MP309

Experiment 12

Resistivity by Four Probe Method

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List of Figures

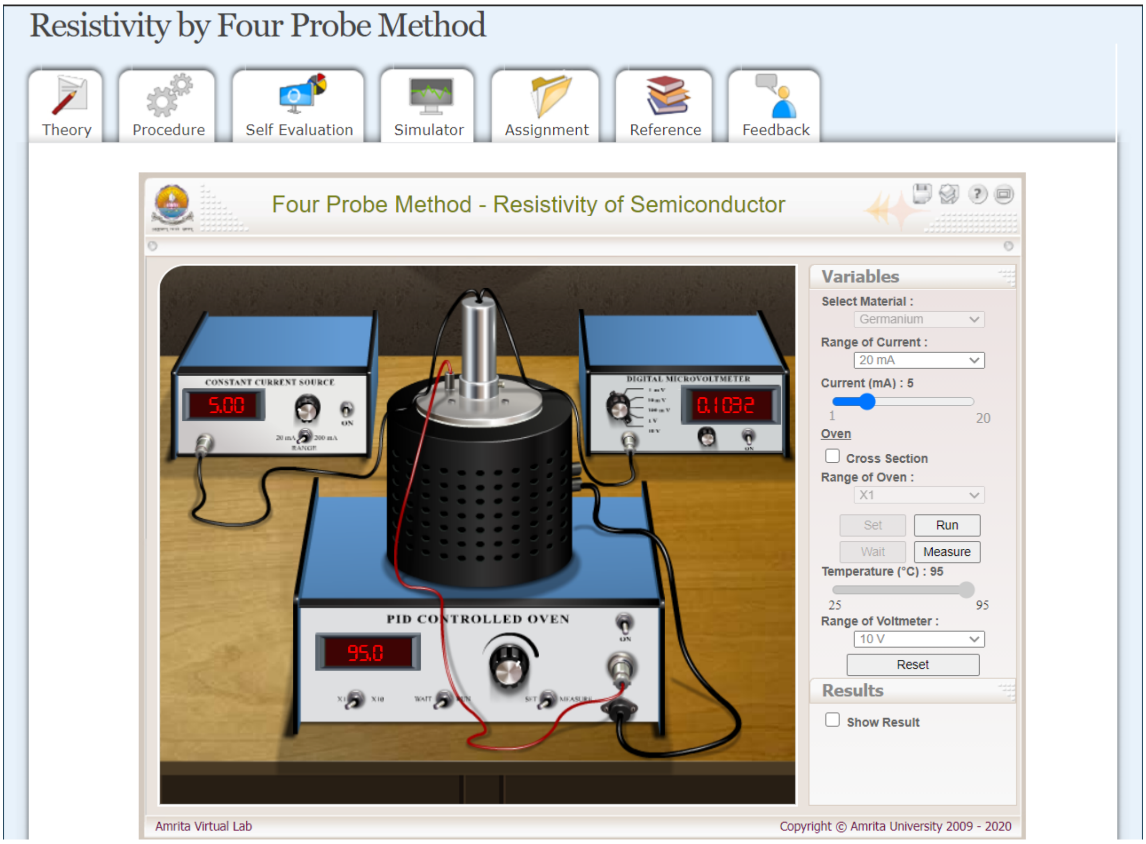

Figure 1: Four Probe instument

Four Probe Circuit Connections

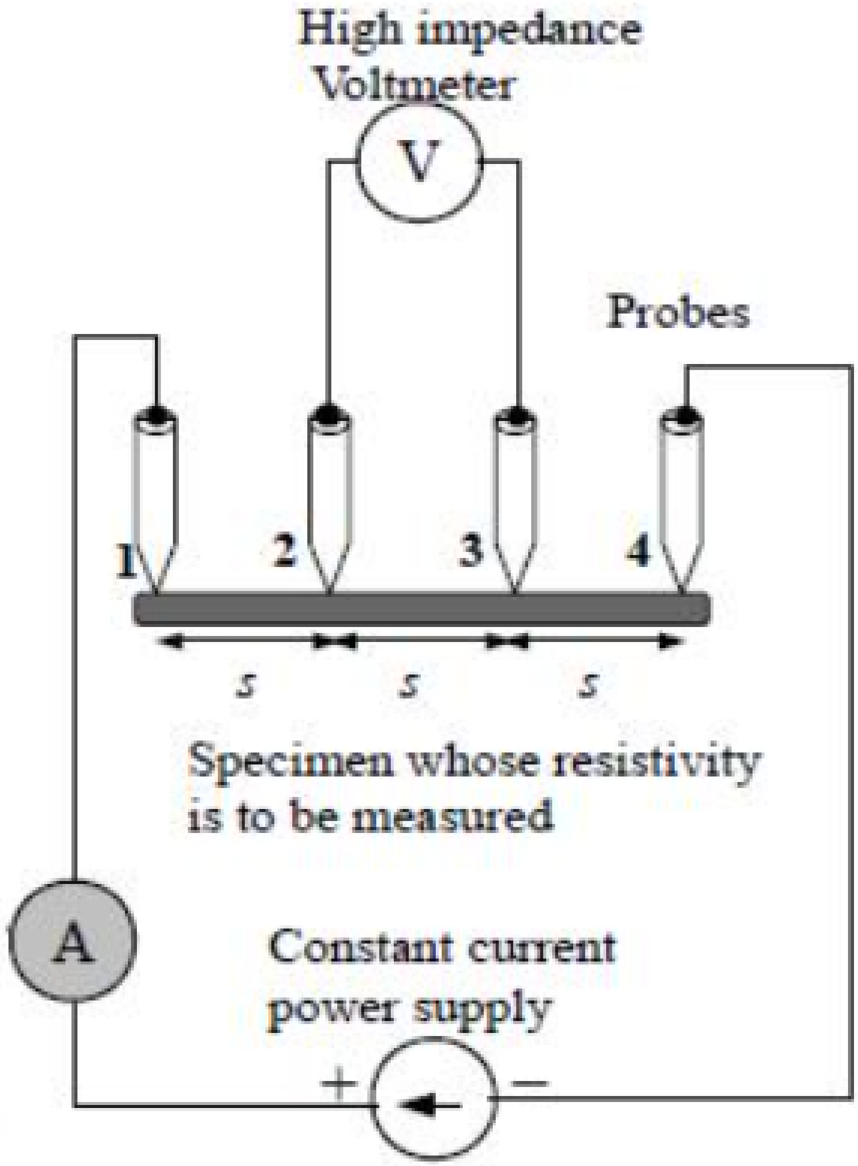

Figure 2: Arrangement of four probes that measure Voltage (V) and supply current (A) to the surface of crystal

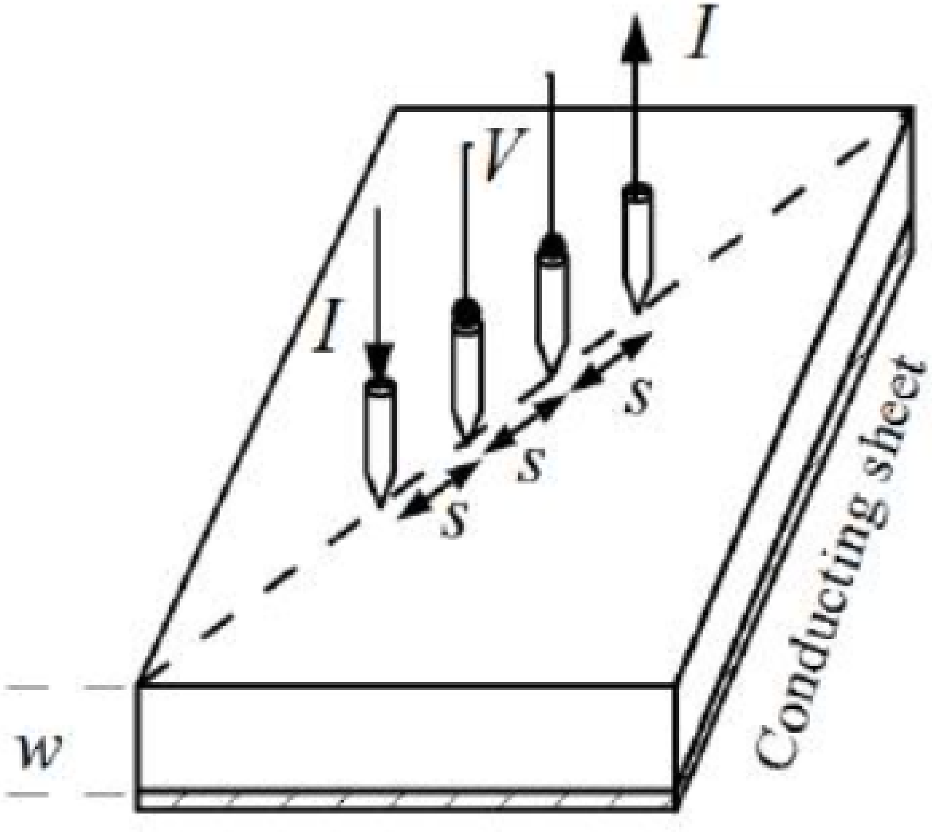

Figure 3: Four Probe on Conducting Sheet

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	0.1454	6.2011	3.354016435	0.7924687349
30	0.1419	6.0531	3.298697015	0.7819778487
35	0.1378	5.8753	3.245172805	0.7690300471
40	0.134	5.7136	3.193357816	0.7569098328
45	0.1303	5.5588	3.14317146	0.7449810488
50	0.1269	5.4125	3.09453814	0.7333979094
55	0.1237	5.2748	3.047386866	0.7222059975
60	0.1206	5.1443	3.001650908	0.7113262874
65	0.1177	5.0206	2.957267485	0.7007556218
70	0.115	4.9047	2.914177473	0.6906124485
75	0.1124	4.7924	2.872325147	0.6805530595
80	0.1099	4.6871	2.831657936	0.6709042194
85	0.1075	4.5869	2.792126204	0.6615192721
90	0.1053	4.4913	2.753683051	0.6523720651
95	0.1032	4.4001	2.716284123	0.6434625467

Figure 4: Observation Table of Germanium for i=5mA

Graph of Germanium for i=5mA

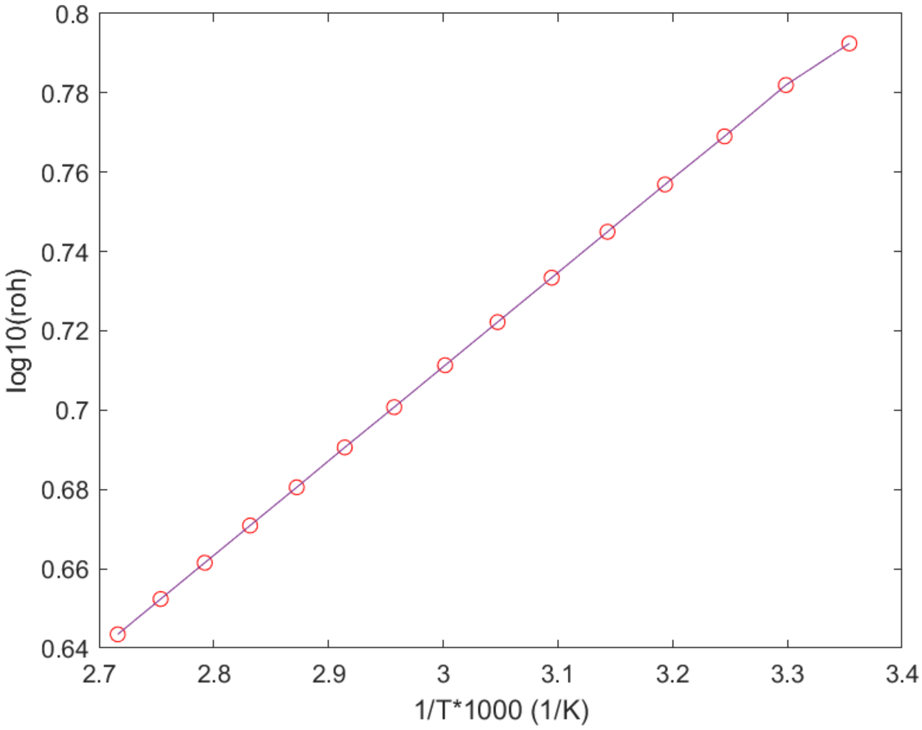

Figure 5: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	0.2908	6.2011	3.354016435	0.7924687349
30	0.2839	6.0531	3.298697015	0.7819778487
35	0.2756	5.878	3.245172805	0.7692295817
40	0.2679	5.7136	3.193357816	0.7569098328
45	0.2607	5.5586	3.14317146	0.7449654231
50	0.2538	5.4138	3.09453814	0.7335022078
55	0.2473	5.276	3.047386866	0.7223047869
60	0.2412	5.1441	3.001650908	0.7113094026
65	0.2354	5.0206	2.957267485	0.7007556218
70	0.2299	4.9035	2.914177473	0.6905061796
75	0.2247	4.7924	2.872325147	0.6805530595
80	0.2198	4.6871	2.831657936	0.6709042194
85	0.2151	4.5866	2.792126204	0.6614908667
90	0.2106	4.4911	2.753683051	0.6523527253
95	0.2064	4.4003	2.716284123	0.6434822865

Figure 6: Observation Table of Germanium for i=10mA

Graph of Germanium for i=10mA

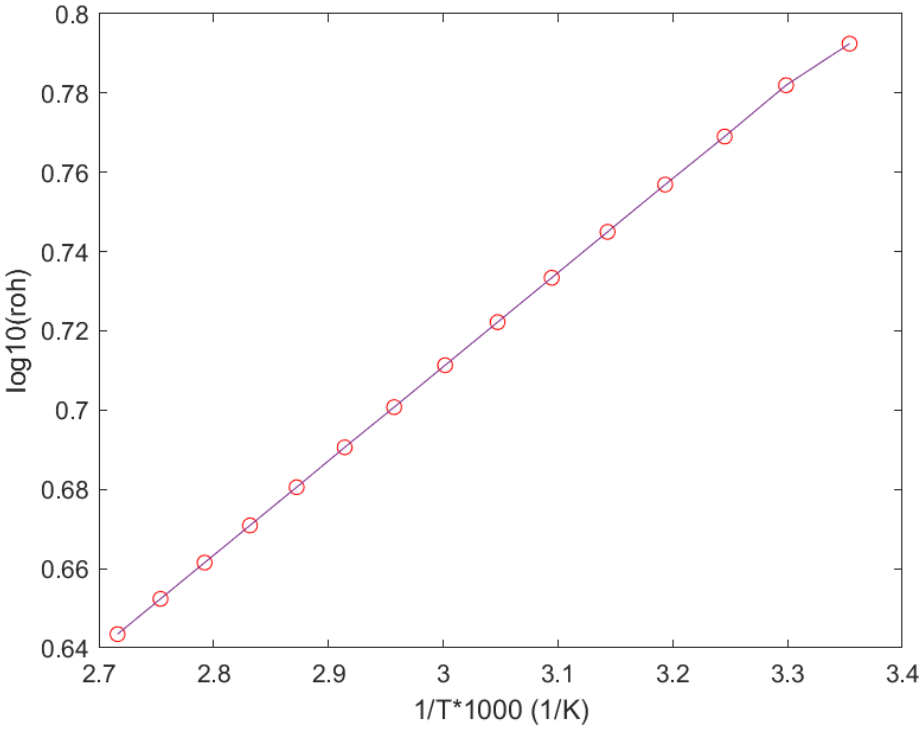

Figure 7: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T < 363°K, conduction is due to impurity carriers (extrinsic region), for T > 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–

$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–

$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	0.5816	6.2011	3.354016435	0.7924687349
30	0.5677	6.053	3.298697015	0.7819706739
35	0.5513	5.878	3.245172805	0.7692295817
40	0.5359	5.7136	3.193357816	0.7569098328
45	0.5213	5.5587	3.14317146	0.744973236
50	0.5076	5.4125	3.09453814	0.7333979094
55	0.4947	5.2746	3.047386866	0.7221895304
60	0.4825	5.1442	3.001650908	0.7113178451
65	0.4709	5.0206	2.957267485	0.7007556218
70	0.4599	4.9036	2.914177473	0.6905150364
75	0.4495	4.7925	2.872325147	0.6805621216
80	0.4396	4.687	2.831657936	0.6708949535
85	0.4302	4.5867	2.792126204	0.6615003354
90	0.4212	4.4912	2.753683051	0.6523623953
95	0.4127	4.4003	2.716284123	0.6434822865

Figure 8: Observation Table of Germanium for i=20mA

Graph of Germanium for i=20mA

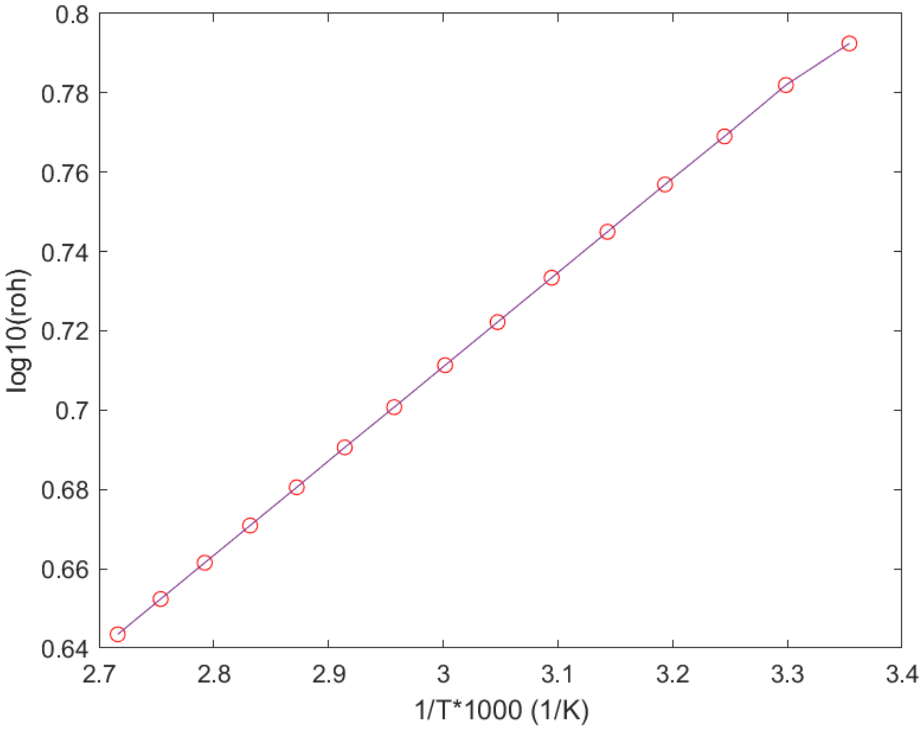

Figure 9: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T < 363°K, conduction is due to impurity carriers (extrinsic region), for T > 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–

$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–

$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$

$= Slope \times 2.3026 \times 10^3 \times 2K$

$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$

$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	1.1923	6.2011	3.354016435	0.7924687349
30	1.1638	6.053	3.298697015	0.7819706739
35	1.1307	5.8781	3.245172805	0.7692369701
40	1.0985	5.7136	3.193357816	0.7569098328
45	1.0688	5.5587	3.14317146	0.744973236
50	1.0407	5.4126	3.09453814	0.7334059332
55	1.0141	5.2744	3.047386866	0.7221730627
60	0.9891	5.1441	3.001650908	0.7113094026
65	0.9653	5.0206	2.957267485	0.7007556218
70	0.9428	4.9036	2.914177473	0.6905150364
75	0.9214	4.7925	2.872325147	0.6805621216
80	0.9012	4.687	2.831657936	0.6708949535
85	0.8819	4.5867	2.792126204	0.6615003354
90	0.8635	4.4912	2.753683051	0.6523623953
95	0.846	4.4002	2.716284123	0.6434724167

Figure 10: Observation Table of Germanium for i=41mA

Graph of Germanium for i=41mA

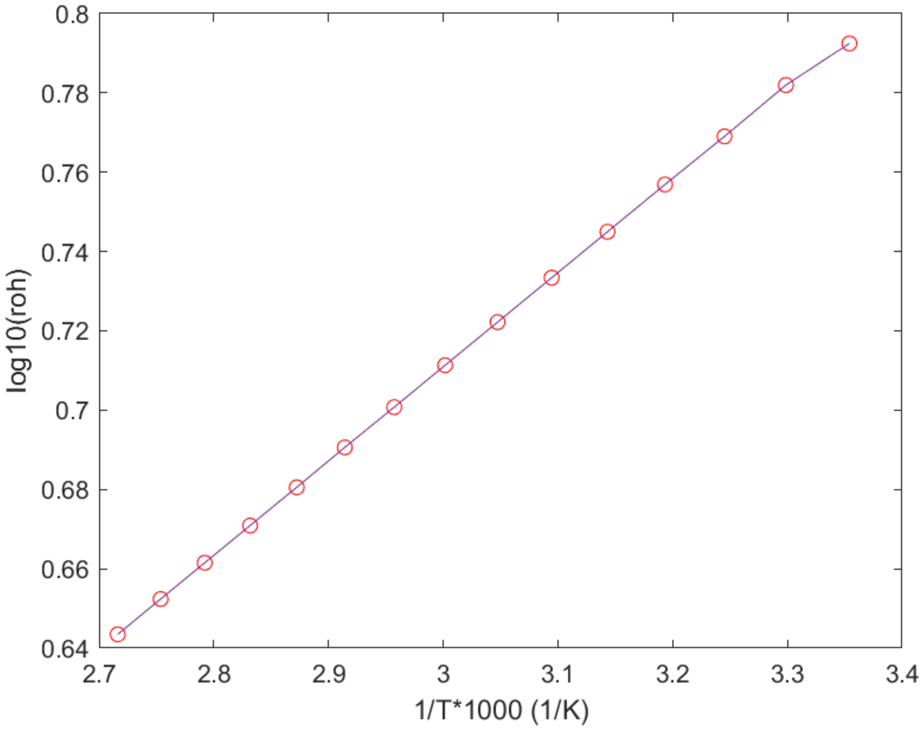

Figure 11: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	2.3555	6.2011	3.354016435	0.7924687349
30	2.2992	6.053	3.298697015	0.7819706739
35	2.2328	5.8781	3.245172805	0.7692369701
40	2.1703	5.7136	3.193357816	0.7569098328
45	2.1114	5.5587	3.14317146	0.744973236
50	2.0559	5.4125	3.09453814	0.7333979094
55	2.0035	5.2746	3.047386866	0.7221895304
60	1.954	5.1441	3.001650908	0.7113094026
65	1.9071	5.0206	2.957267485	0.7007556218
70	1.8626	4.9036	2.914177473	0.6905150364
75	1.8204	4.7925	2.872325147	0.6805621216
80	1.7804	4.687	2.831657936	0.6708949535
85	1.7423	4.5867	2.792126204	0.6615003354
90	1.706	4.4912	2.753683051	0.6523623953
95	1.6714	4.4002	2.716284123	0.6434724167

Figure 12: Observation Table of Germanium for i=81mA

Graph of Germanium for i=81mA

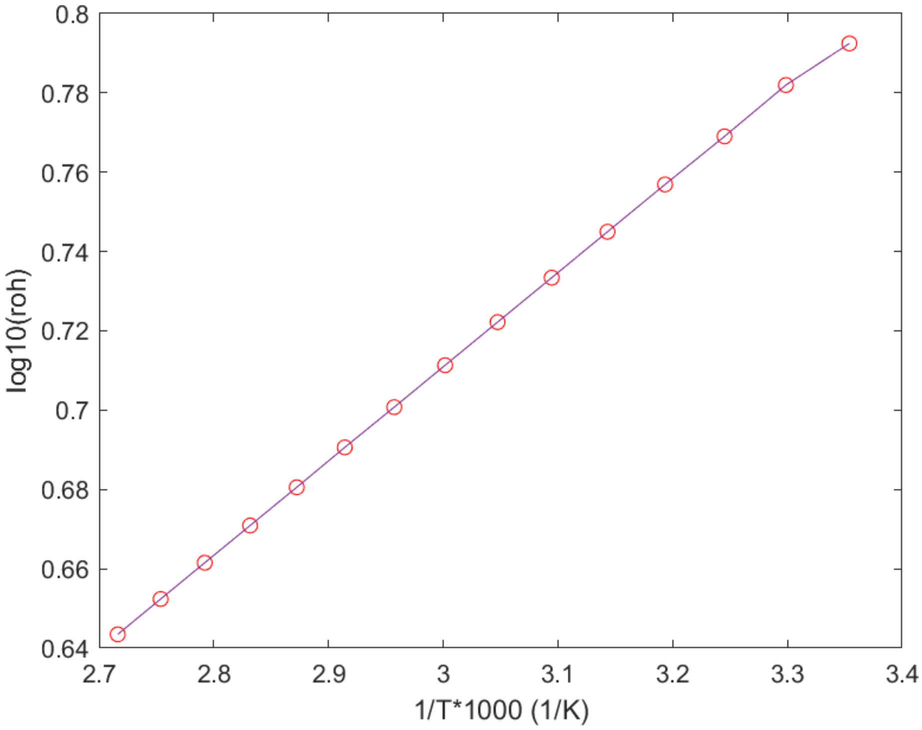

Figure 13: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–
$E_g = \frac{log_e\rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$=1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	2.9371	6.2011	3.354016435	0.7924687349
30	2.8669	6.053	3.298697015	0.7819706739
35	2.7841	5.8781	3.245172805	0.7692369701
40	2.7062	5.7136	3.193357816	0.7569098328
45	2.6328	5.5586	3.14317146	0.7449654231
50	2.5636	5.4125	3.09453814	0.7333979094
55	2.4983	5.2746	3.047386866	0.7221895304
60	2.4365	5.1441	3.001650908	0.7113094026
65	2.378	5.0206	2.957267485	0.7007556218
70	2.3225	4.9036	2.914177473	0.6905150364
75	2.2699	4.7925	2.872325147	0.6805621216
80	2.2199	4.687	2.831657936	0.6708949535
85	2.1724	4.5876	2.792126204	0.6615855441
90	2.1272	4.4912	2.753683051	0.6523623953
95	2.0841	4.4002	2.716284123	0.6434724167

Figure 14: Observation Table of Germanium for i=101mA

Graph of Germanium for i=101mA

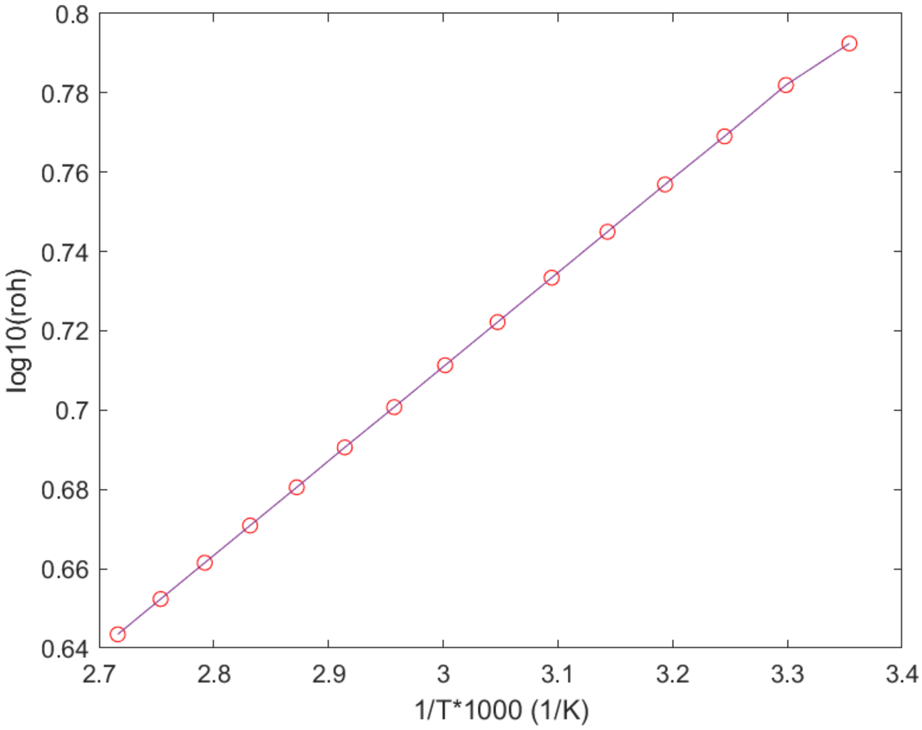

Figure 15: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T < 363°K, conduction is due to impurity carriers (extrinsic region), for T > 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–
$E_g = \frac{log_e\rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

B	C	D	E	F
Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	4.3911	6.2011	3.354016435	0.7924687349
30	4.2862	6.053	3.298697015	0.7819706739
35	4.1623	5.8781	3.245172805	0.7692369701
40	4.0459	5.7136	3.193357816	0.7569098328
45	3.9362	5.5587	3.14317146	0.744973236
50	3.8327	5.4126	3.09453814	0.7334059332
55	3.735	5.2746	3.047386866	0.7221895304
60	3.6426	5.1441	3.001650908	0.7113094026
65	3.5552	5.0206	2.957267485	0.7007556218
70	3.4723	4.9036	2.914177473	0.6905150364
75	3.3936	4.7925	2.872325147	0.6805621216
80	3.3189	4.687	2.831657936	0.6708949535
85	3.2479	4.5867	2.792126204	0.6615003354
90	3.1803	4.4912	2.753683051	0.6523623953
95	3.1159	4.4002	2.716284123	0.6434724167

Figure 16: Observation Table of Germanium for i=151mA

Graph of Germanium for i=151mA

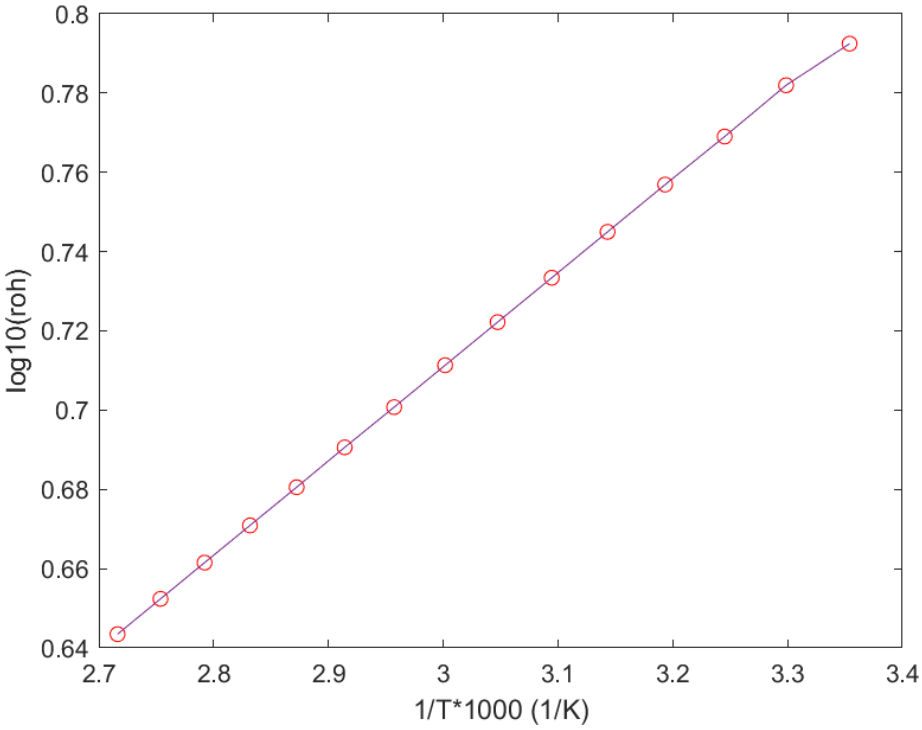

Figure 17: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	5.8451	6.2011	3.354016435	0.7924687349
30	5.7055	6.053	3.298697015	0.7819706739
35	5.5406	5.8781	3.245172805	0.7692369701
40	5.3856	5.7136	3.193357816	0.7569098328
45	5.2395	5.5587	3.14317146	0.744973236
50	5.1018	5.4126	3.09453814	0.7334059332
55	4.9718	5.2746	3.047386866	0.7221895304
60	4.8488	5.1441	3.001650908	0.7113094026
65	4.7324	5.0206	2.957267485	0.7007556218
70	4.622	4.9036	2.914177473	0.6905150364
75	4.5104	4.7923	2.872325147	0.6805439972
80	4.4179	4.687	2.831657936	0.6708949535
85	4.3234	4.5867	2.792126204	0.6615003354
90	4.2334	4.4912	2.753683051	0.6523623953
95	4.1476	4.4002	2.716284123	0.6434724167

Figure 18: Observation Table of Germanium for i=200mA

Graph of Germanium for i=200mA

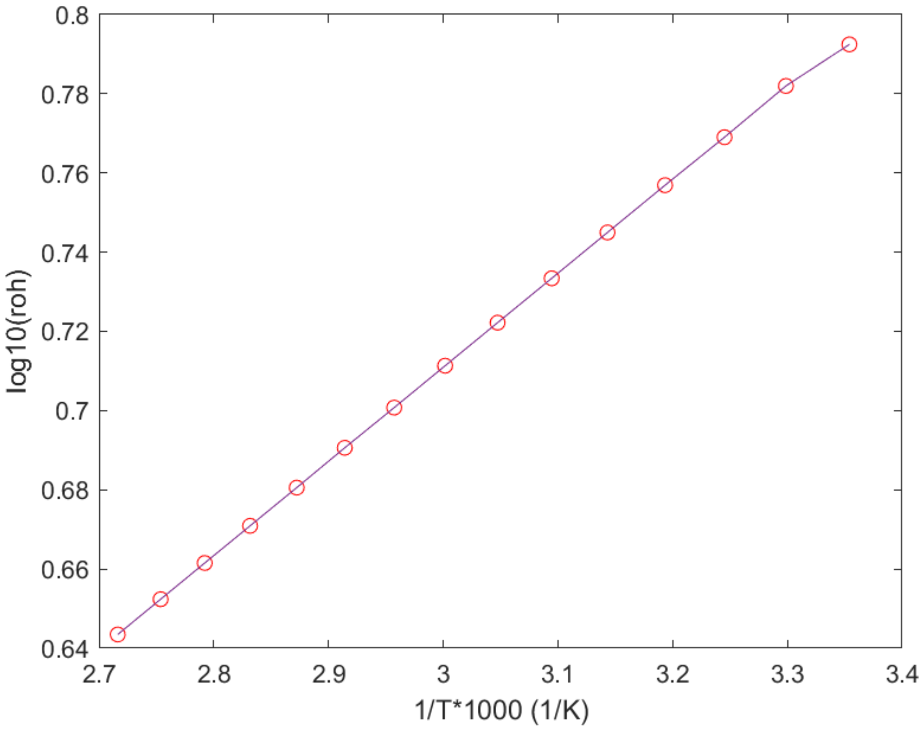

Figure 19: The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (0.6435 - 0.000)/(2.7174 - 2.3371) = 1.6921K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 1.6921 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 0.6702eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	rho (ohm cm)	rho (ohm cm)
25	0.6328	26.988	3.354016435	1.431170701
30	0.6058	25.8356	3.298697015	1.412218552
35	0.5749	24.5029	3.245172805	1.389217488
40	0.5458	23.2784	3.193357816	1.366953127
45	0.5194	22.1508	3.14317146	1.345389416
50	0.495	21.1106	3.09453814	1.324500577
55	0.4724	20.1489	3.047386866	1.304251341
60	0.4516	19.258	3.001650908	1.284611182
65	0.4322	18.431	2.957267485	1.265548899
70	0.4141	17.662	2.914177473	1.24703988
75	0.3974	16.9464	2.872325147	1.229077453
80	0.3817	16.2785	2.831657936	1.211614384
85	0.3671	15.655	2.792126204	1.194653072
90	0.3534	15.0711	2.753683051	1.178144951
95	0.3406	14.5244	2.716284123	1.162098201

Figure 20: Obseration Table of Silicon for i=5mA

Graph of Silicon for i=5mA

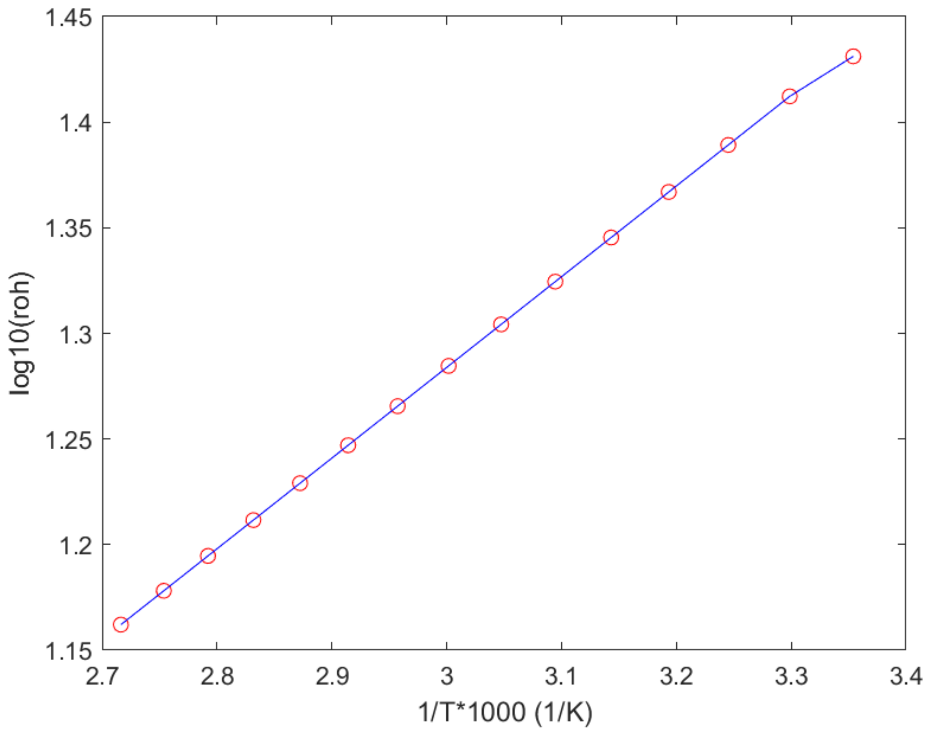

Figure 21: The resistivity of a Silicon crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (1.1621 - 0.000)/(2.7174 - 2.3137) = 2.8786K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 2.8786 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 1.1401eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	rho (ohm cm)	rho (ohm cm)
25	1.2656	26.9882	3.354016435	1.43117392
30	1.2116	25.8356	3.298697015	1.412218552
35	1.1491	24.5029	3.245172805	1.389217488
40	1.0916	23.2784	3.193357816	1.366953127
45	1.0388	22.251	3.14317146	1.347349534
50	0.99	21.1106	3.09453814	1.324500577
55	0.9449	20.1489	3.047386866	1.304251341
60	0.9031	19.2577	3.001650908	1.284604417
65	0.8643	18.431	2.957267485	1.265548899
70	0.8283	17.6623	2.914177473	1.247047257
75	0.7947	16.9464	2.872325147	1.229077453
80	0.7634	16.2787	2.831657936	1.21161972
85	0.7341	15.6548	2.792126204	1.194647524
90	0.7068	15.0711	2.753683051	1.178144951
95	0.6811	14.5244	2.716284123	1.162098201

Figure 22: Obseration Table of Silicon for i=10mA

Graph of Silicon for i=10mA

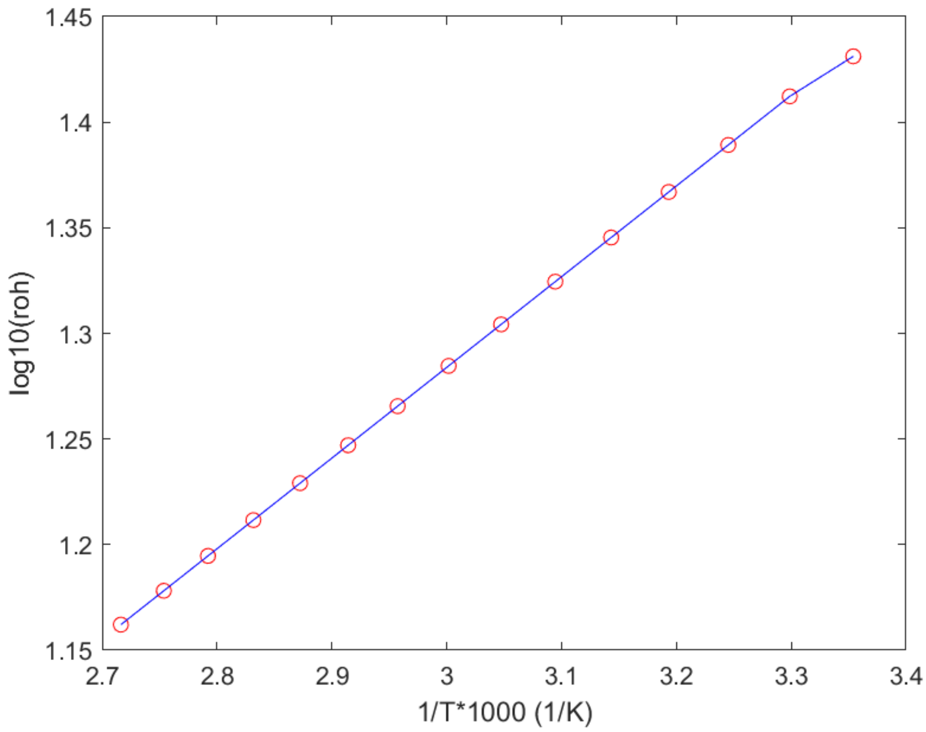

Figure 23: The resistivity of a Silicon crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (1.1621 - 0.000)/(2.7174 - 2.3137) = 2.8786K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 2.8786 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 1.1401eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	rho (ohm cm)	rho (ohm cm)
25	2.5312	26.9882	3.354016435	1.43117392
30	2.4231	25.8355	3.298697015	1.412216871
35	2.2981	24.5029	3.245172805	1.389217488
40	2.1833	23.2784	3.193357816	1.366953127
45	2.0775	22.151	3.14317146	1.345393337
50	1.98	21.1107	3.09453814	1.324502634
55	1.8898	20.1489	3.047386866	1.304251341
60	1.8062	19.2578	3.001650908	1.284606672
65	1.7286	18.431	2.957267485	1.265548899
70	1.6565	17.6623	2.914177473	1.247047257
75	1.5894	16.9464	2.872325147	1.229077453
80	1.5268	16.2786	2.831657936	1.211617052
85	1.4683	15.6549	2.792126204	1.194650298
90	1.4135	15.0713	2.753683051	1.178150715
95	1.3622	14.5244	2.716284123	1.162098201

Figure 24: Obseration Table of Silicon for i=20mA

Graph of Silicon for i=20mA

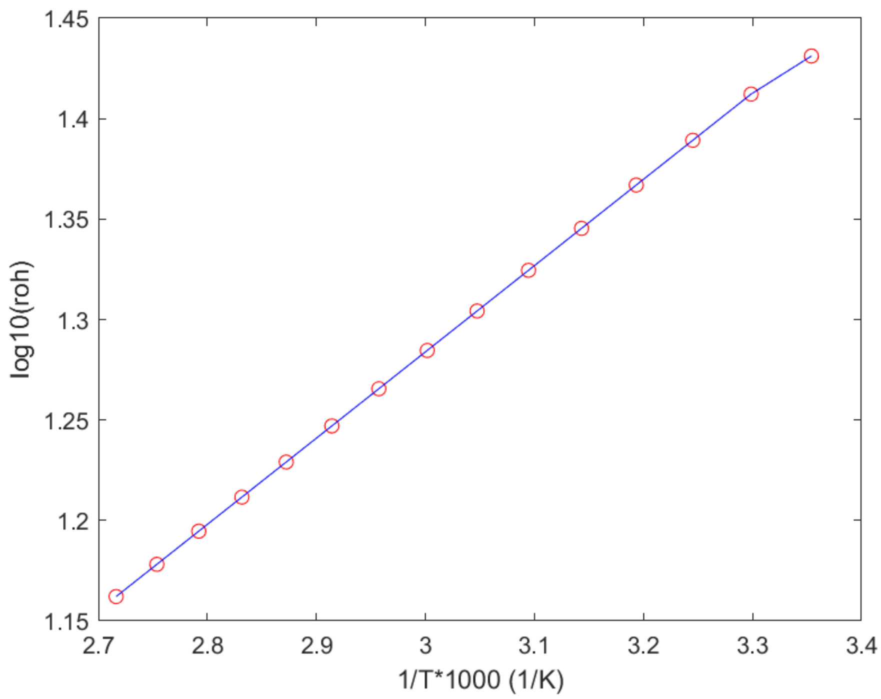

Figure 25: The resistivity of a Silicon crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (1.1621 - 0.000)/(2.7174 - 2.3137) = 2.8786K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 2.8786 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 1.1401eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	5189	26.98821	3.3557	1.431174081
30	4967.4	25.83566	3.3003	1.412219561
35	4711.1	24.50264	3.247	1.389212879
40	4475.7	23.27831	3.195	1.366951447
45	4259	22.15124	3.145	1.345398043
50	4058.9	21.11052	3.096	1.324498931
55	3874	20.14884	3.049	1.304250048
60	3702.7	19.2579	3.003	1.284608927
65	3543.7	18.43094	2.959	1.265547485
70	3395.9	17.66222	2.915	1.24704529
75	3258.3	16.94656	2.874	1.229081554
80	3129.9	16.27875	2.833	1.211621054
85	3009.9	15.65462	2.793	1.19464253
90	2897.7	15.07106	2.755	1.178143799
95	2792.6	14.52443	2.717	1.162099098

Figure 26: Obseration Table of Silicon for i=41mA

Graph of Silicon for i=41mA

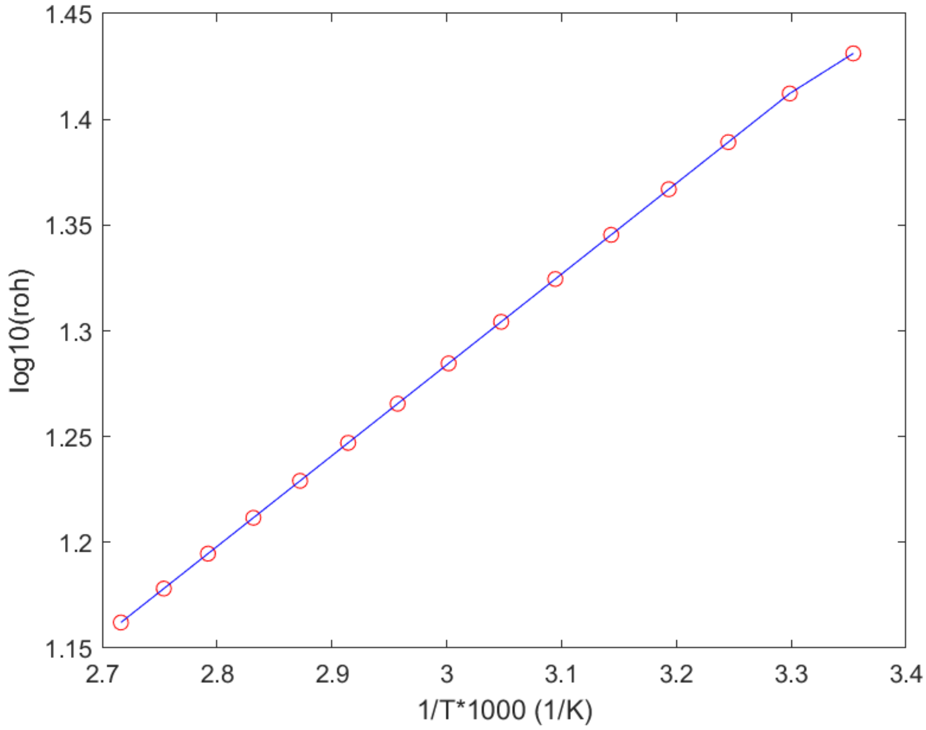

Figure 27: The resistivity of a Silicon crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (1.1621 - 0.000)/(2.7174 - 2.3137) = 2.8786K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 2.8786 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 1.1401eV$

Temperature(T)	Voltage(V)	rho (ohm cm)	T^(-1) x 1000 (1/K)	log10 (rho)
25	--	--	3.354016435	--
30	9.8136	25.8355	3.298697015	1.412216871
35	9.3074	24.5029	3.245172805	1.389217488
40	8.8423	23.2784	3.193357816	1.366953127
45	8.414	22.151	3.14317146	1.345393337
50	8.0189	21.1107	3.09453814	1.324502634
55	7.6535	20.1488	3.047386866	1.304249186
60	7.3151	19.2589	3.001650908	1.284631478
65	7.001	18.431	2.957267485	1.265548899
70	6.709	17.6623	2.914177473	1.247047257
75	6.4371	16.9464	2.872325147	1.229077453
80	6.1834	16.2787	2.831657936	1.21161972
85	5.9465	15.6549	2.792126204	1.194650298
90	5.7248	15.0712	2.753683051	1.178147833
95	5.5171	14.5244	2.716284123	1.162098201

Figure 28: Obseration Table of Silicon for i=81mA

Graph of Silicon for i=81mA

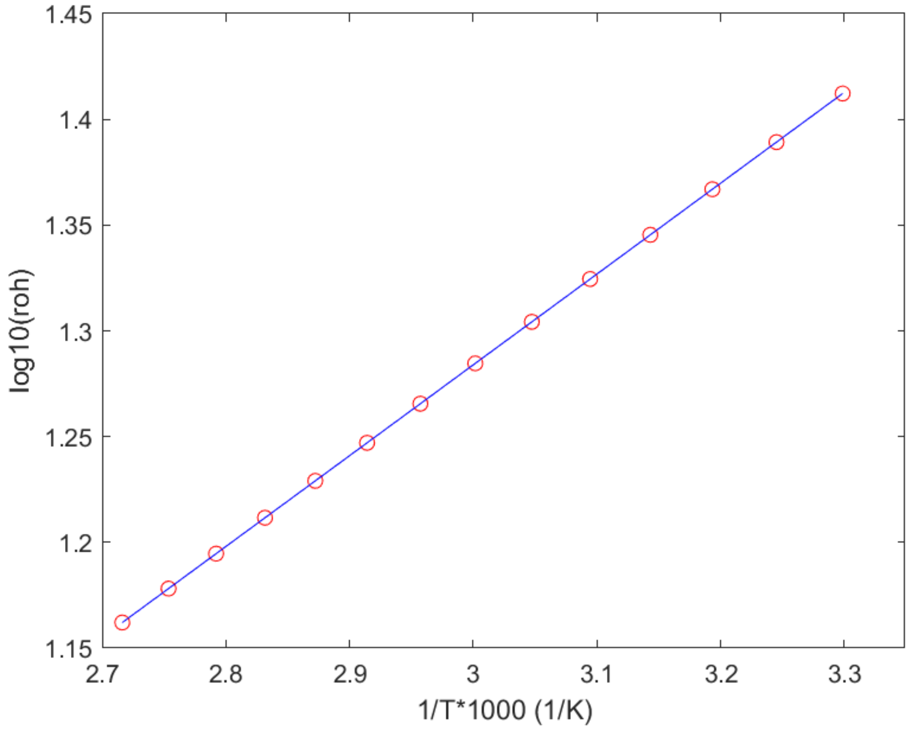

Figure 29: The resistivity of a Silicon crystal as a function of inverse temperature. For this sample T $<$ 363°K, conduction is due to impurity carriers (extrinsic region), for T $>$ 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

Slope of Graph:–
$slope = (1.1621 - 0.000)/(2.7174 - 2.3137) = 2.8786K$

Energy Gap:–
$E_g = \frac{log_e \rho}{T^{-1}} \times 2K$
$= Slope \times 2.3026 \times 10^3 \times 2K$
$= 2.8786 \times 2.3026 \times 10^3 \times 2 \times 8.6 \times 10^5$
$= 1.1401eV$