Available online at www.dergipark.gov.tr

INTERNATIONAL ADVANCED RESEARCHES and ENGINEERING JOURNAL

Journal homepage: www.dergipark.gov.tr/iarej

e-ISSN: 2618-575X

International Open Access

Volume 03
Issue 02

August, 2019

Research Article

Experimental investigation of thermal coefficient of the graphene used concrete

Özkan Köse [a], ***Yıldız Koç*** [a], ***Hüseyin Yağlı*** [a], ***İsmail Üstün*** [a], ***Furkan Kasap*** [a], ***Nurhan Adil Öztürk*** [a] ***and Ali Koç*** [a,*]

[a] *Department of Mechanical Engineering, Iskenderun Technical University, Iskenderun, Hatay, 31200, Turkey*

ARTICLE INFO

Article history:
Received 13 April 2018
Revised 17 October 2018
Accepted 24 October 2018

Keywords:
Graphene
Thermal conductivity coefficient
Concrete materials

ABSTRACT

Today, fossil fuels are used primarily in energy production throughout the world. However, the ever-diminishing energy production and developing technology has encouraged energy recovery, saving or different topics. Grafen is one of the most remarkable studies in the field of nanotechnology in recent years. This nanotechnological product, considered as one of the mainstream products of future technology, has superior properties in some physical and chemical issues compared to many materials. Because of its high conductivity and durability, it continues to attract attention in energy and materials science. In this paper, the concrete samples obtained by mixing the graphene at certain ratios were compared with pure concrete (graphene free concrete) and the thermal conductivity of the grafen added concrete was determined. Finally, the thermal conductivity of the pure concrete (thermal conductivity of 1.3096 W/mK) added with 1 gr, 2 gr, 3 gr, 4 gr and 5 gr graphene were calculated as 1.6516, 1.6668, 1.6773, 1.8080 and 1.8486 (W/mK), respectively.

1. Introduction

Today, fossil fuels such as coal, oil and natural gas, which are known as non-renewable energy sources, are used primarily in energy production around the World [1]. Developing technology and increasing energy consumption have encouraged the scholars to study about energy recovery and savings in the field of nanotechnology. One of the most widely studied topics on nanotechnology in recent years is the use of graphene. The graphene, which has a two-dimensional carbon atom structure, is known as a unique nano-product with a honeycomb appearance [2]. The graphene, seen as one of the mainstream products of future technology, has outstanding properties in some physical and chemical issues compared to many materials. Thanks to such superior properties of the graphene, it is possible that the structural integrity of the buildings and the interior or exterior structure of the buildings are more durable and long-life in isolation applications made by using the graphene [3].

Moreover, if the graphene is used as isolation, it has been determined in a number of studies that it can be able to minimize adverse situations, especially due to seasonal weather variation, over time. In other words, thanks to the use of graphene in building concrete materials, it can increase the resistance of the structure against weather conditions like snow, rain, hot, cold [4,5]. Therefore, many companies in Europe have allocated a large share of their budgets to Research & Development Studies in order to support and develop grafen investigations. Although there are very few studies on the use of graphene materials, some studies are available in the literature. Zenyatta (2017), in this study on Graphene Concrete Pilot Project Developments, the Graphene mixture arising from Albany derivation has been applied to a large volume of concrete. In result of this experimental studies, it was seen that the addition of graphene into the concrete provided a faster curing in the concrete. Besides, it has shown that it can achieve a remarkable mechanical performance that

* Corresponding author. Tel.: +90 (326) 613 56 00; Fax: +90 (326) 613 56 13.
E-mail addresses: ozkan.kose@iste.edu.tr *(Ö. Köse)*, yildiz.koc@iste.edu.tr *(Y. Koç)*, huseyin.yagli@iste.edu.tr *(H. Yağlı)*, ismail.ustun@iste.edu.tr *(İ. Üstün)*, furkankasap05@gmail.com *(F. Kasap)*, nadil.ozturk@iste.edu.tr *(N.A. Öztürk)*, ali.koc@iste.edu.tr *(A. Koç)*
ORCID: 0000-0002-9069-1989 *(Ö. Köse)*, 0000-0002-2219-645X *(Y. Koç)*, 0000-0002-9777-0698 *(H. Yağlı)*, 0000-0001-8885-5510 *(İ. Üstün)*, 0000-0003-1481-0699 *(F. Kasap)*, 0000-0002-9551-8122 *(N.A. Öztürk)*, 0000-0002-7388-2628 *(A. Koç)*
DOI: 10.35860/iarej.415181

prevents premature deterioration of concrete by tolerating external forces during natural disasters. In addition to all these, graphene material usage is thought that it will reduce the amount of cement used in construction [6]. Ahammed, N. et. al. (2015) In this study, the design, development and measurement of graphene-water (nanofluid) thermal conductivity using a hot wire technique are temporarily investigated at ambient temperatures ranging from 10 °C to 50 °C. The equipment is designed to measure thermal conductivity using a single platinum wire with a diameter of 50 µm and a length of 100 mm. Platinum micro-wire is acted as both a temperature sensor and a heating element. SDBS (sodium dodecyl benzene sulphonate) as a surfactant was dispersed in 100 ml of water for a long-time stability and a graphite was used at a low volume concentration (0.05%, 0.1% and 0.15%) smaller than 100 nm. As a result, an increase in thermal conductivity of 37.2% when compared to water at the same temperature for a 0.15% volume concentration of graphene at 50 ° C was observed. Besides, another result from this study is that the average thermal conductivity increment percentage at volume concentration (e.g., 0.05% to 0.15%) at temperatures between 10 °C and 50 °C is found to be 3.3% higher than the average improvement level [7]. In a study by Australian technology minerals company Talga Resources (2017), they have worked on the ability of the grafen to improve the strength of concrete by forming graphite and graphite-added cement and concrete products. As a result of the 28-day waiting period, the increase in the bending strength and the compression strength of the reference concrete were occurred by 26% and 14%, respectively. The obtained data show that graphene will provide significant performance advantages for various industrial applications, particularly the global construction and infrastructure sectors [8]. Wicklein, B. et al. (2014), they have used frozen cellulose nanospheres, graphene oxide, and sepiolite nanorods to increase the energy efficiency of buildings and produce super insulated, fire resistant, strong anisotropic foams. As a result of the study, it was found out that foams that perform better than conventional polymer-based insulation materials have a thermal conductivity of about half (15 W/mK) of the expanded polystyrene and excellent fire resistance [9].

When the studies in the literature considered together, it is clearly seen that almost all the studies on the graphene measures the electrical resistance of the graphene. However, there are only limited studies that uses graphene in the concrete. In this study, the linear heat transfer coefficient of the graphene was investigated, inspiring from the current studies on the graphene. The Concrete samples prepared by using graphene were mixed with pure concrete (graphene free concrete) and the heat transfer coefficient was examined experimentally. The appropriateness of the use of the graphene to the concrete was investigated in terms of heat transfer. Detailed analysis of the material was made using the experimental results obtained.

2. Material and Method

2.1 Graphene Properties

In spite of having a two-dimensional structure, the graphene, which is 300 times more durable than steel, is the lightest and thinnest material known for honeypot appearance of the carbon. Grafen is known as the first two-dimensional crystal material and transmits heat at a much higher rate than copper. Graphene that is the more robust and highly flexible than steel is the thinnest shape brought the graphite to an atomic thickness like a diamond. Thanks to this flexibility, materials made from graphene can easily be folded, twisted and extended. Grafen is one of the rare materials that keeps all these features together [3]. In this study, a graphite named as GNP (3 nm-24 micron-150 m^2/g) was used. The technical characteristics of the used graphene are given in Table 1.

Table 1. The technical characteristics of the used graphene

Properties	**Value**	**Units**
Purity	99.5	*%*
Thickness	6	*nm*
Diameter	24	*µm*
Specific Surface Area	150	m^2/gr
Conductivity	1100-100	*s/m*
Colour	Grey	−

2.2 Preparation of Graphene

In the scope of the experimental study, samples were examined with the help of molds prepared by using cement, water and graphene. The materials included in the samples and the usage rates of these materials are given in Table 2.

Table 2. The materials included in the samples and the usage rates of these materials

	Cement	**Water**	**Graphene**
	gr	*ml*	*gr*
Pure concrete	200	60	0
1. Graphene sample	200	61	1
2. Graphene Sample	200	63.75	2
3. Graphene Sample	200	67	3
4. Graphene Sample	200	69	4
5. Graphene Sample	200	75	5

In the study cement clay (pure concrete) was brought to homogenous consistency with 32% water and the obtained sample was selected as a control sample. Five graphene-cement mixtures of 1 gr, 2 gr, 3 gr, 4 gr and 5 gr were used during the experimental study. In the preparation phase of the samples, five graphene-cement mixture and pure concrete samples were comprised by varying the amount of water since the graphene's water absorption ability was fairly good, provided that the amount of cement was constant. Then the samples which were dried in the mold along one day were removed from the mold and kept in water during 28 days. The samples were taken from the water and contacted with the atmospheric air for a certain period of time for drying material surface. The samples waited in the air were kept at 45 °C for one day in an oven and taken to the drying room. The prepared test samples are shown in Figure 1.

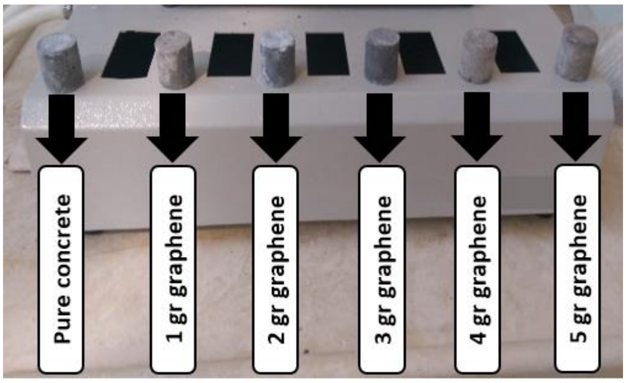

Figure 1. Samples used in the experiment

As the concrete molding is carried out at the appropriate ambient temperature (25 °C), no chemical additive material is used during the preparation of the samples. During all these preparation steps, it has been paid attention to the removal of the samples from the mold without damaging the concrete, the mixing amounts of the materials, the vibration and the presence of any foreign matter in concrete.

2.3 Description of Experimental Setup

All experimental analyses and data recording steps were carried out using a linear heat transfer coefficient measurement instrument available in our laboratory. The linear heat transfer coefficient measurement instrument used is shown in Figure 2.

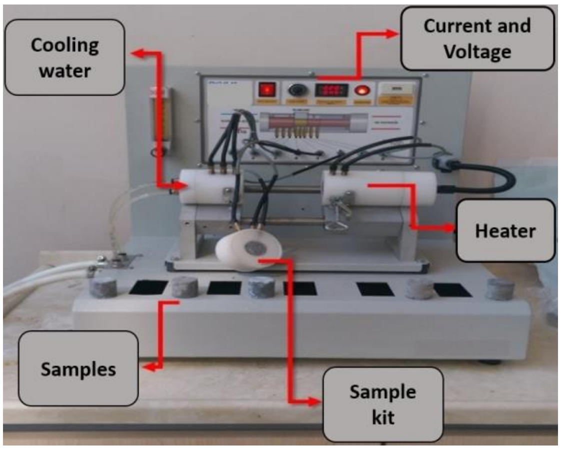

Figure 2. Linear heat transfer coefficient analysing setup

In this part, the water coming from the network is drawing heat from the hot section by getting in touch with the sample. The inlet and outlet temperature of the water entering the cooler section, the area where the water contacts with the sample is measured by the test device. Sample apparatus is the main equipment which is connected to the test device. Three different temperature measurements are made on the surface where the sample is connected. These measurements are; in the contact area where the sample is connected to the cold source, in the middle part of the sample and in the contact area to which the hot source is connected. In the heater section, heat is applied to the sample with the resistor and temperature measurement is made from two different points. All measurements made during the experiment are made automatically by the system at specified time intervals. It is recorded on the computer with the help of data control software. The MDVT data control software interface used during the operation is shown in Figure 3

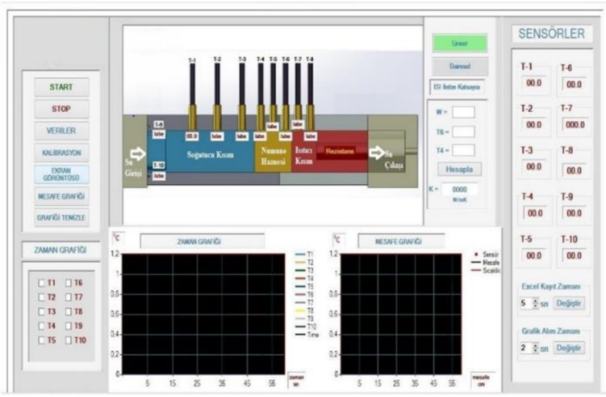

Figure 3. MDVTS data control software interface

The data control software used throughout the study performs the functions of collecting data and sending data from the centre, analysing and then displaying this data on an operator's screen.

2.4 Mathematical Model

As defined in the first law of thermodynamics, heat is transferred from the hot part to the cold part. There are three different types in which heat is transferred. These are convection, conduction and radiation. In this study, since the heat transfer is taking place through a solid body, the heat transfer equilibrium equation via conduction was theoretically used to measure the heat transfer coefficient. Heat transfer coefficient according to Fourier's law;

$$Q_x = -kA\frac{dT}{dx} \tag{1}$$

In the equation, Q_x expresses the amount of heat passing through a certain area in the x direction. A refers to the determined area. k stands for the heat transfer coefficient. Q_x is calculated by reading the voltage (V) and current (A) values from the test device;

$$Q_x = VA \tag{2}$$

The data recorded by the computer using the calculated Q_x values was regulated and k values were found for each sample.

3. Research Findings

Pure concrete (cement clay) and graphene samples between 1 and 5 gr were separately tested in MDVTS. The heat transfer coefficients were recorded to the excel program at intervals of 5 seconds for each sample. Comparison of the heat transfer coefficients of pure concrete and 1gr graphene samples is given in Figure 4.

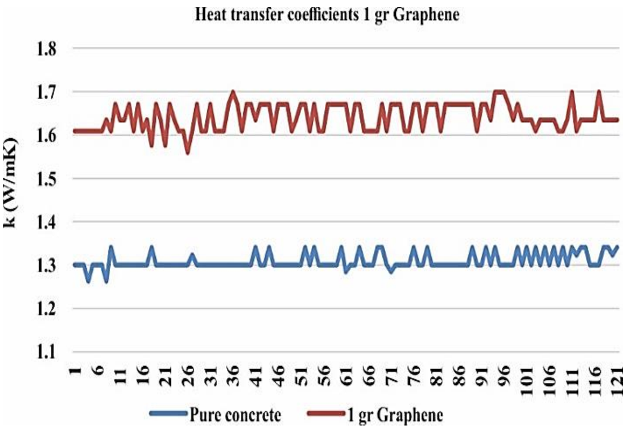

Figure 4. Comparison of heat transfer coefficients of pure concrete and 1gr grafted samples

The heat transfer coefficients of pure concrete and 1 gr graphene samples were examined in the MDVTS and data were recorded at intervals of 5 seconds. Pure concrete and 1gr graphene mixture have reached a balance between the 81st. and 91st. data. The heat transfer coefficient of pure concrete and graphene mixture were 1.30966,1 W/mK and 1.65116 W/mK, respectively. when the graphene was included in pure concrete, it was observed that the heat transfer coefficient has increased seriously. Comparison of heat transfer coefficients of pure concrete and 2 gr of graphene mixture samples are shown in Figure 5.

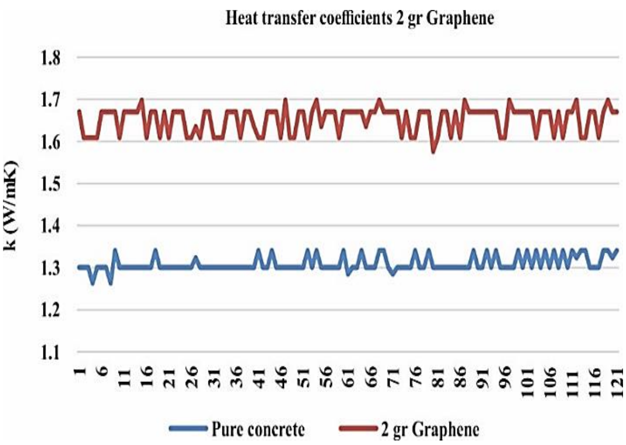

Figure 5. Comparison of heat transfer coefficients of pure concrete and 2 gr graphene mixture

When the data recorded at intervals of 5 seconds were analysed, it was seen that the heat transfer coefficient of the graphene mixture of 2 gr remained constant at between 61. and 65. data and the heat transfer coefficient of the 2 gr graphene mixture was approximately 1.66648 W/mK. Heat transfer coefficient has increased a little more when adding 2 gr graphene to the mixture. comparison of heat transfer coefficient of 3 gr graphene included pure cement is given Figure 6.

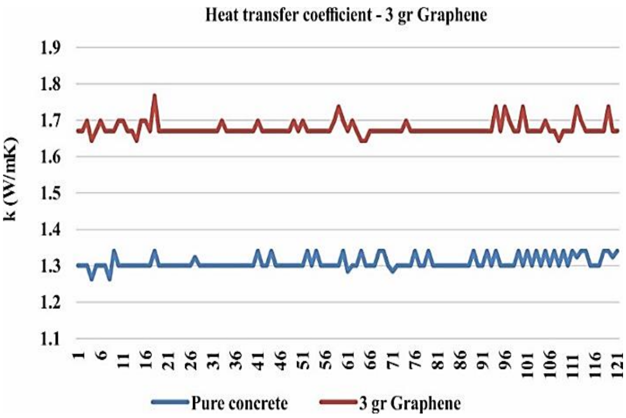

Figure 6. Comparison of heat transfer coefficients of pure concrete and 3 gr graphene mixture

The heat transfer coefficient of the graphene mixture reaching the balance between 73. and 97. points was found to be about 1.67783 W/mK. It was found that there was no significant increase in the heat transfer coefficient when the obtained data were compared with the mixture containing 2 gr of graphene. Comparison of heat transfer coefficient of 4 gr graphene included a sample with pure cement is shown Figure 7.

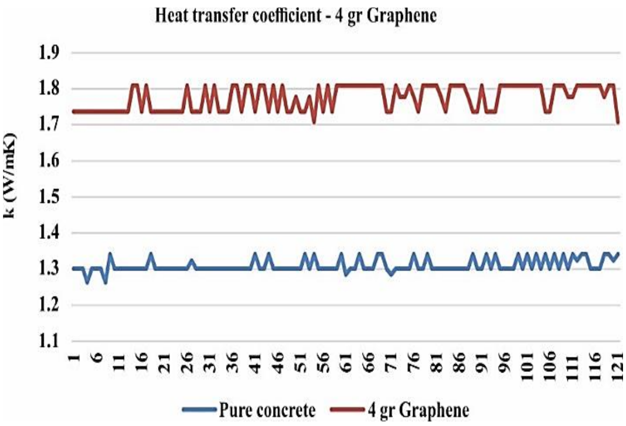

Figure 7. Comparison of heat transfer coefficient of 4 gr graphene included a sample with pure cement

The heat transfer coefficient of 4 gr graphene added sample was balanced between 57. and 73. points and approximately calculated as 1.80890 W/mK. After the amount of 3 g of graphene, a significant increase has occurred in the heat transfer coefficient. Comparison of heat transfer coefficient of 5 gr graphene included a sample with pure cement is demonstrated Figure 8.

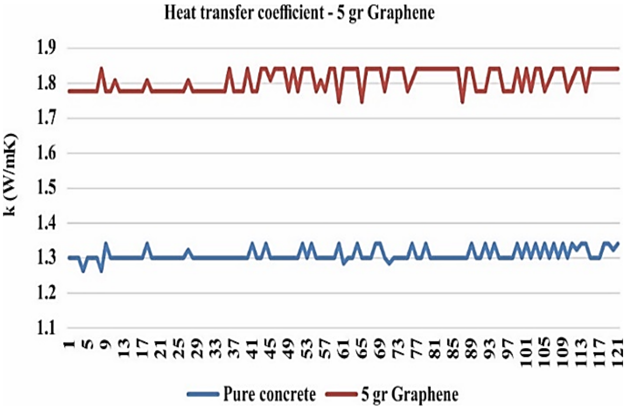

Figure 8. Comparison of heat transfer coefficient of 5 gr graphene included a sample with pure cement

5 gr of graphene included sample have reached a balance between the 77. and 89. points. The heat transfer coefficient of graphene sample is determined as 1.84846 W/mK. It was observed that the increase in the heat transfer coefficient of 5 g of graphene added sample was slower than that of the graphene sample of 4 g. Comparison of heat transfer coefficients of graphene included samples between 1 and 5 gr is displayed Figure 9.

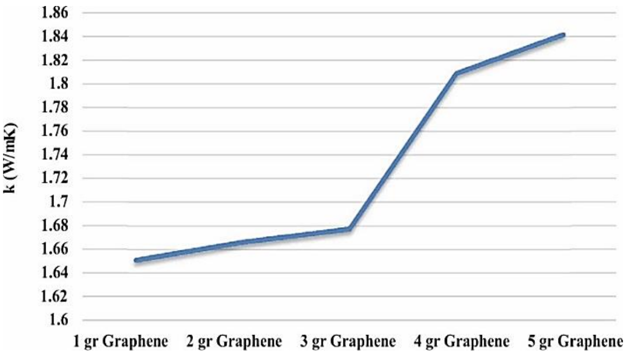

Figure 9. Comparison of heat transfer coefficients of graphene included samples between 1 and 5 gr

When the heat transfer coefficients of all graphene included concrete samples are examined in detail, it is seen that the amount of graphene has a considerable effect on the heat transfer coefficient. Although a linear increase was observed between 1 gr and 3 gr graphene, the heat transfer coefficient has increased substantially when 4 g of graphene is added to the sample. Eventually, it was observed that the rate of increase of the heat transfer coefficient decreased when 5 gr graphene was added to the sample.

4. Conclusions

In the calculations made in the experiment study, 121 data were recorded and plotted. The heat transfer coefficients of pure concrete were compared with the graphene added samples between 1gr and 5 gr. When the above graphs were taken into consideration, it was seen that the heat transfer coefficients of graphene-based samples have increased approximately between 35% and 50% compared to pure concrete. Heat transfer coefficients according to graphene amount is given Table 3.

Table 3. Heat transfer coefficients according to graphene amount

Samples	k	Unit
Pure Concrete	1.3096	*W/mK*
1. Graphene Sample	1.6516	*W/mK*
2. Graphene Sample	1.6668	*W/mK*
3. Graphene Sample	1.6773	*W/mK*
4. Graphene Sample	1.8080	*W/mK*
5. Graphene Sample	1.8486	*W/mK*

The obtained results showed that as the amount of graphene in pure concrete increases, the heat transfer coefficient escalates significantly. Although the concrete structure is desired to have a high thermal resistance for many applications, it can be more appropriate to use the concrete structure with a high heat transfer coefficient in some applications. The use of the graphene-based material in the work areas where high heat transfer coefficient is required (in the fields where rapid cooling is desired) will provide serious advantages. Graphene is suitable for use on concrete walls of cooling towers used in thermal and nuclear power plants, where heat must be removed quickly and high strength is required. Besides, it is considered that the use of graphene-reinforced concrete tapes will be advantageous in order to achieve the desired rapid cooling on the concrete tape surfaces where steel billet is transferred to the rolling mill

Nomenclature

k : Heat transfer coefficient (*W/mK*)
A : Current (*Amper*)
A : Area (m^2)
V : Voltage (*Volt*)
Q : Energy obtained from current and voltage (*J/s*)
T : Temperature (*℃*)

References

1. Koç, A., Yağlı, H., Koç, Y. and Uğurlu, İ., Dünyada ve Türkiye'de enerji görünümünün genel değerlendirilmesi. Engineer & the Machinery Magazine, 2018. **59**(692): p. 86-114.
2. Grafen-Nanografi Türkiye. (n.d.). [cited 2018 10 October]; Retrieved from http://nanografi.com.tr/grafen/
3. Novoselov, K. S., Fal, V. I., Colombo, L., Gellert, P. R., Schwab, M. G., & Kim, K., A roadmap for graphene. nature, 2012. **490**(7419): p. 192.
4. Cao, M. L., Zhang, H. X., & Zhang, C., Effect of graphene on mechanical properties of cement mortars. Journal of Central South University, 2016. **23**(4), p. 919-925.
5. Monash University. [cited 2018 11 October]; Retrieved from; https://www.monash.edu/__data/assets/pdf_file/0006/356973/Graphene-Reinforced-Concrete-Composites.pdf
6. Zenyatta. [cited 2018 11 October]; Retrieved from; http://www.zenyatta.ca/article/press-release-4468.asp
7. Ahammed N., Asirvatham, L.G., Titus J., Bose J.R. and S. Wongwises, Measurement of thermal conductivity of graphene–water nanofluid at below and above ambient

temperatures. International Communications in Heat and Mass Transfer, 2016. **70**: p. 66-74.

8. Talgaresources. [cited 2018 11 October]; Retrieved from; http://www.talgaresources.com/irm/PDF/2056_0/GrapheneMalaysia2017Presentation.
9. Wicklein, B., Kocjan, A., Salazar-Alvarez, G., Carosio, F., Camino, G., Antonietti, M., & Bergström, L., Thermally insulating and fire-retardant lightweight anisotropic foams based on nanocellulose and graphene oxide. Nature nanotechnology, 2015. **10**(3), 277.