Thermal measurements of candidate thermal epoxy and thermal epoxy rubber.

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Abstract –

This note describes the thermal conductivity measurements of the two candidate epoxies: Epoxies, Etc #50-3170 (black flexible epoxy rubber) and Epoxies, Etc. #50-3100 (grey rigid epoxy). Both materials were exposed in an irradiation test at IBR-30 at JINR. The test setup is described and the thermal conductivity measurements are presented. There is no measurable change in the thermal conductivity between the non-irradiated and irradiated samples.

Introduction –

Since a good thermal connection between the cooling tabs and the readout electronics is required for operation of TRT, thermal epoxy will be used in the assembly of the electronics. Two types of thermal epoxy were considered: Epoxies, Etc #50-3170 (black flexible epoxy rubber) and Epoxies, Etc. #50-3100 (grey rigid epoxy).
Black epoxy rubber is more flexible than grey epoxy. Samples of the black rubber and the grey epoxy were irradiated in the reactor hall (IBR-30) at JINR. The measured particle flux was $8.0\text{x}10^6$ charged particles/sec*cm^2, $8.0\text{x}10^8$ photons/sec*cm^2 and $6.9\text{x}10^8$ photons/sec*cm^2. Further details about the radiation exposure can be found in a note written by Pauline Gagnon: http://pauline.home.cern.ch/pauline/publications/report.htm.
We measured the thermal conductivity of irradiated and non-irradiated samples of each type of epoxy. There were no significant mechanical changes to either epoxy after the irradiation. Neither material appeared to have been adversely effected by the radiation dose received. The black epoxy rubber is the preferred solution as it flexible, can be repaired and is designed for potting electronics packages. Table #1 shows information taken from the epoxy manufacturer's web
Site (http://www.epoxies.com/therm.htm).

Table 1 – List of properties for thermal epoxies tested.

THERMALLY CONDUCTIVE RESINS					
PRODUCT	DESCRIPTION	MIXED VISCOSITY CPS	THERMAL CONDUCTIVITY watts cm / (cm^2 °C)	TENSILE STRENGTH PSI	OPERATING TEMP. °C
50-3100 (Grey)	High thermal transfer epoxy resin. Has outstanding thermal shock and high temperature resistance. Flame retardant version available; 50-3100 FR.	180,000	0.022	8,800	-60 to +200
50-3170 (Black)	Highly filled thermally conductive epoxy rubber. Ideal for potting electronic packages with low stress requirements. 50-3170 is a repairable system.	15,000	0.017	2,500	-70 to +150

Experiment setup –

In order to measure the thermal conductivity of the epoxy samples the following setup was constructed for the measurement. The thermal epoxy was placed between a copper cylinder which contained a thermistor (Thermometrics # P60BB103N) and two 100 Ohm 1/4 watt resistors (in parallel) and a copper plate containing another thermistor. The resistors provided the heat for the setup. Figure 1 shows the copper block without thermistor or resistors, an example of the epoxy test samples and the aluminum block used as a heat sink. Using calibration data provided by the thermistor manufacturer, temperature dependence is given by the equation: $T = -22.727 \ln(R/R25) + 25.109$ (^{o}C) where R25 is resistance of the thermistors @ 25^{o}C. One thermistor was used to measure the aluminum plate and another was used to measure the air temperature. The voltage across the resistors and the resistance of the thermistors were read out using a Fluke data acquisition unit and free demonstration software (the software had a 60 minute time limit – hence the length of the tests presented here). The precision of the resistance measurement for each channel is 0.013% + 6 Ohms (30 KOhm full scale). The copper heater cylinder and sample under test were wrapped in insulation to direct the heat flow from the copper cylinder through the epoxy sample and into the thermal mass. Figure 2 shows the assembled setup. A thin layer of thermal grease was applied between the copper heater cylinder, the sample under test, the copper plate and the aluminum block. The entire sandwich was pressed together using a threaded nylon rod shown in figure 2. After the voltage was applied to the resistors the resistances of the thermistors were read out every 2 minutes for ~ 1 hour. The one-dimensional heat flow equation is $P = k*A*|dT/dx| = k*A*|(Ttop – Tbottom)/L|$, where P – power, A – area, L – length, Ttop – temperature at the top of the epoxy sample, Tbottom – temperature at the bottom of the epoxy sample and L – length of the epoxy sample.

Measurements –

Each epoxy sample was tested with three different power values. Most of the thermal conductivity measurements were made with constant voltage across the resistors. Some of the deviation in the thermal conductivity was attributed to the change in resistance as a function of temperature because the resistors were operated out of their power rating. Figure 3 - Figure 8 show the thermal conductivity measurements for the four samples tested as a function of time and for different input power. Table 1 contains the thermal conductivity measurements for each types of epoxy irradiated and non-irradiated with input power ~ 0.25 watts.

Table 2 - Thermal conductivity measurements for each type of epoxy including both irradiated and non-irradiated samples. Note – ¼ watt resistors were used as heat sources – most measurements described in this note were done with the power supply providing constant voltage to the resistors. One set of measurements were done providing constant current to the resistors because the resistance changed as the power increased.

Thermal Conductivity		
Power ~ 0.25 watts		
	Non-irradiated	Irradiated
Grey (constant voltage)	0.018 watts/(cm*^{o}K)	0.019 watts/(cm*^{o}K)
Black (constant voltage)	0.018 watts/(cm*^{o}K)	0.018 watts/(cm*^{o}K)
Black (constant current)		0.021 watts/(cm*^{o}K)

Conclusions –

There is no measurable change in the thermal conductivity between the non-irradiated and irradiated samples.

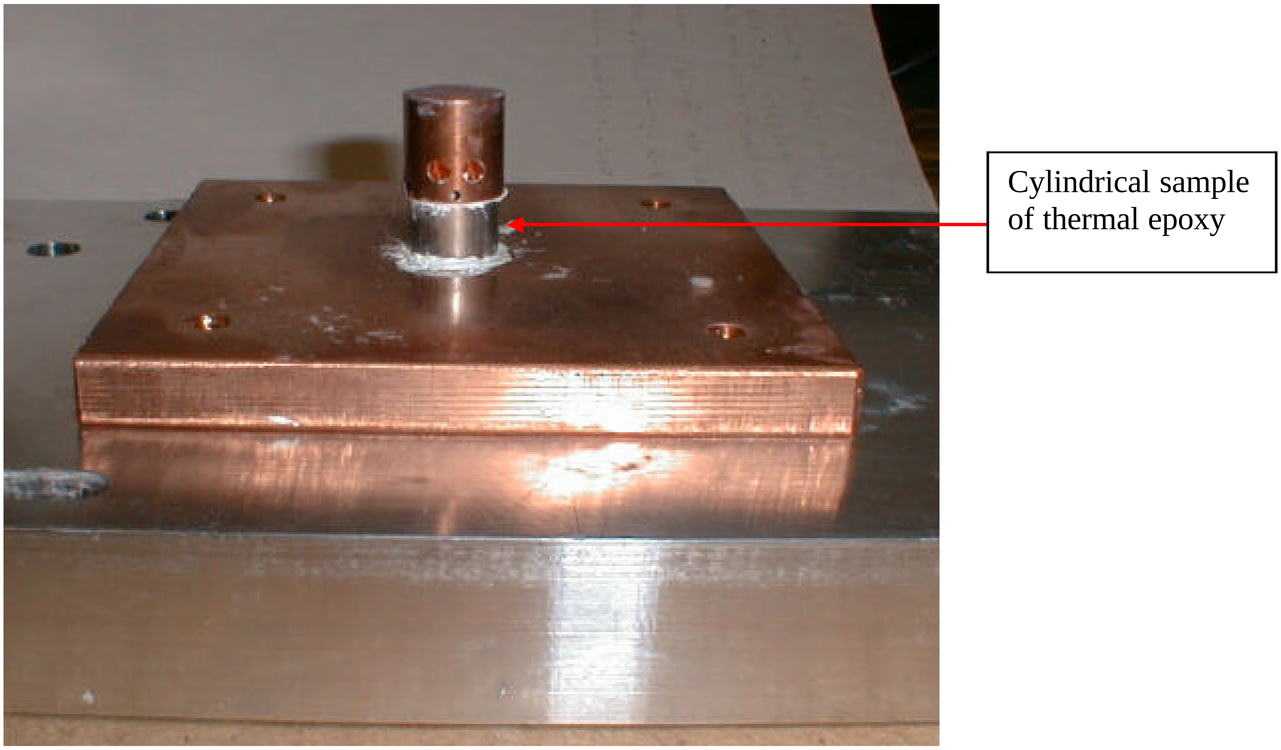

Figure 1 – This photograph shows the copper cylinder used as part of the heater unit. The two larger holes are for the 100 Ohm resistors that are used for heat sources. The small hole is for the thermistor which is used to measure the temperature. Below the copper cylinder is an epoxy sample. The copper plate below the epoxy sample under test has a thermistor (not shown) used to measure the temperature drop across the epoxy. Part of the aluminum bar used as a heat sink is shown. The white material is thermal grease.

Figure 2 – This photograph shows the assembled thermal conductivity test setup. The gray cylinder and white insulation surround the copper heater cylinder and epoxy sample shown in figure 1.

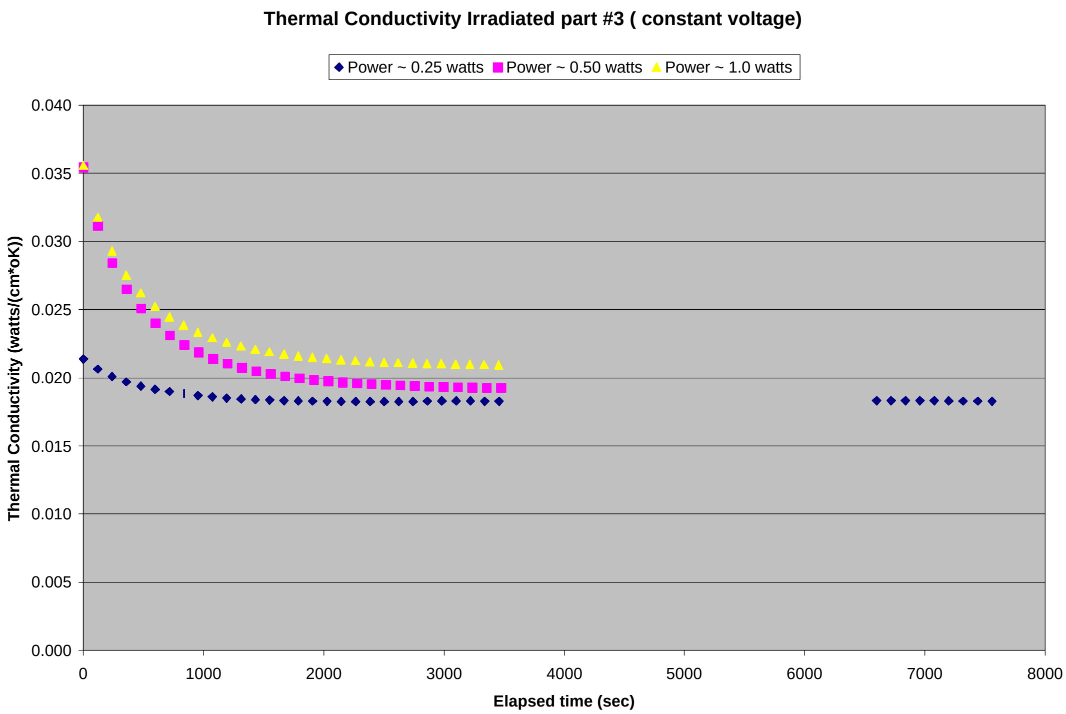

Figure 3 – Plot of thermal conductivity for epoxy sample #3 (irradiated sample of black rubber). Each group of points corresponds to constant voltage applied across the resistors of 3.6V, 5.1V and 7.2V. The deviation in the thermal conditivity can be attributed to variation of the resistors as they were heated.

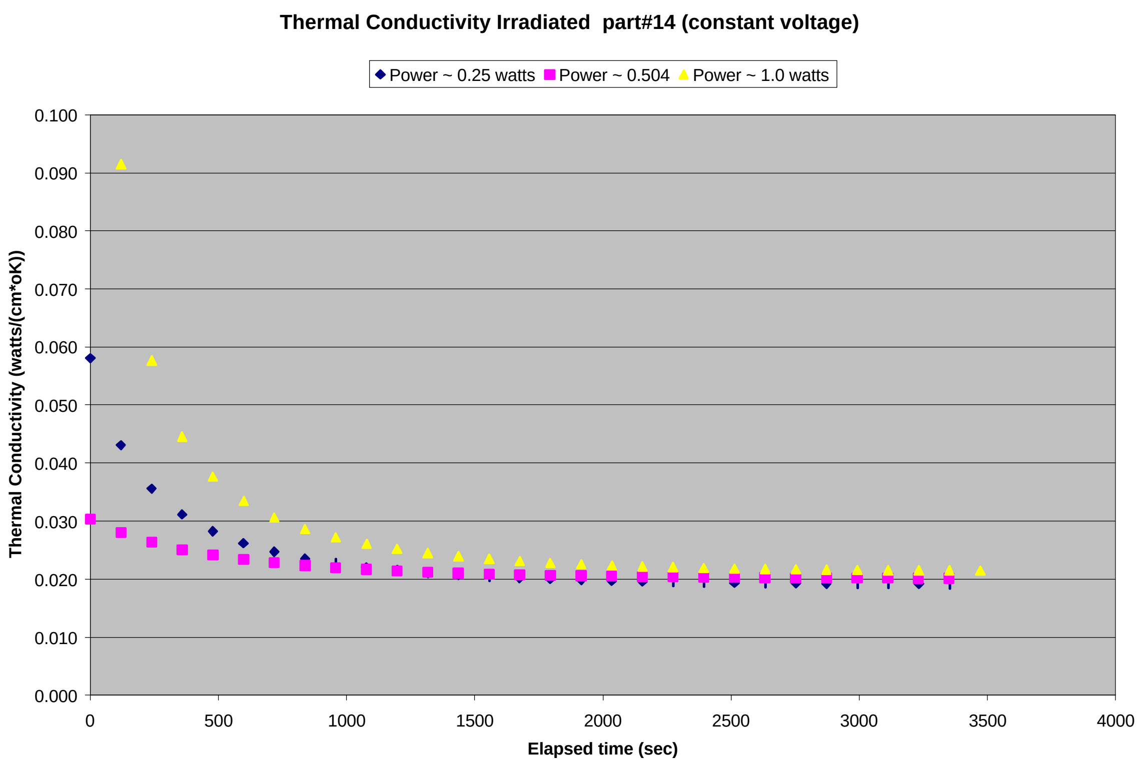

Figure 4 - Plot of thermal conductivity for epoxy sample #14 (irradiated sample of grey epoxy). Each group of points corresponds to constant voltage applied across the resistors of 3.6V, 5.1V and 7.2V.

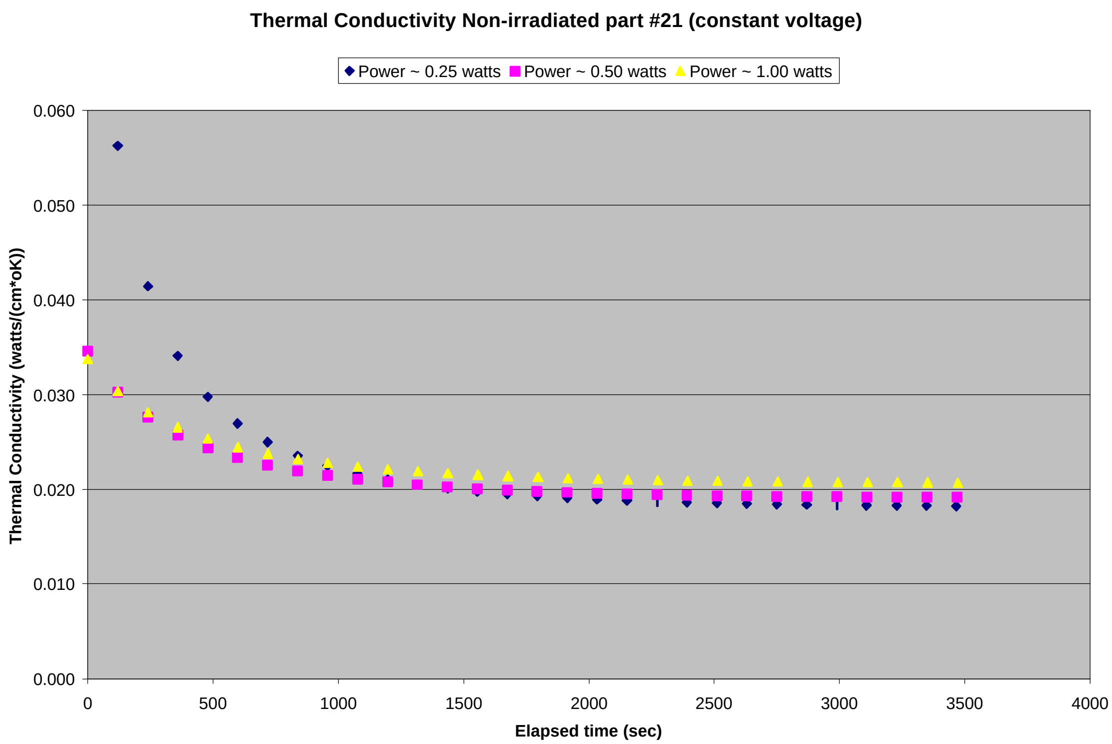

Figure 5 - Plot of thermal conductivity for epoxy sample #21 (irradiated sample of black rubber). Each group of points corresponds to constant voltage applied across the resistors of 3.6V, 5.1V and 7.2V.

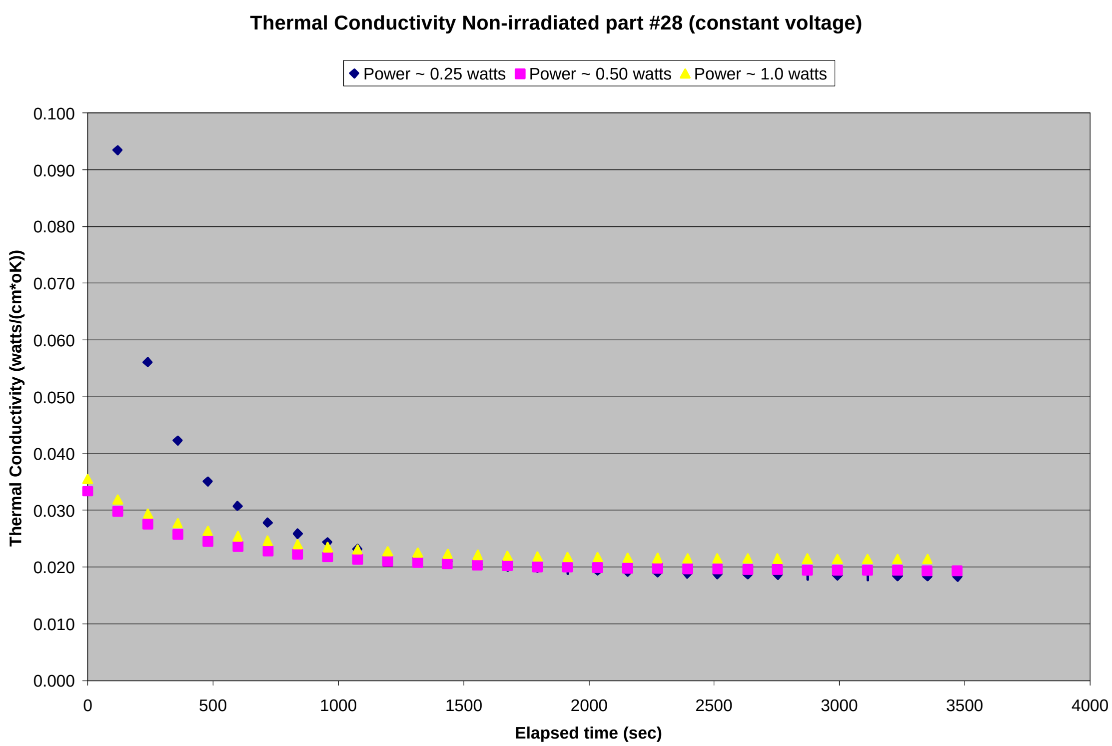

Figure 6- Plot of thermal conductivity for epoxy sample #28 (irradiated sample of grey epoxy). Each group of points corresponds to constant voltage applied across the resistors of 3.6V, 5.1V and 7.2V.

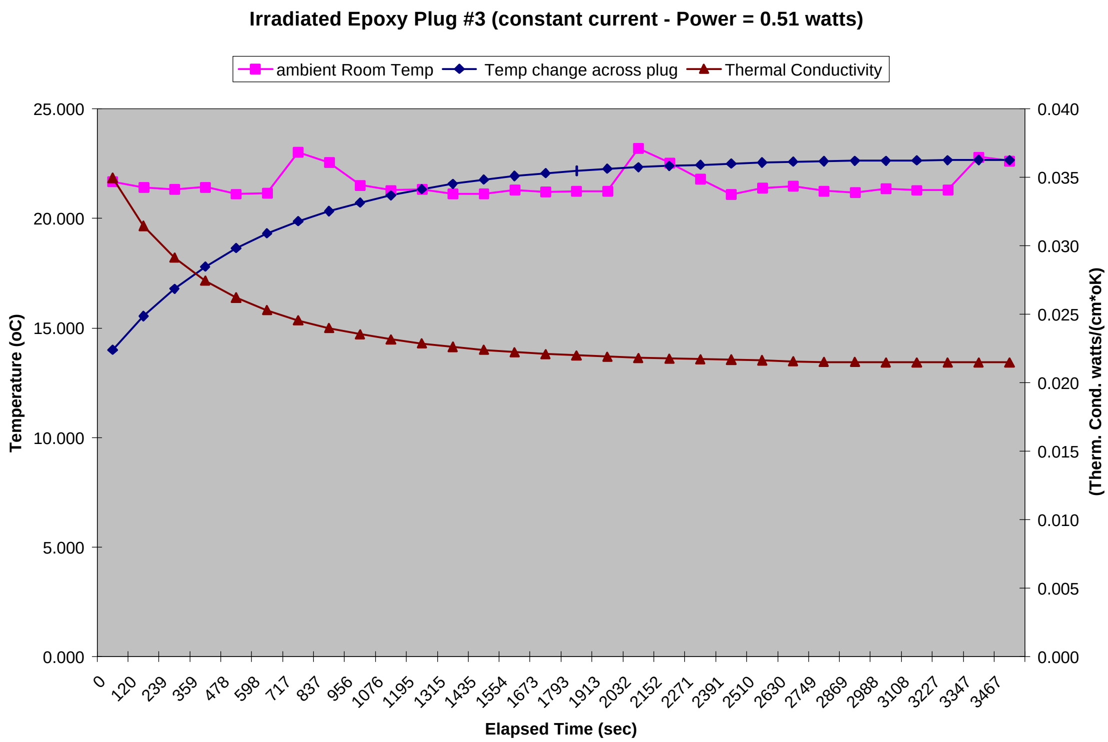

Figure 7 – Plot of temperature changes across the epoxy sample #3 (irradiated sample of black rubber), ambient room temperature and the corresponding thermal conductivity for the sample. These measurements were taken with constant current (100 ma) applied to the resistors. The resistors were used as heat sources.

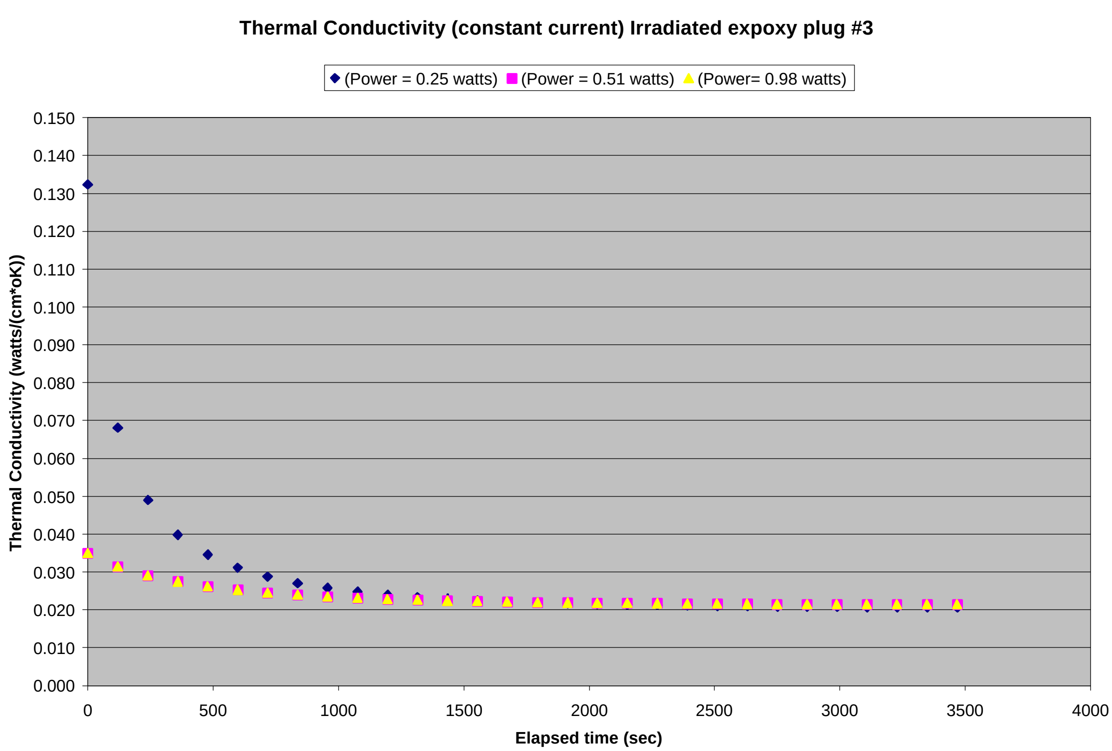

Figure 8 – Plot of thermal conductivity for the irradiated epoxy sample #3 (Black rubber). These measurements were taken with three different current settings (70ma, 100ma and 140ma).