7.858	5.878		281.7			7.718	7.994	5.966	0.5361	296.2	1.810	10.5
U424	PCEA	Edge	WG	950	6.2	7.620	7.870	5.846		281.7			7.718	7.979	5.977	0.5348	295.9	1.807	11.3
U425	PCEA	Edge	WG	950	7.0	7.624	7.881	5.862		283.1			7.717	7.981	5.982	0.5332	296.2	1.800	11.2
U427	PCEA	Edge	WG	850	3.4	7.654	7.934	5.922	0.5339	289.5	1.844	17.8	7.703	7.983	5.974	0.5345	295.7	1.807	11.3
U428	PCEA	Edge	WG	950	7.0	7.605	7.871	5.828	0.5311	280.6	1.893	37.5	7.702	7.983	5.970	0.5346	295.5	1.809	11.2
U429	PCEA	Edge	AG	950	6.1	7.553	7.814	5.916		280.8			7.707	7.974	5.974	0.5330	295.3	1.805	10.3
U430	PCEA	Edge	AG	950	6.8	7.544	7.817	5.914		280.8			7.708	7.971	5.981	0.5331	295.5	1.804	10.2
U431	PCEA	Edge	AG	950	6.9	7.542	7.841	5.928	0.5358	282.6	1.896		7.705	7.983	5.973	0.5360	295.7	1.813	11.5
U432	PCEA	Edge	AG	850	3.5	7.642	7.923	5.925	0.5351	288.9	1.852	16.4	7.704	7.982	5.971	0.5354	295.5	1.812	10.4

Appendix C CTE data of INNOGRAPH-1B and INNOGRAPH-2B

Table C.1 CTE measurement results for SGL graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation CTE [10^{-6} K^{-1}]				Pre irradiation CTE [10^{-6} K^{-1}]		
Specimen code	Grade	Location	Orientation	Tirr [°C]	dpa	30-120°C	30-200°C	30-650°C	30-750°C	30-120°C	30-200°C	30-750°C
S030	NBG-10	Centre	WG	750	20.1	2.19	2.37		3.27	1.88	2.03	3.21
S031	NBG-10	Centre	WG	750	16.9	1.70	1.95		3.15	4.03	4.22	5.23
S033	NBG-10	Centre	WG	750	22.2	1.70	2.00		3.30	4.03	4.22	5.23
S035	NBG-10	Centre	WG	650	7.3	3.72	3.92	4.76		4.19	4.31	5.21
S038	NBG-10	Centre	WG	750	11.9	1.81	2.06		3.38	4.16	4.28	5.22
S041	NBG-10	Centre	AG	750	21.1	2.02	2.32		3.50	2.15	2.33	3.53
S042	NBG-10	Centre	AG	750	22.3	2.04	2.28		3.44	4.19	4.38	5.32
S043	NBG-10	Centre	AG	750	17.3	2.42	2.65		3.75	4.19	4.38	5.32
S051	NBG-10	Centre	AG	750	12.8	1.87	2.11		3.35	4.27	4.39	5.35
S064	NBG-10	Edge	WG	750	10.4	2.30	2.49		3.55	4.09	4.35	5.39
S065	NBG-10	Edge	WG	750	21.7	1.79	2.04		3.19	1.58	1.82	3.14
S066	NBG-10	Edge	WG	750	12.7	1.92	2.12		3.22	4.00	4.23	5.23
S067	NBG-10	Edge	WG	750	18.6	1.83	2.10		3.31	2.08	2.24	3.45
S068	NBG-10	Edge	WG	750	13.5	1.79	2.01		2.92	3.48	3.79	4.90
S074	NBG-10	Edge	AG	750	19.0	2.07	2.23		3.15	2.31	2.46	3.67
S076	NBG-10	Edge	AG	750	20.4	2.16	2.38		3.48	2.23	2.49	3.80
S078	NBG-10	Edge	AG	750	11.2	2.11	2.32		3.48	4.29	4.50	5.49
S081	NBG-10	Edge	AG	750	10.1	1.89	2.08		3.27	4.26	4.47	5.49
S094	NBG-25	Centre	AG	750	19.4	1.67	1.92		3.16	2.93	3.05	4.11
S101	NBG-25	Centre	AG	750	13.1	2.00	2.17		3.10	3.98	4.28	5.31
S103	NBG-25	Centre	AG	750	12.5	2.04	2.29		3.45	4.23	4.36	5.32
S107	NBG-25	Centre	WG	750	11.0	2.21	2.39		3.38	3.31	3.51	4.62
S108	NBG-25	Centre	WG	750	13.2	1.86	2.06		3.09	3.47	3.65	4.66
S111	NBG-25	Centre	WG	750	15.2	1.86	2.09		3.15	2.33	2.54	3.66
S115	NBG-25	Centre	WG	750	12.0	1.67	1.92		3.08	3.61	3.72	4.66
S130	NBG-25	Edge	AG	750	21.8	2.00	2.16		3.02	2.01	2.23	3.41
S139	NBG-25	Edge	WG	750	23.0	1.55	1.78		2.87	1.86	2.01	3.21
S140	NBG-25	Edge	WG	750	20.4	1.68	1.94		3.13	2.18	2.32	3.49
S466	NBG-18	Edge	WG	650	7.0	3.88	4.06	4.93		4.40	4.51	5.47
S468	NBG-18	Edge	WG	750	13.1	1.70	1.95		3.17	4.38	4.52	5.47
S469	NBG-18	Edge	WG	750	10.4	1.92	2.14		3.22	4.23	4.50	5.52
S476	NBG-18	Edge	AG	750	10.0	2.06	2.31		3.72	4.33	4.55	5.53
S478	NBG-18	Edge	AG	750	12.6	2.07	2.36		3.63	4.47	4.65	5.65
S479	NBG-18	Edge	AG	750	9.2	2.03	2.37		3.83	4.26	4.57	5.64
S512	NBG-18	Centre	WG	750	11.1	1.95	2.18		3.46	3.89	4.13	5.20
S514	NBG-18	Centre	WG	750	12.0	2.04	2.28		3.45	4.11	4.32	5.34
S523	NBG-18	Centre	AG	750	13.2	1.72	1.97		3.29	4.47	4.64	5.63
S524	NBG-18	Centre	AG	750	11.4	2.00	2.22		3.32	4.48	4.68	5.66
S568	NBG-17	Edge	AG	750	13.2	2.03	2.25		3.29	4.13	4.50	5.59
S571	NBG-17	Edge	AG	750	10.8	2.07	2.31		3.46	4.21	4.57	5.64
S579	NBG-17	Edge	WG	750	13.2	1.80	2.05		3.35	3.95	4.31	5.38
S580	NBG-17	Edge	WG	750	12.1	1.90	2.12		3.13	3.69	4.16	5.28
S604	NBG-17	Centre	WG	650	7.2	3.77	3.96	4.89		4.24	4.45	5.44
S617	NBG-17	Centre	AG	750	12.6	1.98	2.24		3.42	4.29	4.60	5.62
S619	NBG-17	Centre	AG	750	8.3	2.19	2.47		3.77	1.63	2.77	3.44
S626	NBG-17	Centre	WG	750	9.4	2.05	2.32		3.58	4.06	4.36	5.42

Table C.2 CTE measurement results for Graftech graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation CTE [10^{-6} K^{-1}]				Pre irradiation CTE [10^{-6} K^{-1}]		
Specimen code	Grade	Location	Orientation	Tirr [°C]	dpa	30-120°C	30-200°C	30-650°C	30-750°C	30-120°C	30-200°C	30-750°C
U004	PCEA	Centre	WG	750	17.8	1.54	1.81		3.03	3.61	3.82	4.85
U005	PCEA	Centre	WG	750	22.4	1.50	1.83		3.15	3.47	3.69	4.66
U006	PCEA	Centre	WG	750	18.7	1.76	2.03		3.19	2.27	2.50	3.86
U021	PCEA	Centre	AG	750	17.0	1.75	2.05		3.39	3.83	4.05	5.02
U023	PCEA	Centre	AG	750	22.2	2.16	2.43		3.63	3.83	4.04	5.05
U024	PCEA	Centre	AG	750	17.9	1.80	2.18		3.44	2.67	2.90	4.22
U042	PCEA	Centre	AG	750	13.2	2.07	2.37		3.64	3.58	3.93	5.03
U043	PCEA	Centre	AG	750	11.6	2.25	2.49		3.63	3.81	4.04	5.11
U053	PCEA	Centre	WG	750	11.8	2.00	2.28		3.52	3.53	3.70	4.72
U070	PCEA	Edge	WG	750	20.6	1.97	2.12		3.02	2.36	2.60	3.90
U077	PCEA	Edge	AG	750	20.5	1.82	2.08		3.15	4.13	4.35	5.28
U093	PCEA	Edge	AG	650	7.9	4.04	4.21	5.12		4.30	4.37	5.34
U104	PCEA	Edge	WG	750	13.0	1.95	2.24		3.50	3.66	3.88	4.87
U114	PCIB	Centre	AG	750	21.1	1.63	1.91		3.06	1.81	2.08	3.28
U123	PCIB	Centre	WG	750	18.2	1.83	2.01		2.93	3.64	3.57	4.44
U124	PCIB	Centre	WG	750	20.2	1.92	2.14		3.09	1.86	2.16	3.42
U148	PCIB	Centre	WG	750	13.6	1.83	2.05		3.11	4.09	4.15	5.07
U165	PCIB	Centre	AG	750	9.8	2.20	2.38		3.35	4.14	4.34	5.25
U166	PCIB	Centre	AG	750	13.4	1.97	2.15		3.08	4.01	4.32	5.35
U167	PCIB	Centre	AG	750	12.0	1.92	2.13		3.20	4.46	4.57	5.52
U191	PCIB	Edge	WG	750	23.4	1.71	1.98		2.93	1.77	2.07	3.29
U197	PCIB	Edge	AG	750	23.6	1.83	2.04		3.07	1.97	2.26	3.44
U236	PPEA	Centre	AG	750	19.9	1.67	1.94		3.16	4.71	4.89	5.81
U238	PPEA	Centre	AG	750	22.4	1.92	2.16		3.32	4.60	4.80	5.78
U239	PPEA	Centre	AG	750	14.3	2.04	2.26		3.26	2.30	2.63	3.87
U240	PPEA	Centre	AG	750	17.7	1.75	2.03		3.25	2.34	2.61	3.82
U242	PPEA	Centre	AG	650	11.0	2.63	2.82	3.82		4.81	4.88	5.82
U258	PPEA	Centre	AG	750	12.8	1.93	2.13		3.21	4.56	4.74	5.76
U277	PPEA	Centre	WG	750	18.7	1.45	1.77		2.99	4.34	4.53	5.48
U279	PPEA	Centre	WG	750	22.2	1.34	1.67		3.10	4.31	4.48	5.45
U310	PPEA	Edge	WG	750	13.6	1.68	1.94		3.15	0.00	0.00	0.00
U314	PPEA	Edge	AG	750	10.3	2.02	2.22		3.28	4.53	4.71	5.75
U329	PPEA	Edge	WG	750	12.2	1.74	1.97		3.19	4.27	4.44	5.47
U330	PPEA	Edge	WG	750	10.8	1.67	1.96		3.22	4.06	4.41	5.49
U334	LPEB	Edge	WG	750	9.1	2.14	2.37		3.70	3.24	3.98	4.50
U364	LPEB	Centre	AG	750	13.0	2.83	2.98		4.00	4.07	4.21	5.11
U374	LPIB	--	AG	750	12.4	2.76	3.07		4.55	4.12	4.27	5.20

Table C.3 CTE measurement results for SGL graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation CTE [10^{-6} K^{-1}]					Pre irradiation CTE [10^{-6} K^{-1}]			
Specimen code	Grade	Location	Orientation	Tirr [°C]	dpa	30-120°C	30-200°C	30-750°C	30-850°C	30-950°C	30-120°C	30-200°C	30-750°C	30-950°C
S036	NBG-10	Centre	WG	950	11.7	1.93	2.15	3.24		3.52	4.05	4.17	5.08	5.34
S062	NBG-10	Edge	WG	950	11.8	1.98	2.24	3.42		3.71	4.27	4.35	5.34	5.58
S077	NBG-10	Edge	AG	950	12.7	2.42	2.70	3.80		4.04	5.22	5.11	6.12	6.42
S350	NBG-10	Edge	WG	950	10.8	2.21	2.50	3.58		3.82	3.61	3.89	5.12	5.40
S352	NBG-10	Edge	WG	950	11.3	2.34	2.63	3.82		4.14	3.76	4.01	5.19	5.46
S358	NBG-10	Edge	AG	950	12.6	2.7	3.1	4.3		4.5	3.91	4.32	5.27	5.52
S359	NBG-10	Edge	AG	950	12.4	2.7	2.8	3.9		4.1	4.38	4.55	5.14	5.72
S380	NBG-10	Centre	WG	850	7.8	1.79	1.98	3.10	3.25		4.15	4.37	5.19	5.32
S382	NBG-10	Centre	WG	950	11	2.0	2.2	3.3		3.6	3.93	4.25	5.25	5.48
S389	NBG-10	Centre	AG	950	13.9	2.69	2.99	4.10		4.36	4.22	4.45	5.41	5.64
S391	NBG-10	Centre	AG	850	7.9	1.69	1.92	3.28	3.45		5.06	4.92	5.84	6.00
S410	NBG-25	Edge	AG	950	7.1	1.64	1.86	3.00		3.27	3.74	4.09	5.22	5.45
S414	NBG-25	Edge	AG	950	12.3	1.22	1.38	2.35		2.55	3.94	4.02	5.06	5.28
S416	NBG-25	Edge	WG	950	13.6	1.08	1.30	2.33		2.54	3.63	3.74	4.68	4.91
S438	NBG-25	Centre	AG	950	12.2	1.83	1.97	2.83		3.02	3.93	4.19	5.18	5.39
S446	NBG-25	Centre	WG	950	10.5	1.2	1.5	2.7		3.0	3.50	3.58	4.56	4.78
S448	NBG-25	Centre	WG	950	12.2	1.07	1.32	2.47		2.71	4.11	4.04	4.68	4.85
S462	NBG-18	Edge	WG	950	13.3	2.10	2.27	3.30		3.64	4.33	4.49	5.40	5.64
S463	NBG-18	Edge	WG	950	12.2	1.8	2.0	3.2		3.5	4.29	4.47	5.46	5.69
S464	NBG-18	Edge	WG	950	9.6	2.08	2.37	3.63		3.90	3.87	4.28	5.32	5.57
S470	NBG-18	Edge	AG	950	10.7	0.91	1.23	2.63		2.89	4.64	4.74	5.65	5.92
S473	NBG-18	Edge	AG	950	13	2.02	2.30	3.26		3.50	4.40	4.62	5.61	5.84
S475	NBG-18	Edge	AG	950	10.4	2.40	2.68	3.85		4.09	5.39	5.21	6.14	6.42
S506	NBG-18	Centre	WG	950	11.7	1.9	2.1	3.2		3.4	4.29	4.40	5.34	5.62
S511	NBG-18	Centre	WG	950	10.3	1.40	1.60	2.66		2.93	5.06	4.93	5.87	6.16
S518	NBG-18	Centre	AG	850	7.6	2.22	2.39	3.36	3.49		4.55	4.71	5.67	5.81
S519	NBG-18	Centre	AG	950	11.5	1.7	2.0	3.4		3.7	4.44	4.56	5.45	5.71
S552	NBG-17	Edge	WG	950	11.4	2.0	2.2	3.4		3.7	4.49	4.53	5.48	5.69
S598	NBG-17	Centre	WG	950	11.7	2.15	2.35	3.31		3.52	4.55	4.60	5.52	5.75
S599	NBG-17	Centre	WG	950	13.7	1.35	1.60	2.63		2.91	4.55	4.58	5.54	5.77
S608	NBG-17	Centre	AG	950	12.1	1.84	2.09	3.25		3.54	4.82	4.86	5.80	6.02
S612	NBG-17	Centre	AG	850	7.4	2.18	2.42	3.67	3.83		4.86	4.89	5.83	5.95
S620	NBG-17	Centre	AG	950	7.1	1.79	2.02	3.21		3.46	4.57	4.74	5.72	5.96
S646	NBG-10	Centre	WG	950	7.2	1.57	1.84	3.22		3.54	3.57	3.97	5.30	5.63
S651	NBG-10	Centre	AG	950	7.2	1.69	1.94	3.21		3.47	3.90	4.27	5.51	5.82
S657	NBG-10	Edge	WG	850	3.3	3.19	3.41	4.42	4.54		3.59	3.96	5.24	5.57
S672	NBG-18	Centre	AG	950	7	1.70	1.92	3.03		3.31	4.58	4.74	5.82	6.06
S673	NBG-18	Centre	AG	850	3.7	3.39	3.58	4.70	4.84		4.58	4.74	5.82	6.06

Table C.4 CTE measurement results for Toyo Tanso graphite grades irradiated at 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation CTE [10^{-6} K^{-1}]					Pre irradiation CTE [10^{-6} K^{-1}]			
Specimen code	Grade	Location	Orientation	Tirr [°C]	dpa	30-120°C	30-200°C	30-750°C	30-850°C	30-950°C	30-120°C	30-200°C	30-750°C	30-950°C
T044	IG-110	Edge	AG	950	13.2	2.07	2.28	3.38		3.62	3.61	3.74	4.70	4.90
T087	IG-430	Centre	WG	950	12	1.77	1.96	3.05		3.31	3.78	3.92	4.82	5.09

Table C.5 CTE measurement results for Graftech graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation CTE [10^{-6} K^{-1}]					Pre irradiation CTE [10^{-6} K^{-1}]			
Specimen code	Grade	Location	Orientation	Tirr [°C]	dpa	30-120°C	30-200°C	30-750°C	30-850°C	30-950°C	30-120°C	30-200°C	30-750°C	30-950°C
U010	PCEA	Centre	WG	950	11.2	1.2	1.5	2.8		3.0	3.30	3.73	4.73	4.98
U011	PCEA	Centre	WG	950	10.8	1.85	2.17	3.33		3.56	3.32	3.75	4.63	4.91
U033	PCEA	Centre	AG	950	13.4	2.2	2.4	3.6		3.9	3.30	3.73	4.73	4.98
U034	PCEA	Centre	AG	950	11.2	2.10	2.37	3.77		4.03	3.80	4.01	4.95	5.16
U035	PCEA	Centre	AG	950	11.3	1.9	2.0	3.0		3.2	3.59	3.93	4.92	5.18
U036	PCEA	Centre	AG	950	9.8	1.90	2.13	3.19		3.41	3.59	3.93	4.92	5.18
U050	PCEA	Centre	WG	850	7.8	2.13	2.35	3.53	3.69		3.58	3.77	4.81	4.96
U074	PCEA	Edge	AG	950	12.1	2.4	2.7	3.9		4.2	3.78	4.02	4.99	5.24
U083	PCEA	Edge	WG	950	11.2	1.5	1.8	3.0		3.3	3.43	3.76	4.72	4.97
U084	PCEA	Edge	WG	950	13.3	2.19	2.55	3.80		4.14	3.32	3.72	4.70	4.95
U087	PCEA	Edge	WG	950	11.8	1.23	1.48	2.71		3.02	3.36	3.79	4.76	4.99
U089	PCEA	Edge	AG	950	10.7	1.81	2.07	3.30		3.56	3.73	4.00	5.11	5.37
U090	PCEA	Edge	AG	850	7	2.79	3.01	4.26	4.42		2.97	3.53	5.11	5.19
U143	PCIB	Centre	WG	950	10.7	1.54	1.75	2.90		3.16	3.63	3.97	5.00	5.22
U146	PCIB	Centre	WG	950	12.4	1.34	1.54	2.67		2.93	3.86	4.05	5.02	5.21
U164	PCIB	Centre	AG	950	6.7	1.86	2.07	3.09		3.33	4.07	4.29	5.33	5.55
U171	PCIB	Centre	AG	950	10.3	1.68	1.89	3.02		3.27	3.88	4.24	5.26	5.49
U175	PCIB	Centre	AG	950	11.7	1.27	1.46	2.49		2.69	3.78	3.98	5.20	5.43
U201	PCIB	Edge	WG	950	13.3	1.15	1.26	2.20		2.45	3.54	3.95	4.95	5.18
U202	PCIB	Edge	WG	950	6.9	1.57	1.81	2.89		3.11	3.52	3.94	5.14	5.41
U226	PPEA	Centre	WG	950	13.6	1.90	2.18	3.36		3.66	4.30	4.48	5.41	5.66
U227	PPEA	Centre	WG	950	13.1	1.5	1.7	3.0		3.3	4.10	4.24	5.21	5.44
U241	PPEA	Centre	AG	950	12.5	1.74	1.94	2.94		3.18	4.61	4.78	5.70	5.95
U248	PPEA	Centre	AG	950	13.3	2.28	2.54	3.56		3.79	4.67	4.82	5.74	5.98
U250	PPEA	Centre	AG	850	7.1	1.56	1.69	2.98	3.17		4.69	4.85	5.75	5.87
U295	PPEA	Edge	WG	950	10.5	2.03	2.34	3.60		3.86	4.28	4.41	5.36	5.62
U303	PPEA	Edge	AG	950	10.5	2.2	2.4	3.4		3.7	4.70	4.90	5.86	6.10
U305	PPEA	Edge	AG	850	7.7	1.85	2.15	3.51	3.67		4.77	4.92	5.84	5.96
U313	PPEA	Edge	WG	850	7.8	1.76	1.95	3.03	3.17		4.23	4.41	5.36	5.49
U358	LPEB	Centre	WG	950	6.7	2.04	2.27	3.54		3.85	3.98	4.03	4.91	5.12
U368	LPEB	Centre	AG	950	7	2.17	2.35	3.58		3.87	4.00	4.15	5.09	5.31
U375	LPIB	--	AG	950	13.5	3.88	4.10	5.16		5.37	4.68	4.82	5.78	6.08
U405	PPEA	Edge	WG	950	7.1	1.54	1.77	2.99		3.26	3.85	4.23	5.51	5.79
U407	PPEA	Edge	WG	850	3.4	3.44	3.63	4.63	4.77		3.83	4.22	5.48	5.77
U427	PCEA	Edge	WG	850	3.4	3.36	3.56	4.60	4.74		3.13	3.53	4.87	5.18
U428	PCEA	Edge	WG	950	7	1.91	2.17	3.38		3.64	3.13	3.53	4.87	5.18

Appendix D Thermal diffusivity and conductivity for INNOGRAPH-1B and INNOGRAPH-2B

Table D.1 Thermal diffusivity measurement results for all graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation Thermal diffusivity [mm^2 s^{-1}]										Pre irradiation Thermal diffusivity [mm^2 s^{-1}]							
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	25°C	100°C	200°C	300°C	400°C	500°C	600°C	650°C	700°C	750°C	27°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C
S030	NBG-10	Centre	WG	750	20.1	12.7	11.5	10.1	9.2	8.4	7.9	7.5		7.1	7.1	109.4	81.5	56.9	42.5	34.6	29.5	25.0	21.9
S031	NBG-10	Centre	WG	750	16.9	15.1	13.5	11.8	10.6	9.7	9.0	8.5		8.1	7.9	106.6	79.7	56.1	42.5	34.8	29.0	25.2	22.5
S033	NBG-10	Centre	WG	750	22.2	11.5	10.5	9.2	8.3	7.7	7.3	6.9		6.7	6.6	106.6	79.7	56.1	42.5	34.8	29.0	25.2	22.5
S035	NBG-10	Centre	WG	650	7.3	23.2	20.2	17.2	15.1	13.4	12.3	11.5	11.2			116.8	82.9	58.7	44.1	35.7	30.6	26.9	23.7
S041	NBG-10	Centre	AG	750	21.1	13.2	11.7	10.2	9.2	8.4	7.9	7.4		7.0	6.9	104.3	79.7	55.0	41.3	34.9	29.3	25.3	22.5
S042	NBG-10	Centre	AG	750	22.3	10.9	9.7	8.6	7.8	7.1	6.8	6.5		6.1	6.0	104.9	79.7	55.7	42.7	35.1	29.8	25.5	23.0
S043	NBG-10	Centre	AG	750	17.3	11.7	10.3	9.1	8.2	7.5	7.1	6.8		6.5	6.3	104.9	79.7	55.7	42.7	35.1	29.8	25.5	23.0
S051	NBG-10	Centre	AG	750	12.8	19.4	17.2	15.0	13.3	12.1	11.1	10.3		9.8	9.6	109.3	79.0	54.5	40.4	32.8	27.9	24.4	21.5
S064	NBG-10	Edge	WG	750	10.4	22.4	19.9	17.1	15.2	13.6	12.5	11.7		11.0	10.7	114.1	85.1	60.9	46.6	37.8	32.3	28.0	24.5
S068	NBG-10	Edge	WG	750	13.5	17.9	16.1	14.0	12.5	11.3	10.5	9.8		9.3	9.1	117.6	86.2	61.8	46.6	37.9	32.4	27.9	24.8
S069	NBG-10	Edge	WG	750	18.4	16.5	14.6	12.9	11.5	10.5	9.8	9.1		8.8	8.6	108.0	79.1	56.6	42.3	35.3	29.7	25.4	22.6
S074	NBG-10	Edge	AG	750	19.0	15.7	13.9	12.2	11.0	10.0	9.4	8.8		8.4	8.2	104.5	76.4	55.2	41.2	34.2	28.5	24.7	21.6
S078	NBG-10	Edge	AG	750	11.2	21.1	18.6	16.0	14.1	12.7	11.6	10.8		10.2	9.9	103.1	79.9	56.8	41.8	33.8	28.9	24.8	22.3
S107	NBG-25	Centre	WG	750	11.0	20.3	17.9	15.6	13.8	12.4	11.5	10.7		10.2	9.9	102.6	75.9	54.5	40.9	33.5	28.5	25.3	22.5
S111	NBG-25	Centre	WG	750	15.2	12.7	11.2	9.9	8.9	8.3	7.7	7.3		7.0	6.9	98.8	74.7	53.9	41.8	34.5	29.3	25.3	22.6
S466	NBG-18	Edge	WG	650	7.0	22.7	20.1	16.9	14.8	13.2	11.7	10.8	10.7			99.2	73.5	52.5	38.7	31.4	27.3	23.7	20.9
S468	NBG-18	Edge	WG	750	13.1	16.9	15.1	13.2	11.9	10.9	10.1	9.5		9.0	8.9	103.2	76.4	55.2	42.2	34.7	29.1	25.6	22.6
S469	NBG-18	Edge	WG	750	10.4	17.9	15.6	13.7	12.1	11.0	10.3	9.6		9.0	8.7	106.4	76.6	55.6	42.9	34.7	29.5	25.6	22.8
S476	NBG-18	Edge	AG	750	10.0	20.6	18.0	15.6	13.8	12.4	11.5	10.7		10.1	9.8	97.1	72.1	50.6	37.9	30.5	26.2	22.9	20.3
S478	NBG-18	Edge	AG	750	12.6	16.6	14.8	12.9	11.5	10.5	9.8	9.2		8.8	8.6	101.2	74.0	51.2	37.7	30.9	26.5	23.1	20.0
S479	NBG-18	Edge	AG	750	9.2	18.3	16.2	14.0	12.5	11.4	10.5	9.9		9.4	9.2	103.2	76.4	55.2	42.2	34.7	29.1	25.6	22.6
S512	NBG-18	Centre	WG	750	11.1	20.7	18.3	15.9	14.1	12.7	11.7	10.9		10.2	10.0	102.4	76.2	53.7	40.0	32.0	27.6	24.5	21.6
S514	NBG-18	Centre	WG	750	12.0	17.2	15.4	13.4	12.0	10.9	10.1	9.5		9.0	8.7	104.7	76.8	53.8	39.7	32.2	27.9	24.5	21.5
S523	NBG-18	Centre	AG	750	13.2	16.8	14.9	13.0	11.7	10.7	10.0	9.4		9.0	8.8	104.3	76.2	51.7	39.6	32.2	27.9	24.2	21.5
S524	NBG-18	Centre	AG	750	11.4	17.2	15.4	13.4	12.0	11.0	10.2	9.6		9.1	9.0	100.3	74.4	51.6	38.3	31.0	26.9	23.7	21.0
S568	NBG-17	Edge	AG	750	13.2	16.1	14.4	12.5	11.2	10.3	9.6	9.0		8.5	8.3	99.3	69.4	48.3	34.6	27.6	24.6	21.5	19.4
S571	NBG-17	Edge	AG	750	10.8	16.9	15.1	13.0	11.5	10.4	9.7	9.1		8.6	8.4	99.3	69.4	48.3	34.6	27.6	24.6	21.5	19.4
S579	NBG-17	Edge	WG	750	13.2	16.3	14.7	12.9	11.6	10.6	9.8	9.3		8.8	8.6	101.4	73.4	52.0	39.2	31.6	27.0	23.5	20.8
S580	NBG-17	Edge	WG	750	12.1	16.0	14.6	12.8	11.5	10.5	9.9	9.2		8.7	8.6	101.6	71.4	48.5	35.2	28.0	24.9	22.2	19.7
S604	NBG-17	Centre	WG	650	7.2	22.9	20.0	17.0	14.9	13.4	12.1	11.4	10.9			106.7	77.5	53.9	39.9	32.1	27.7	24.4	21.0
S617	NBG-17	Centre	AG	750	12.6	16.2	14.3	12.5	11.2	10.2	9.4	8.9		8.5	8.2	93.6	73.1	51.5	38.5	31.3	27.0	23.7	20.8
S619	NBG-17	Centre	AG	750	8.3	18.4	16.3	14.1	12.5	11.2	10.4	9.6		9.1	8.9	100.3	75.6	54.0	40.9	33.4	28.9	25.2	22.4
S626	NBG-17	Centre	WG	750	9.4	18.4	16.3	14.1	12.6	11.5	10.6	10.0		9.3	9.3	105.2	78.3	57.1	43.7	35.6	30.3	26.4	23.3
U004	PCEA	Centre	WG	750	17.8	18.3	16.6	14.5	13.0	11.9	11.0	10.4		9.8	9.6	118.2	89.1	63.3	47.4	38.1	32.7	28.2	24.9
U005	PCEA	Centre	WG	750	22.4	13.0	11.8	10.5	9.5	8.7	8.1	7.7		7.3	7.2	120.3	90.1	64.2	48.3	39.3	32.6	28.6	24.9
U021	PCEA	Centre	AG	750	17.0	19.0	17.1	14.9	13.4	12.2	11.3	10.5		10.0	9.8	115.1	89.1	63.2	47.0	39.2	33.2	28.3	25.4
U023	PCEA	Centre	AG	750	22.2	13.0	11.6	10.3	9.3	8.6	8.1	7.7		7.3	7.2	120.9	88.4	62.9	47.5	39.7	32.6	28.6	25.5
U024	PCEA	Centre	AG	750	17.9	15.5	13.6	11.9	10.7	9.8	9.2	8.7		8.3	8.2	115.1	88.4	62.6	46.3	38.8	32.6	27.8	25.0
U042	PCEA	Centre	AG	750	13.2	21.0	18.4	16.0	14.2	12.7	11.8	11.0		10.4	10.2	130.7	94.5	66.1	50.8	40.5	34.5	30.1	26.1
U043	PCEA	Centre	AG	750	11.6	21.3	18.8	16.3	14.4	13.1	12.2	11.4		10.7	10.4	124.5	91.6	63.5	47.0	37.6	32.2	27.5	24.1
U053	PCEA	Centre	WG	750	11.8	21.1	18.6	16.1	14.2	12.8	11.9	11.0		10.4	10.1	137.7	101.1	72.7	55.5	44.4	37.7	32.6	28.8
U070	PCEA	Edge	WG	750	20.6	16.4	14.8	13.1	11.7	10.7	10.0	9.5		9.1	8.8	125.8	96.1	67.7	51.2	41.9	35.3	30.3	26.6
U077	PCEA	Edge	AG	750	20.5	16.5	14.6	12.8	11.5	10.6	9.8	9.2		8.8	8.6	118.9	90.2	64.0	47.6	40.1	33.2	28.4	25.2
U081	PCEA	Edge	AG	750	19.3	15.1	13.7	12.0	10.9	10.0	9.3	8.8		8.5	8.3	116.5	90.0	62.7	47.5	39.3	32.6	28.1	25.2
U093	PCEA	Edge	AG	650	7.9	25.4	22.1	18.7	16.3	14.4	13.3	12.4	11.9			124.7	90.5	63.2	47.7	37.8	31.8	27.9	24.7
U104	PCEA	Edge	WG	750	13.0	23.3	20.7	17.9	15.9	14.3	13.2	12.4		11.6	11.3	131.9	95.4	66.2	50.7	41.2	34.6	30.2	26.6
U114	PCIB	Centre	AG	750	21.1	11.2	9.9	8.7	7.8	7.1	6.7	6.4		6.1	6.0	88.8	67.7	49.4	37.6	32.0	27.1	23.7	20.8
U165	PCIB	Centre	AG	750	9.8	16.6	14.7	12.9	11.4	10.5	9.8	9.2		8.7	8.6	86.7	64.9	47.9	36.4	29.6	25.6	22.6	20.1
U166	PCIB	Centre	AG	750	13.4	15.4	14.1	12.2	11.0	9.9	9.4	8.7		8.3	8.2	90.0	68.3	50.3	39.4	32.5	27.6	24.0	21.6
U236	PPEA	Centre	AG	750	19.9	13.0	11.7	10.3	9.3	8.5	8.0	7.5		7.3	7.1	93.4	70.6	49.6	38.1	33.1	27.5	23.9	21.9
U239	PPEA	Centre	AG	750	14.3	13.0	11.6	10.1	9.0	8.1	7.7	7.4		7.0	6.8	92.6	70.5	51.9	38.7	32.6	27.6	23.8	21.8
U258	PPEA	Centre	AG	750	12.8	16.9	14.7	12.8	11.6	10.6	9.9	9.3		8.8	8.6	100.8	73.0	52.3	39.3	31.9	27.6	24.7	21.2
U277	PPEA	Centre	WG	750	18.7	15.0	13.4	11.8	10.6	9.7	9.1	8.6		8.3	8.1	97.9	74.3	53.3	40.1	33.6	28.0	24.7	22.3
U310	PPEA	Edge	WG	750	13.6	16.5	14.9	13.0	11.6	10.6	9.9	9.2		8.7	8.6	104.9	79.0	57.1	44.3	36.1	30.7	26.7	23.8
U329	PPEA	Edge	WG	750	12.2	19.6	17.7	15.3	13.6	12.4	11.4	10.7		10.1	9.9	102.9	76.2	54.8	40.4	32.8	28.6	25.2	22.3
U334	LPEB	Edge	WG	750	9.1	22.0	19.7	17.0	15.1	13.5	12.3	11.6		10.8	10.6	145.0	102.4	72.4	54.2	42.7	36.0	31.6	27.8
U364	LPEB	Centre	AG	750	13.0	20.9	18.4	15.9	14.1	12.5	11.3	10.3		9.9	9.6	130.1	94.0	64.6	49.0	39.7	32.7	28.7	25.1
U374	LPIB	--	AG	750	12.4	13.2	11.8	10.2	9.1	8.3	7.7	7.2		6.8	6.7	77.3	56.9	40.0	30.3	24.6	21.0	18.0	16.0

Table D.2 Thermal conductivity measurement results for all graphite grades irradiated at 650°C and 750°C in the INNOGRAPH-1B experiment

Sample						Post irradiation Thermal conductivity [W m^{-1} K^{-1}]										Pre irradiation Thermal conductivity [W m^{-1} K^{-1}]							
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	25°C	100°C	200°C	300°C	400°C	500°C	600°C	650°C	700°C	750°C	27°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C
S030	NBG-10	Centre	WG	750	20.1	15.4	17.6	19.6	20.9	21.3	21.8	21.9		21.7	21.9	141.8	132.3	116.8	102.4	93.1	86.1	77.2	70.6
S031	NBG-10	Centre	WG	750	16.9	19.3	21.9	24.2	25.5	25.9	26.1	26.0		26.1	25.9	137.4	128.6	114.6	101.6	93.2	83.9	77.6	72.3
S033	NBG-10	Centre	WG	750	22.2	13.7	15.9	17.6	18.6	19.2	19.7	19.6		20.0	20.1	137.4	128.6	114.6	101.6	93.2	83.9	77.6	72.3
S035	NBG-10	Centre	WG	650	7.3	30.6	33.7	36.2	37.2	36.8	36.5	36.3	36.3			146.9	131.4	117.6	103.6	93.7	87.1	81.0	74.6
S041	NBG-10	Centre	AG	750	21.1	16.2	18.3	20.1	21.2	21.7	22.0	21.8		21.7	21.6	134.3	128.6	112.1	98.8	93.2	84.7	77.6	72.2
S042	NBG-10	Centre	AG	750	22.3	12.8	14.5	16.0	17.0	17.4	18.1	18.2		18.0	18.0	135.6	129.0	114.1	102.5	94.1	86.5	78.5	74.1
S043	NBG-10	Centre	AG	750	17.3	14.4	15.9	17.8	18.8	19.3	19.8	19.9		19.8	19.6	135.6	129.0	114.1	102.5	94.1	86.5	78.5	74.1
S051	NBG-10	Centre	AG	750	12.8	26.2	29.2	32.2	33.4	34.0	33.9	33.4		33.3	33.2	140.0	127.5	111.3	96.8	87.6	80.7	74.9	69.1
S064	NBG-10	Edge	WG	750	10.4	30.2	33.9	36.8	38.2	38.4	38.1	37.9		37.3	36.9	147.3	138.5	125.2	112.3	101.8	94.1	86.6	79.3
S068	NBG-10	Edge	WG	750	13.5	24.0	27.1	29.9	31.1	31.5	31.7	31.5		31.2	30.9	152.2	140.6	127.5	112.6	102.4	94.9	86.5	80.5
S069	NBG-10	Edge	WG	750	18.4	21.4	23.9	26.6	27.8	28.5	28.7	28.3		28.7	28.4	140.3	128.8	116.4	102.0	95.0	86.7	78.6	73.3
S074	NBG-10	Edge	AG	750	19.0	20.4	22.9	25.4	26.7	27.2	27.6	27.5		27.5	27.4	136.2	124.8	113.9	99.9	92.4	83.6	76.8	70.2
S078	NBG-10	Edge	AG	750	11.2	28.4	31.6	34.2	35.6	35.6	35.4	34.9		34.6	34.0	133.2	129.1	116.2	100.2	90.4	83.7	76.3	71.8
S107	NBG-25	Centre	WG	750	11.0	27.3	30.4	33.3	34.6	34.9	34.9	34.6		34.2	33.9	131.9	123.0	111.5	98.1	89.7	82.6	78.0	72.4
S111	NBG-25	Centre	WG	750	15.2	16.2	18.0	20.0	21.3	22.1	22.2	22.5		22.4	22.3	128.3	121.5	110.8	100.8	93.0	85.4	78.4	73.1
S466	NBG-18	Edge	WG	650	7.0	30.2	33.7	36.0	36.8	36.7	35.4	34.5	35.1			128.3	120.0	108.4	93.6	84.9	79.7	73.6	67.9
S468	NBG-18	Edge	WG	750	13.1	22.4	25.4	28.0	29.5	30.1	30.3	30.2		29.9	30.2	134.4	125.3	114.5	102.5	94.1	85.4	79.9	73.8
S469	NBG-18	Edge	WG	750	10.4	23.8	26.2	29.1	30.3	30.5	31.0	30.6		30.3	29.7	137.0	124.4	114.2	103.2	93.3	85.8	79.2	73.5
S476	NBG-18	Edge	AG	750	10.0	27.6	30.5	33.3	34.5	34.8	34.7	34.3		33.9	33.4	124.2	116.3	103.2	90.7	81.6	75.7	70.3	65.1
S478	NBG-18	Edge	AG	750	12.6	21.9	24.7	27.2	28.5	29.2	29.5	29.1		29.3	29.1	130.9	120.6	105.5	91.1	83.4	77.6	71.6	65.0
S479	NBG-18	Edge	AG	750	9.2	24.8	27.6	30.2	31.5	32.1	32.2	32.0		31.9	31.7	134.4	125.3	114.5	102.5	94.1	85.4	79.9	73.8
S512	NBG-18	Centre	WG	750	11.1	28.5	31.9	34.9	36.2	36.5	36.4	35.8		35.2	35.2	136.4	126.9	113.1	98.8	88.3	82.6	77.7	71.5
S514	NBG-18	Centre	WG	750	12.0	23.3	26.3	28.9	30.3	30.7	31.0	30.8		30.6	30.1	138.7	128.4	113.7	98.4	89.1	83.6	77.8	71.4
S523	NBG-18	Centre	AG	750	13.2	22.8	25.5	28.1	29.6	30.2	30.5	30.3		30.3	30.4	137.5	126.6	108.6	97.5	88.6	83.2	76.4	71.2
S524	NBG-18	Centre	AG	750	11.4	23.5	26.6	29.3	30.7	31.4	31.4	31.4		31.3	31.3	133.4	124.7	109.2	95.2	86.1	80.8	75.4	70.0
S568	NBG-17	Edge	AG	750	13.2	21.4	24.1	26.6	27.9	28.6	28.8	28.8		28.4	28.3	133.0	116.8	102.7	86.4	76.9	74.2	68.8	65.0
S571	NBG-17	Edge	AG	750	10.8	22.6	25.5	27.9	28.9	29.2	29.5	29.1		29.0	28.6	133.0	116.8	102.7	86.4	76.9	74.2	68.8	65.0
S579	NBG-17	Edge	WG	750	13.2	21.7	24.6	27.2	28.6	29.2	29.4	29.4		29.1	29.2	132.3	120.6	108.1	95.5	86.0	79.7	73.5	68.1
S580	NBG-17	Edge	WG	750	12.1	21.4	24.5	27.2	28.7	29.1	29.7	29.5		29.0	29.2	134.7	118.9	102.2	87.0	77.2	74.5	70.2	65.2
S604	NBG-17	Centre	WG	650	7.2	31.3	34.5	37.2	38.1	38.3	37.5	37.5	36.7			142.8	130.8	114.9	99.9	89.8	84.0	78.2	70.4
S617	NBG-17	Centre	AG	750	12.6	21.6	23.9	26.4	27.8	28.3	28.4	28.2		28.5	27.9	125.2	123.2	109.7	96.1	87.2	81.6	75.9	69.6
S619	NBG-17	Centre	AG	750	8.3	25.0	27.9	30.6	31.7	31.7	31.9	31.3		30.9	31.0	133.1	126.9	114.7	101.7	92.9	86.9	80.4	74.8
S626	NBG-17	Centre	WG	750	9.4	24.9	27.7	30.4	31.8	32.4	32.4	32.4		31.7	32.1	139.9	131.1	120.7	108.2	98.3	90.6	83.4	77.2
U004	PCEA	Centre	WG	750	17.8	24.2	27.7	30.6	32.1	32.8	32.7	32.9		32.5	32.3	153.3	144.8	129.9	114.2	102.4	95.2	87.2	80.5
U005	PCEA	Centre	WG	750	22.4	16.0	18.3	20.5	21.6	22.2	22.5	22.5		22.4	22.6	159.0	155.3	142.0	124.0	110.8	97.8	89.9	81.1
U021	PCEA	Centre	AG	750	17.0	25.4	28.9	31.8	33.4	34.1	34.1	33.7		33.5	33.4	148.1	143.7	128.9	112.5	104.7	96.2	86.9	81.5
U023	PCEA	Centre	AG	750	22.2	15.5	17.6	19.7	20.8	21.4	21.9	22.0		21.9	21.8	156.3	143.1	128.8	113.9	106.6	94.7	88.0	82.0
U024	PCEA	Centre	AG	750	17.9	19.7	21.8	24.2	25.4	26.1	26.5	26.7		26.4	26.7	148.2	142.6	127.6	110.6	103.6	94.3	85.2	80.2
U042	PCEA	Centre	AG	750	13.2	28.5	31.5	34.6	36.1	36.0	36.2	35.7		35.5	35.2	167.5	152.9	135.0	121.7	108.5	99.9	92.5	84.0
U043	PCEA	Centre	AG	750	11.6	29.0	32.3	35.4	36.7	37.2	37.4	37.2		36.4	36.0	159.6	148.1	129.7	112.7	100.5	93.4	84.7	77.4
U053	PCEA	Centre	WG	750	11.8	28.6	31.7	34.8	36.1	36.3	36.4	35.8		35.3	35.0	176.2	163.0	148.3	132.6	118.6	108.9	99.9	92.3
U070	PCEA	Edge	WG	750	20.6	21.1	24.0	26.7	28.0	28.7	29.1	29.3		29.1	28.9	165.0	157.8	140.5	124.7	113.9	104.1	94.8	87.0
U077	PCEA	Edge	AG	750	20.5	21.5	24.0	26.6	28.0	28.6	28.8	28.6		28.5	28.5	153.7	146.1	131.0	114.2	107.5	96.5	87.6	81.2
U081	PCEA	Edge	AG	750	19.3	19.4	22.2	24.7	26.1	26.8	27.1	27.1		27.4	27.2	152.3	147.4	129.9	115.4	106.6	95.9	87.5	82.1
U093	PCEA	Edge	AG	650	7.9	34.7	38.1	40.7	41.6	41.2	41.0	40.5	39.9			162.6	148.8	131.5	116.4	103.0	93.9	87.3	80.7
U104	PCEA	Edge	WG	750	13.0	32.2	36.1	39.4	41.0	41.3	41.2	40.9		40.2	39.9	171.2	156.2	136.9	123.0	111.6	101.5	94.0	86.6
U114	PCIB	Centre	AG	750	21.1	13.9	15.4	17.0	18.0	18.3	18.7	19.0		18.9	18.9	118.0	112.6	103.9	92.7	88.3	80.8	75.0	68.7
U165	PCIB	Centre	AG	750	9.8	22.0	24.6	27.2	28.4	29.1	29.3	29.4		29.0	29.0	113.8	107.4	100.2	89.3	81.0	76.0	71.2	66.1
U166	PCIB	Centre	AG	750	13.4	20.2	23.2	25.5	27.0	27.2	27.9	27.3		27.3	27.5	118.1	112.8	105.0	96.5	88.7	81.7	75.3	71.1
U236	PPEA	Centre	AG	750	19.9	16.3	18.6	20.6	21.8	22.2	22.7	22.6		22.9	22.6	121.9	115.4	102.6	92.2	89.5	80.5	74.5	71.3
U239	PPEA	Centre	AG	750	14.3	16.5	18.5	20.4	21.5	21.5	22.0	22.5		22.2	22.0	120.6	114.9	107.0	93.6	88.0	80.9	74.0	70.7
U258	PPEA	Centre	AG	750	12.8	22.5	24.7	27.1	28.8	29.5	29.6	29.6		29.4	29.2	129.7	118.6	107.2	94.6	85.7	80.2	76.1	68.4
U277	PPEA	Centre	WG	750	18.7	19.3	21.9	24.3	25.6	26.2	26.6	26.6		26.6	26.7	126.9	120.7	109.6	96.5	90.4	81.5	76.5	72.2
U310	PPEA	Edge	WG	750	13.6	21.7	24.8	27.3	28.5	29.0	29.3	29.1		28.8	28.7	137.0	129.7	118.4	107.7	98.0	90.2	83.4	77.5
U329	PPEA	Edge	WG	750	12.2	26.7	30.4	33.3	34.7	35.3	35.2	35.0		34.4	34.5	134.6	125.7	114.2	98.9	89.4	84.5	79.1	73.0
U334	LPEB	Edge	WG	750	9.1	30.0	33.9	37.0	38.4	38.5	37.9	38.0		37.0	36.9	192.4	171.3	153.2	134.4	118.4	107.9	100.5	92.6
U364	LPEB	Centre	AG	750	13.0	28.0	31.2	34.0	35.3	35.0	34.4	33.0		33.4	32.9	171.7	156.4	135.9	120.9	109.4	97.6	90.8	82.9
U374	LPIB	--	AG	750	12.4	13.7	15.4	16.9	17.6	17.9	17.9	18.0		17.8	17.8	73.3	68.1	60.5	53.6	48.6	45.0	40.9	38.1

Table D.3 Thermal diffusivity measurement results for all graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation Thermal diffusivity [mm² s⁻¹]												Pre irradiation Thermal diffusivity [mm² s⁻¹]										
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	25°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	850°C	900°C	950°C	25°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	950°C
S380	NBG-10	Centre	WG	850	7.8	30.1	26.1	21.9	18.8	16.6	14.9	13.9	12.8	12.2	11.8			113.9	85.9	60.5	46.2	37.5	31.7	27.3	24.6	21.9	20.0	19.2
S382	NBG-10	Centre	WG	950	11	16.9	14.9	12.9	11.4	10.4	9.5	8.9	8.5	8.2		7.9	7.5	115.6	86.2	61.1	46.3	37.5	32.0	27.6	24.6	22.0	20.4	19.4
S438	NBG-25	Centre	AG	950	12.2	10.1	9.0	8.0	7.1	6.7	6.2	5.9	5.6	5.5		5.2	5.0	97.5	73.4	52.5	40.8	33.8	28.4	24.5	22.2	20.2	18.2	17.3
S446	NBG-25	Centre	WG	950	10.5	12.6	11.5	10.1	9.1	8.4	7.9	7.5	7.2	7.0		6.7	6.7	103.0	77.6	56.0	44.0	35.9	30.2	26.5	23.4	20.9	19.4	18.6
S464	NBG-18	Edge	WG	950	9.6	13.4	12.1	10.7	9.6	8.8	8.2	7.8	7.4	7.2		7.0	6.9	109.2	79.7	56.7	44.0	36.3	30.7	26.9	23.5	21.3	19.5	18.7
S475	NBG-18	Edge	AG	950	10.4	12.7	11.4	10.0	9.0	8.4	7.8	7.5	7.1	6.9		6.6	6.5	104.6	75.5	53.1	40.4	32.6	28.0	24.2	21.6	19.4	17.6	17.0
S518	NBG-18	Centre	AG	850	7.6	27.5	23.9	20.0	17.3	15.3	13.8	12.7	11.8	11.1	10.7			106.4	79.4	56.5	43.2	35.7	29.9	26.2	23.3	20.8	19.1	18.3
S646	NBG-10	Centre	WG	950	7.2	26.1	22.2	19.0	16.6	14.7	13.5	12.4	11.6	11.0		10.5	10.1	115.3	84.9	60.8	46.7	38.4	32.1	27.9	24.6	22.2	19.9	19.2
S657	NBG-10	Edge	WG	850	3.3	34.4	29.1	24.1	20.5	18.0	16.2	14.7	13.6	12.9	12.5			109.4	81.5	56.9	42.5	34.6	29.5	25.0	21.9			
S673	NBG-18	Centre	AG	850	3.7	31.6	27.0	22.5	19.1	16.5	15.1	13.8	12.6	11.9	11.5			106.4	79.4	56.5	43.2	35.7	29.9	26.2	23.3	20.8	19.1	18.3
S681	NBG-18	Edge	AG	950	6.8	22.5	19.8	17.0	15.0	13.4	12.2	11.4	10.7	10.1		9.8	9.7	104.4	75.9	53.2	39.1	32.3	28.0	24.6	21.7	19.7	17.6	17.0
T044	IG-110	Edge	AG	950	13.2	9.1	8.3	7.3	6.7	6.1	5.7	5.4	5.2	4.8		4.7	4.5	98.0	72.0	51.8	40.1	33.0	27.6	24.0	21.4	19.3	17.5	16.9
U011	PCEA	Centre	WG	950	10.8	16.8	14.7	12.8	11.5	10.4	9.6	9.1	8.7	8.2		8.0	7.8	129.9	97.9	69.4	52.4	42.2	35.8	30.6	27.5	24.5	22.0	21.2
U034	PCEA	Centre	AG	950	11.2	13.5	12.0	10.6	9.5	8.7	8.2	7.7	7.5	7.1		7.0	6.6	123.2	92.8	65.1	48.7	39.5	33.1	29.0	25.4	22.8	20.8	19.4
U035	PCEA	Centre	AG	950	11.3	14.4	12.7	11.2	10.0	9.2	8.5	8.0	7.7	7.1		7.0	6.6	128.5	93.9	67.4	50.5	40.9	34.8	30.2	26.5	23.9	21.8	20.8
U036	PCEA	Centre	AG	950	9.8	24.8	22.4	19.1	16.7	15.0	13.7	12.6	11.8	11.2		10.7	10.4	128.3	93.6	66.8	50.4	41.3	34.9	30.0	26.3	23.7	21.5	20.7
U050	PCEA	Centre	WG	850	7.8	35.0	30.0	25.0	21.3	18.7	16.9	15.1	14.3	13.4	13.1			131.4	96.9	68.6	51.7	42.1	35.7	30.7	27.1	24.3	22.3	21.0
U074	PCEA	Edge	AG	950	12.1	18.4	16.2	14.1	12.5	11.3	10.4	9.7	9.2	8.8		8.3	8.0	126.4	92.7	66.1	49.9	40.3	34.4	29.6	26.2	23.7	21.6	20.5
U083	PCEA	Edge	WG	950	11.2	21.8	19.6	16.7	14.7	13.2	12.1	11.2	10.5	10.0		9.5	9.1	137.8	100.2	70.7	54.1	43.7	36.8	32.0	28.4	25.5	23.1	21.8
U089	PCEA	Edge	AG	950	10.7	23.9	20.7	17.7	15.6	14.0	12.8	11.8	11.1	10.5		10.1	9.4	124.4	92.4	65.7	49.6	40.4	34.2	30.1	26.3	23.3	21.5	20.6
U143	PCIB	Centre	WG	950	10.7	10.5	9.5	8.5	7.7	7.1	6.7	6.3	6.1	5.9		5.7	5.6	94.8	71.4	52.8	41.0	33.8	28.9	24.9	22.7	20.5	18.6	17.8
U164	PCIB	Centre	AG	950	6.7	18.8	16.9	14.5	12.8	11.5	10.7	9.9	9.2	8.7		8.2	8.3	88.8	67.4	49.5	37.6	31.3	26.3	23.1	20.0	0.0	0.0	0.0
U171	PCIB	Centre	AG	950	10.3	11.2	10.2	9.1	8.2	7.7	7.3	7.0	6.7	6.5		6.5	6.3	91.1	69.9	51.1	39.8	32.3	28.0	24.2	21.9	19.6	17.8	17.5
U295	PPEA	Edge	WG	950	10.5	13.4	11.8	10.4	9.3	8.5	8.0	7.6	7.1	6.9		6.8	6.5	101.3	79.3	57.6	44.3	36.5	30.9	26.9	24.0	21.7	20.1	18.8
U303	PPEA	Edge	AG	950	10.5	12.0	10.7	9.4	8.4	7.8	7.3	6.9	6.6	6.4		6.1	5.8	99.6	76.7	55.2	42.7	35.0	29.8	25.8	23.1	20.8	19.0	18.4
U313	PPEA	Edge	WG	850	7.8	29.5	25.6	21.5	18.6	16.2	14.8	13.7	12.6	11.9	11.5			106.9	80.7	58.4	44.8	37.1	31.1	27.2	24.1	22.2	20.1	19.5
U358	LPEB	Centre	WG	950	6.7	33.4	28.4	23.5	20.0	17.5	15.8	14.5	13.4	12.6		12.0	11.6	135.4	93.8	66.3	49.5	40.4	33.9	29.3	25.5	22.7	21.0	20.1
U359	LPEB	Centre	WG	950	7	33.1	28.1	23.6	20.1	17.8	15.8	14.4	13.5	12.5		12.0	11.6	145.1	103.8	71.1	53.5	42.4	35.8	31.1	27.6	24.4	22.3	21.5
U407	PPEA	Edge	WG	850	3.4	34.7	29.9	24.8	21.2	18.6	16.7	15.1	14.0	13.1	12.8			102.9	76.2	54.8	40.4	32.8	28.6	25.2	22.3			
U427	PCEA	Edge	WG	850	3.4	37.7	32.1	26.7	22.6	19.7	17.5	16.0	14.8	13.8	13.5			135.8	100.4	72.0	54.8	44.0	37.1	31.9	28.5	25.7	23.2	22.2

Table D.4 Thermal conductivity measurement results for all graphite grades irradiated at 850°C and 950°C in the INNOGRAPH-2B experiment

Sample						Post irradiation Thermal conductivity [W m⁻¹ K⁻¹]												Pre irradiation Thermal conductivity [W m⁻¹ K⁻¹]										
Specimen code	Grade	Location	Orientation	T_{irr} [°C]	dpa	25°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	850°C	900°C	950°C	25°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	950°C
S380	NBG-10	Centre	WG	850	7.8	39.8	43.7	46.4	46.6	46.0	44.7	44.1	42.6	41.9	41.1			144.3	137.1	121.9	108.9	98.8	90.2	82.3	77.4	71.3	66.9	64.7
S382	NBG-10	Centre	WG	950	11	20.2	22.5	24.6	25.5	26.0	25.7	25.6	25.5	25.5		25.2	24.2	149.1	140.2	125.4	111.2	100.5	92.8	85.0	78.9	73.0	69.5	66.6
S438	NBG-25	Centre	AG	950	12.2	12.0	13.5	15.1	15.8	16.5	16.7	16.8	16.7	16.8		16.5	16.1	125.3	118.8	107.2	97.7	90.4	82.0	74.9	70.9	66.7	61.6	59.3
S446	NBG-25	Centre	WG	950	10.5	15.8	18.2	20.2	21.3	22.0	22.4	22.5	22.6	22.7		22.4	22.6	132.3	125.6	114.3	105.3	95.8	87.1	81.0	74.7	69.1	65.5	63.7
S464	NBG-18	Edge	WG	950	9.6	16.6	18.9	21.2	22.3	22.8	23.0	23.2	23.0	23.2		23.1	23.1	143.2	131.7	118.3	107.4	99.0	90.4	83.8	76.8	71.6	67.5	65.4
S475	NBG-18	Edge	AG	950	10.4	15.2	17.2	19.0	20.1	20.9	21.0	21.5	21.2	21.4		21.0	20.9	136.8	124.4	110.5	98.4	88.7	82.5	75.5	70.2	65.4	60.7	59.2
S518	NBG-18	Centre	AG	850	7.6	37.4	41.0	43.4	43.9	43.3	42.5	41.4	40.2	39.0	38.4			140.9	132.4	119.0	106.5	98.1	88.9	82.6	76.7	70.6	66.6	64.7
S646	NBG-10	Centre	WG	950	7.2	34.4	36.9	40.0	41.0	40.6	40.2	39.3	38.4	37.7		36.8	36.0	148.6	137.8	124.5	112.0	102.7	92.9	85.5	78.9	73.5	67.6	66.1
S657	NBG-10	Edge	WG	850	3.3	44.5	47.5	49.7	49.7	48.6	47.2	45.5	44.1	43.1	42.5			141.8	132.3	116.8	102.4	93.1	86.1	77.2	70.6			
S673	NBG-18	Centre	AG	850	3.7	41.8	45.0	47.3	47.1	45.6	45.1	43.7	41.6	40.9	40.0			140.9	132.4	119.0	106.5	98.1	88.9	82.6	76.7	70.6	66.6	64.7
S681	NBG-18	Edge	AG	950	6.8	29.7	33.0	35.8	37.0	37.1	36.6	36.1	35.4	34.8		34.5	34.6	136.0	124.6	110.2	95.0	87.4	82.0	76.3	70.4	65.8	60.3	59.0
T044	IG-110	Edge	AG	950	13.2	10.5	12.1	13.5	14.5	14.7	14.9	15.0	15.1	14.4		14.5	14.0	122.9	113.7	103.3	93.5	86.0	77.8	71.7	66.8	62.1	58.0	56.4
U011	PCEA	Centre	WG	950	10.8	20.5	22.7	24.9	26.3	26.5	26.5	26.7	26.7	26.0		26.1	25.7	166.9	158.4	141.8	125.3	112.6	103.5	93.6	87.8	80.7	74.4	72.7
U034	PCEA	Centre	AG	950	11.2	15.7	17.6	19.7	20.7	21.2	21.6	21.5	21.9	21.5		21.8	20.8	157.0	149.0	132.0	115.7	104.7	95.0	88.0	80.4	74.7	69.9	66.0
U035	PCEA	Centre	AG	950	11.3	17.2	19.1	21.3	22.3	23.0	23.0	22.9	23.1	22.0		22.3	21.3	164.6	151.6	137.3	120.4	108.8	100.1	92.1	84.3	78.6	73.6	70.9
U036	PCEA	Centre	AG	950	9.8	32.1	36.6	39.5	40.5	40.6	40.1	39.2	38.4	37.7		36.9	36.3	164.4	151.1	136.0	120.2	110.1	100.4	91.4	84.0	77.9	72.8	70.6
U050	PCEA	Centre	WG	850	7.8	47.4	51.2	53.8	53.9	52.9	51.8	49.1	48.5	47.0	46.5			168.6	156.6	140.1	123.5	112.4	103.1	93.9	86.6	80.2	75.4	71.7
U074	PCEA	Edge	AG	950	12.1	22.1	24.6	27.0	28.1	28.4	28.3	28.0	27.8	27.5		26.6	25.9	164.2	151.8	136.7	120.8	108.9	100.5	91.6	84.6	79.0	73.9	71.1
U083	PCEA	Edge	WG	950	11.2	27.2	30.9	33.3	34.3	34.4	34.2	33.6	32.9	32.4		31.6	30.7	178.8	163.7	145.9	130.8	117.9	107.3	98.7	91.6	85.0	79.0	75.6
U089	PCEA	Edge	AG	950	10.7	30.7	33.5	36.2	37.4	37.5	37.2	36.3	35.7	35.0		34.5	32.5	162.6	152.1	136.5	120.6	109.7	100.4	93.8	85.6	78.4	74.1	71.7
U143	PCIB	Centre	WG	950	10.7	13.0	14.8	16.8	17.8	18.3	18.7	18.7	18.9	18.9		18.8	18.7	124.4	118.1	110.2	100.3	92.2	85.3	77.7	74.0	69.0	64.6	62.4
U164	PCIB	Centre	AG	950	6.7	23.9	27.2	29.5	30.4	30.6	30.8	30.4	29.6	28.8		27.9	28.5	117.6	111.8	103.8	92.4	86.0	78.3	72.8	66.1	0.0	0.0	0.0
U171	PCIB	Centre	AG	950	10.3	13.9	16.0	18.0	19.1	20.0	20.5	20.9	20.9	21.0		21.5	21.1	119.6	115.7	106.8	97.3	88.1	82.7	75.7	71.6	66.1	61.7	61.4
U295	PPEA	Edge	WG	950	10.5	16.4	18.2	20.3	21.3	21.6	22.1	22.3	21.7	22.0		22.1	21.4	131.6	129.9	119.1	107.3	98.7	90.2	83.4	77.5	72.4	68.9	65.2
U303	PPEA	Edge	AG	950	10.5	14.6	16.4	18.2	19.0	19.8	20.0	20.1	20.1	20.1		19.7	19.0	130.7	126.9	115.2	104.5	95.6	87.9	80.5	75.6	70.2	65.7	64.5
U313	PPEA	Edge	WG	850	7.8	39.7	43.4	46.1	46.7	45.6	45.0	44.1	42.3	41.5	40.5			138.9	132.2	120.8	108.6	100.2	90.8	84.3	78.0	74.0	68.8	67.4
U358	LPEB	Centre	WG	950	6.7	45.1	48.3	50.4	50.4	49.2	48.2	46.8	45.4	44.1		43.0	42.1	179.6	156.8	139.8	122.3	111.3	101.1	92.5	84.2	77.3	73.3	71.0
U359	LPEB	Centre	WG	950	7	44.4	47.5	50.5	50.5	49.8	48.0	46.5	45.3	43.5		42.7	42.0	191.1	172.2	148.9	131.2	116.1	106.0	97.4	90.2	82.7	77.4	75.4
U407	PPEA	Edge	WG	850	3.4	45.8	49.7	52.2	52.3	51.2	49.8	47.8	46.3	44.9	44.3			134.6	125.7	114.2	98.9	89.4	84.5	79.1	73.0			
U427	PCEA	Edge	WG	850	3.4	49.3	53.0	55.6	55.2	53.8	51.8	50.2	48.6	46.7	46.3			176.4	164.3	148.7	132.4	118.8	108.4	98.7	92.1	85.7	79.3	76.9

Appendix E Graphs $CTE_{30°C-950°C}$ for INNOGRAPH-2A and 2B

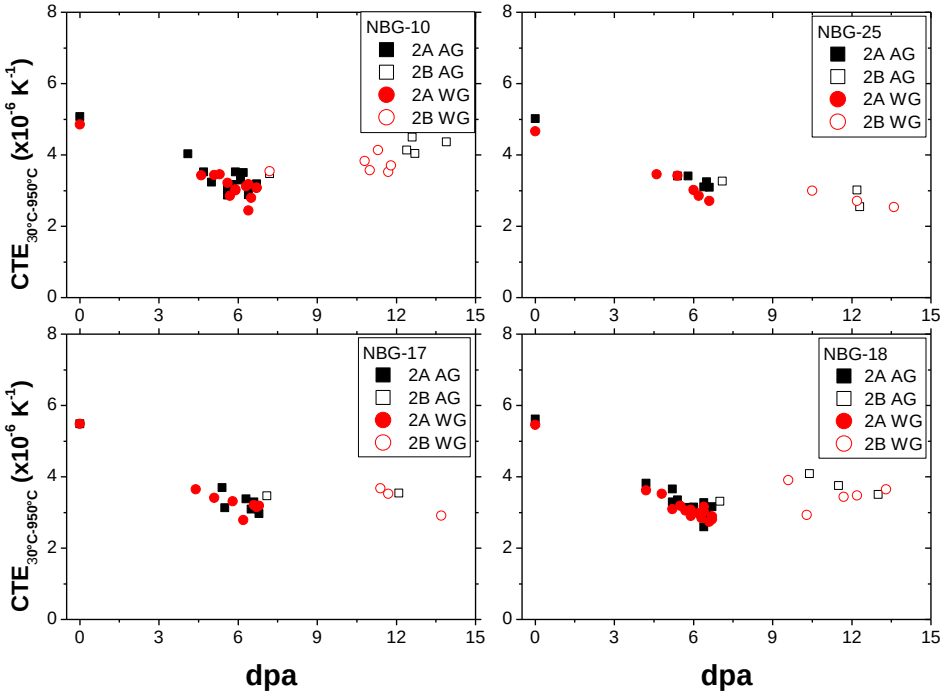

Figure E.1 Coefficient of thermal expansion over the range of 30°C to 950°C for SGL graphite grades irradiated at 950°C

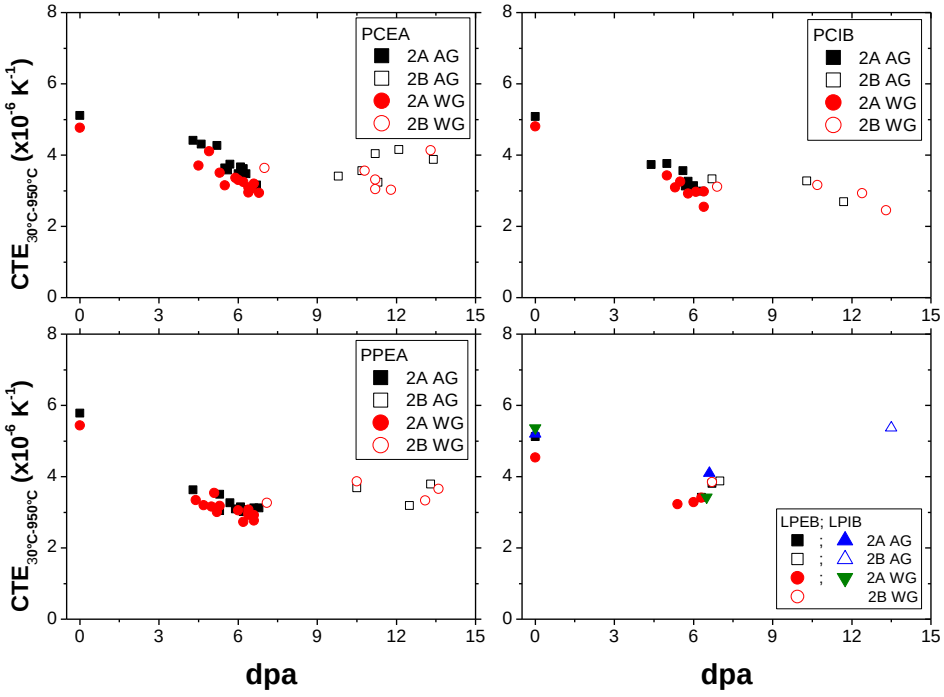

Figure E.2 Coefficient of thermal expansion over the range of 30°C to 950°C for GrafTech graphite grades irradiated at 950°C

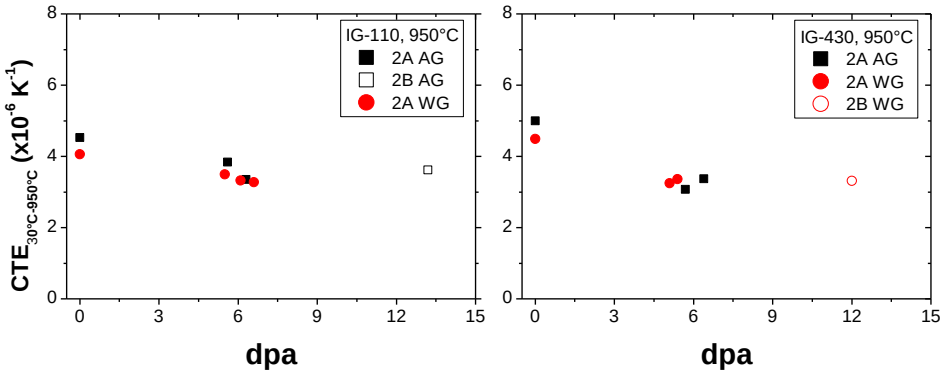

Figure E.3 Coefficient of thermal expansion over the range of 30°C to 950°C for Toyo Tanso graphite grades irradiated at 950°C

Appendix F Graphs LFA measurements at 950°C for INNOGRAPH-2A and 2B

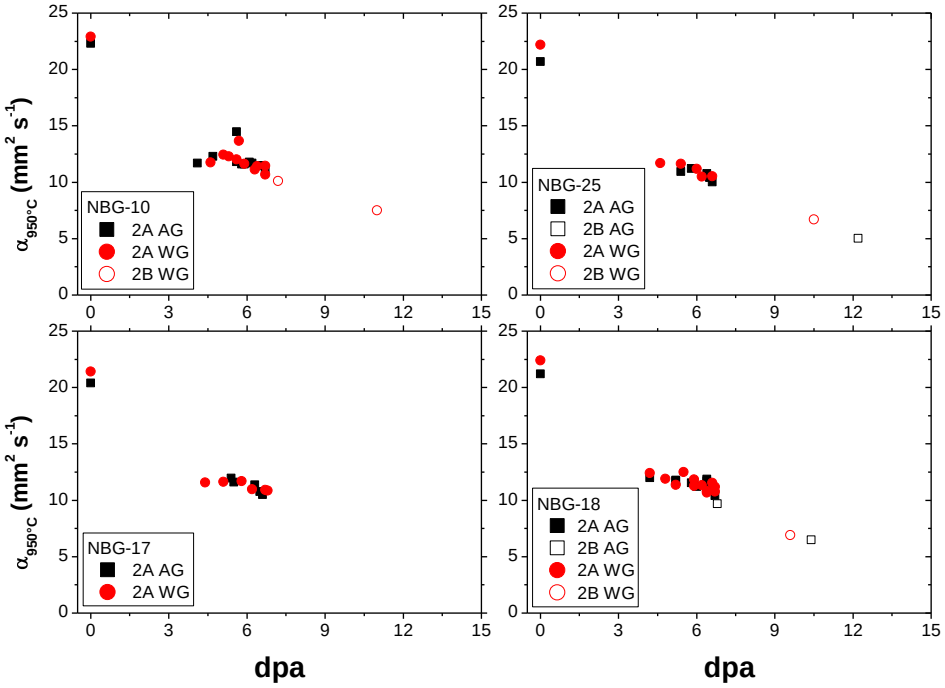

Figure F.1 Thermal diffusivity at 950°C for SGL graphite grades irradiated at 950°C

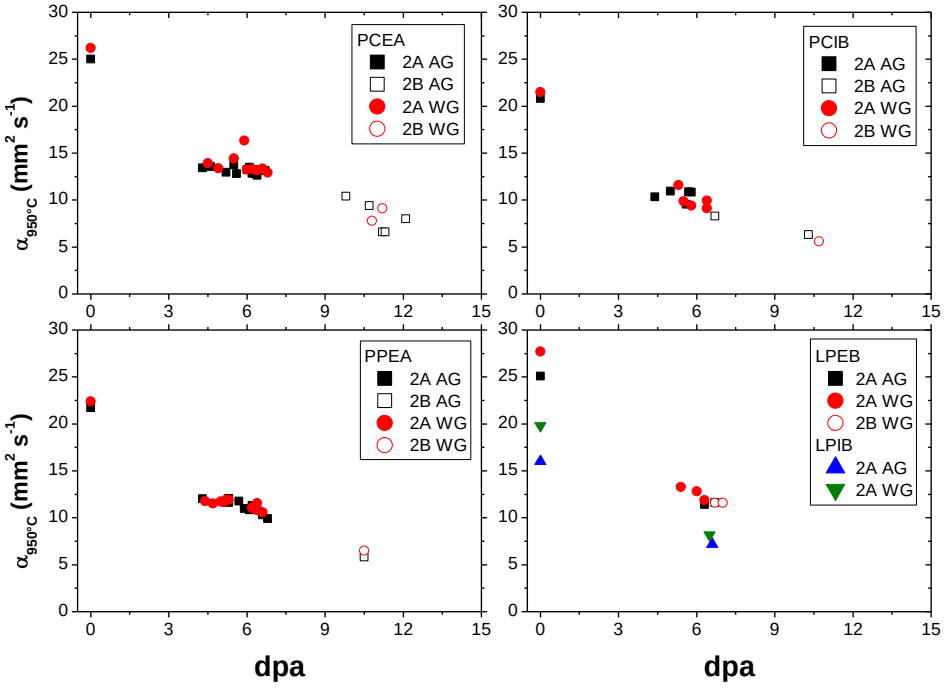

Figure F.2 Thermal diffusivity at 950°C for GrafTech graphite grades irradiated at 950°C

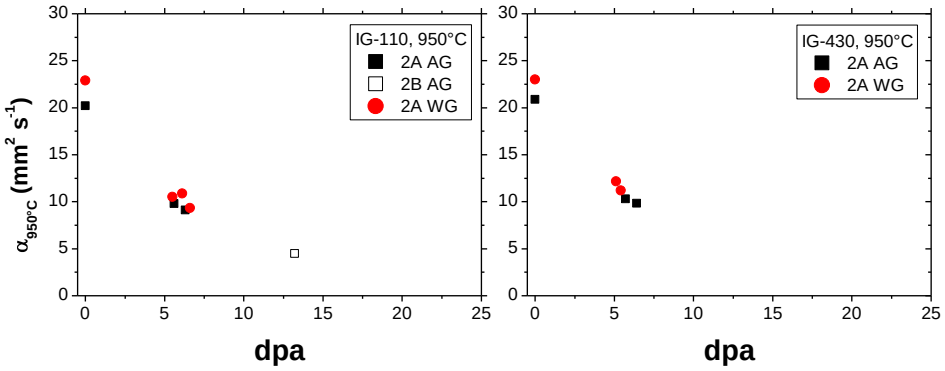

Figure F.3 Thermal diffusivity at 950°C for Toyo Tanso graphite grades irradiated at 950°C

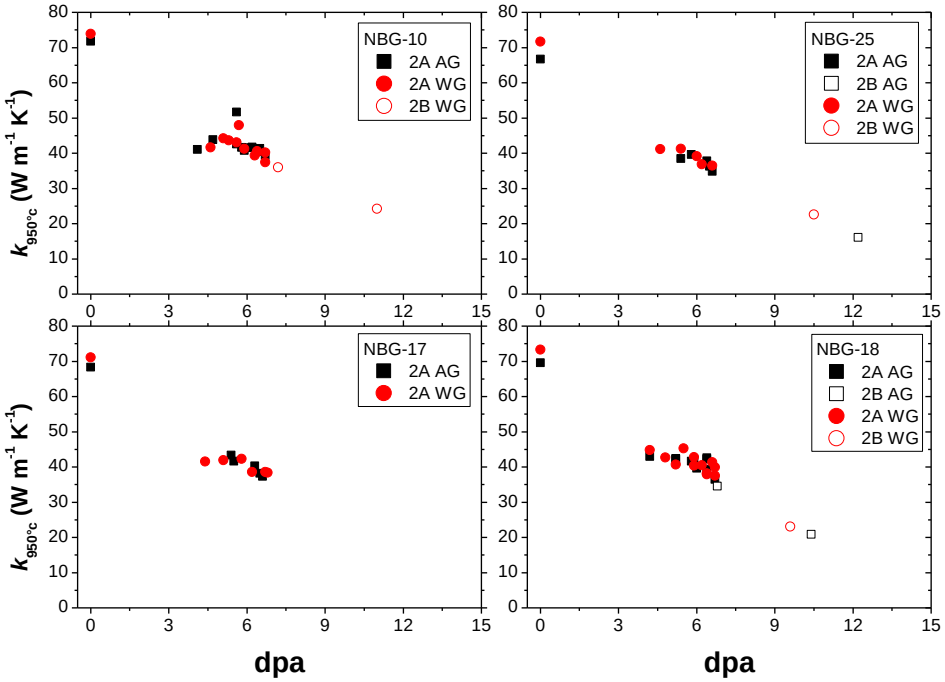

Figure F.4 Thermal conductivity at 950°C for SGL graphite grades irradiated at 950°C

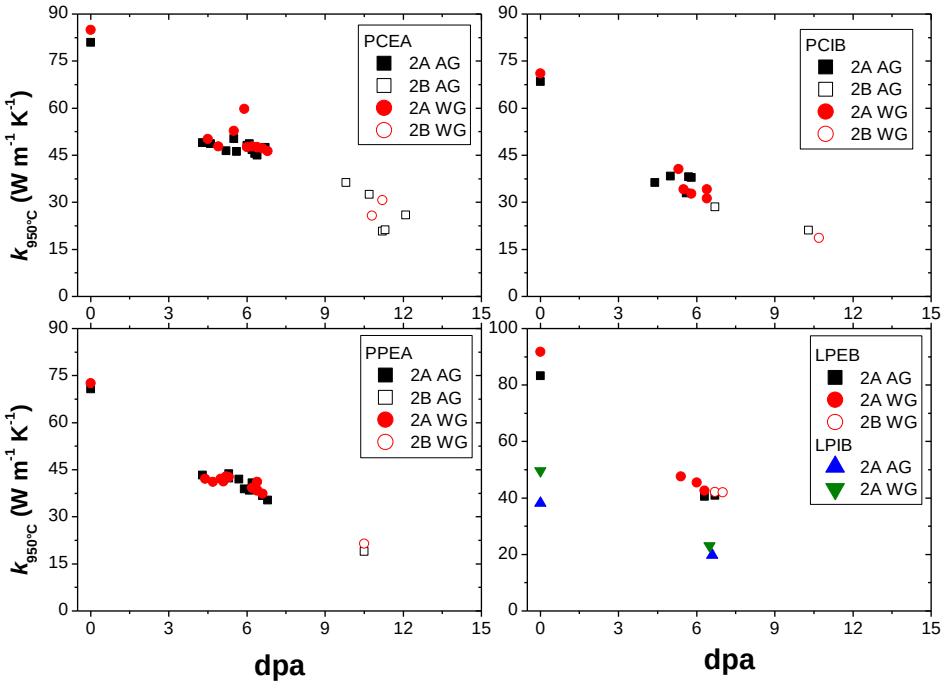

Figure F.5 Thermal conductivity at 950°C for GrafTech graphite grades irradiated at 950°C

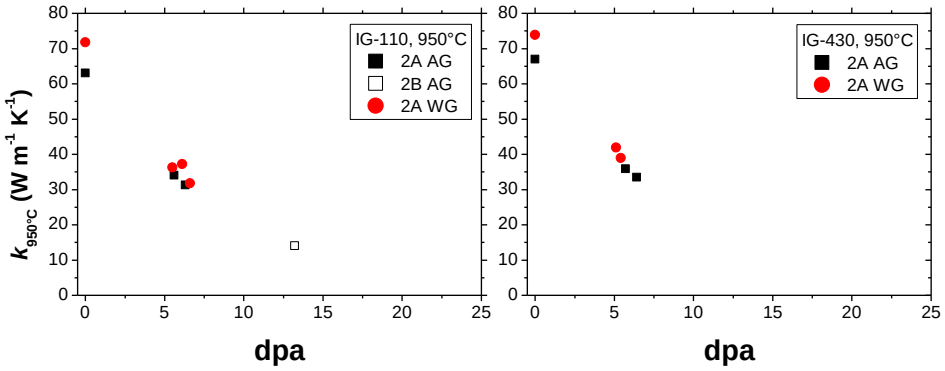

Figure F.6 Thermal conductivity at 950°C for Toyo Tanso graphite grades irradiated at 950°C