Appendix A

Peltier Element

Peltier devices, also known as thermoelectric (TE) modules, are small solid-state devices that function as heat pumps that operate on the Peltier effect., the theory that there is a heating or cooling effect when electric current passes through two conductors. A typical unit is a few millimeters thick by a few millimeters to a few centimeters square. It is a sandwich formed by two ceramic plates with an array of small Bismuth Telluride cubes ("couples") in between. When a DC current is applied heat will moved from one side of the device to the other where it must be removed with a heatsink. The cold side is commonly used to cool an electronic device such as a microprocessor or a photodetector. If the current is reversed the device makes an excellent heater. As with any device, TE modules work best when applied properly. They are not meant to serve as room air conditioners. They are best suited to smaller cooling applications, although they are used in applications as large as portable picnic-type coolers. They can be stacked to achieve a lower temperatures, although reaching cryogenic temperatures would require a great care.

A applied voltage to the free ends of two dissimilar materials creates a temperature difference. With this temperature difference, Peltier effect will cause heat to move from one end to the other. A typical thermoelectric cooler will consist of an array of p- and n-type semiconductor elements that act as the two dissimilar conductors. The array of elements is soldered between two ceramic plates, electrically in series and thermally in parallel. As a DC current passes through one or more pairs of elements from n- to p- there is a decrease in temperature at the junction ("cold side") resulting in the absorption of heat from the environment. The heat is carried through the cooler by electron transport and released on the opposite ("hot side") side as the electrons move from a high to low energy state. The heat pumping capacity of a cooler is proportional to the current and the number of pairs of n-and p-type elements (or couples).

Appendix B

Material properties of epoxy

Material Properties	Unit	LY5318 /HY5318	Standard Deviation
Dielectric Properties			
ε @ 1 kHz	1	5.048	0.334
Dissipation Factor, tan δ	%	2.250	0.071
Density	kg/m^3	1150	12.0
Acoustic velocity			
υ_L	m/s	2450	105.1
υ_s	m/s	1123	115.5
Acoustic impedance			
Z_L	$10^6\ kg/m^2 s$	2.817	0.121
Z_S	$10^6\ kg/m^2 s$	1.291	0.133
Stiffness			
$c_{11} = c_{22} = c_{33}$	$10^9 Pa$	6.911	0.581
$c_{44} = c_{55} = c_{66}$	$10^9 Pa$	1.460	0.311
$c_{12} = c_{21} = c_{13} = c_{31} = c_{23} = c_{32}$	$10^9 Pa$	3.991	0.676
Compliance			
$s_{11} = s_{22} = s_{33}$	$10^{-12}\ m^2/N$	257.7	41.79
$s_{44} = s_{55} = s_{66}$	$10^{-12}\ m^2/N$	705.3	128.1
$s_{12} = s_{21} = s_{13} = s_{31} = s_{23} = s_{32}$	$10^{-12}\ m^2/N$	-94.92	22.50
Modulus			
Shear modulus	$10^{10} Pa$	0.146	0.031
Bulk modulus	$10^{10} Pa$	0.496	0.058
Young's modulus	$10^{10} Pa$	0.397	0.075
Mechanical quality factor, Q_m	1	24.65	1.10

Appendix C

Heat capacity

Heat capacity is the quantity of heat required to increase the temperature of the substance one-degree of temperature. The heat capacity refers to the ability of a material to store heat and is a mass independent property. DSC instrument is its ability to measure heat capacity which are both accurate and precise.

The heat flow is going to be show in unit of heat (*q*) supplied per unit time (*t*). The heating rate is temperature rate is temperature increase per unit time.

$$\frac{heat}{time} = \frac{q}{t} = heat\ flow \tag{1}$$

$$\frac{temperature\ increase}{time} = \frac{\Delta T}{t} = heating\ rate \tag{2}$$

$$\frac{\frac{q}{t}}{\frac{\Delta T}{t}} = \frac{q}{\Delta t} = c_p = heat\ capacity \tag{3}$$

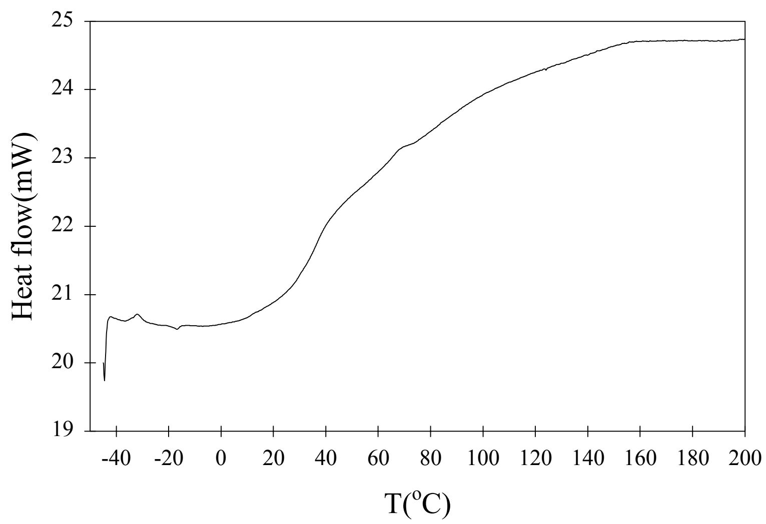

Figure A.1 Heat flow plotted as a function of the temperature of the 1-3 composite PZT/epoxy ($\phi = 0.4$)

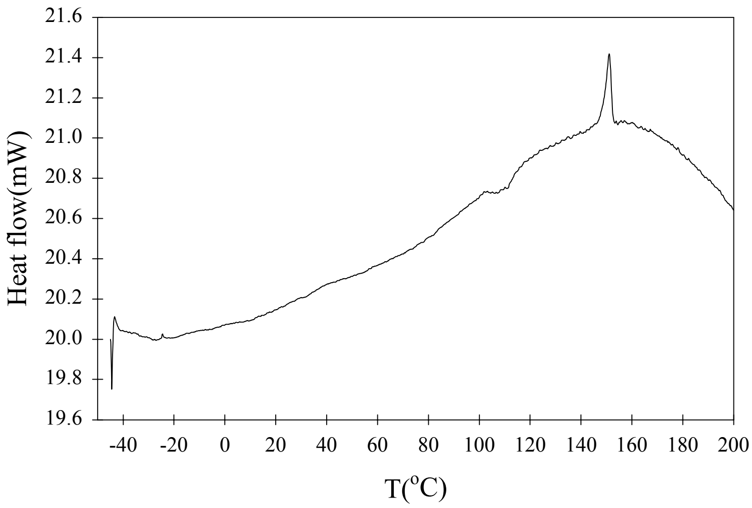

Figure A.2 Heat flow plotted as a function of the temperature of the 0-3 composite PZT/P(VDF-TrFE) ($\phi = 0.3$)

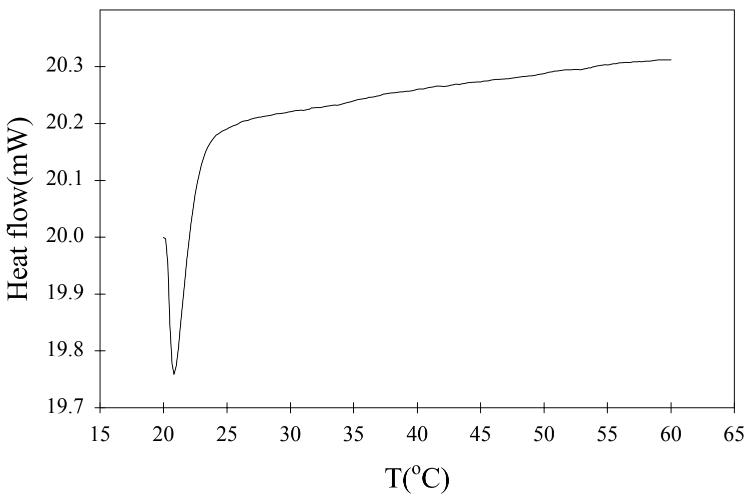

Figure A.3 Heat flow plotted as a function of the temperature of epoxy

Table A.1 Heat capacity of 1-3 composite PZT/epoxy (ϕ=0.4)

Temperature(°C)	heat capacity (J/kg °C)
20.00	211.66
20.17	211.70
20.33	211.73
20.50	211.77
20.67	211.81
20.83	211.85
21.00	211.90
21.17	211.95
21.33	212.00
21.50	212.05
21.67	212.09
21.83	212.15
22.00	212.20
22.17	212.26
22.33	212.30
22.50	212.35
22.67	212.40
22.83	212.45
23.00	212.50
23.17	212.56
23.33	212.62
23.50	212.67
23.67	212.72
23.83	212.77
24.00	212.84
24.17	212.91
24.33	212.98
24.50	213.03
24.67	213.08
24.83	213.14
25.00	213.20

Temperature(°C)	Heat capacity (J/kg °C)
25.17	213.27
25.33	213.36
25.50	213.43
25.67	213.48
25.83	213.53
26.00	213.59
26.17	213.65
26.33	213.72
26.50	213.79
26.67	213.87
26.83	213.94
27.00	214.00
27.17	214.07
27.33	214.16
27.50	214.24
27.67	214.34
27.83	214.41
28.00	214.49
28.17	214.58
28.33	214.66
28.50	214.76
28.67	214.85
28.83	214.95
29.00	215.05
29.17	215.15
29.33	215.25
29.50	215.36
29.67	215.48
29.83	215.58
30.00	215.69

Table A.2 Heat capacity of 0-3 composite PZT/P(VDF-TrFE) (ϕ =0.3)

Temperature (^oC)	heat capacity (J/kg ^oC)
20.17	2731.85
20.33	2731.98
20.50	2748.53
20.67	2732.04
20.83	2732.33
21.00	2749.03
21.17	2732.65
21.33	2733.17
21.50	2749.72
21.67	2733.14
21.83	2733.58
22.00	2750.26
22.17	2733.79
22.33	2733.96
22.50	2750.33
22.67	2733.55
22.83	2733.69
23.00	2750.29
23.17	2733.89
23.33	2734.26
23.50	2750.86
23.67	2734.27
23.83	2734.64
24.00	2751.36
24.17	2735.00
24.33	2735.44
24.50	2752.13
24.67	2735.65
24.83	2735.94
25.00	2752.59

Temperature (^oC)	heat capacity (J/kg ^oC)
25.17	2736.14
25.33	2736.63
25.50	2753.28
25.67	2736.64
25.83	2736.89
26.00	2753.47
26.17	2736.90
26.33	2737.20
26.50	2753.77
26.67	2737.21
26.83	2737.50
27.00	2754.00
27.17	2737.32
27.33	2737.57
27.50	2754.30
27.67	2737.96
27.83	2738.25
28.00	2754.96
28.17	2738.50
28.33	2738.83
28.50	2755.57
28.67	2739.03
28.83	2739.32
29.00	2755.91
29.17	2739.26
29.33	2739.51
29.50	2756.14
29.67	2739.71
29.83	2739.92
30.00	2756.56

Table A.3 Heat capacity of epoxy

Temperature(^{o}C)	heat capacity (J/kg ^{o}C)
20.17	2750.64
20.33	2744.30
20.50	2730.16
20.67	2720.43
20.83	2717.82
21.00	2719.81
21.17	2724.17
21.33	2729.42
21.50	2734.91
21.67	2740.40
21.83	2745.50
22.00	2750.10
22.17	2754.26
22.33	2758.00
22.50	2761.35
22.67	2764.23
22.83	2766.64
23.00	2768.67
23.17	2770.34
23.33	2771.74
23.50	2772.87
23.67	2773.81
23.83	2774.55
24.00	2775.25
24.17	2775.75
24.33	2776.11
24.50	2776.50
24.67	2776.73
24.83	2777.04
25.00	2777.23

Temperature(^{o}C)	heat capacity (J/kg ^{o}C)
25.17	2777.54
25.33	2777.78
25.50	2778.01
25.67	2778.17
25.83	2778.44
26.00	2778.71
26.17	2778.99
26.33	2779.18
26.50	2779.26
26.67	2779.38
26.83	2779.57
27.00	2779.72
27.17	2779.84
27.33	2779.96
27.50	2780.08
27.67	2780.12
27.83	2780.23
28.00	2780.35
28.17	2780.43
28.33	2780.50
28.50	2780.58
28.67	2780.74
28.83	2780.85
29.00	2780.93
29.17	2780.97
29.33	2781.05
29.50	2781.13
29.67	2781.17
29.83	2781.32
30.00	2781.40

Vitae

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Publications :

Yaowaluck Phermponsagul and Supasarote Muensit. 2545. "Pyroelectric properties of PZT/epoxy 1-3 composites" Proceeding of The Second Thailand Materials Science and Technology Conference, 6-7 August, Bangkok

Y. Phermponsakul, S. Muensit and I.L.Guy. 2002 "Piezoelectricity of 1-3 PZT/epoxy Composites" Proceeding of 11th International Symposium on Electrets, 1-3 October 2002, Melbourne, Australia.

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