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TEP Measurements of Tungsten Diselenide WSe2 Single Crystals grown Using DVT Method

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ABSTRACT

The Tungsten diselenide (WSe2) single crystal is a member of transition metal dichalcogenides group. The thermoelectric power of as grown crystals was measured in the temperature range of 318K to 403K. Band gap eg, See back coefficients, effective mass of holes mh were carried out for grown crystals. The positive sign of thermoelectric power depicted their p-type nature within the temperature range studied.
Keywords : Crystal Growth, Hall Effect, Thermoelectric Effect, Seebeck Effect

I. INTRODUCTION

The transition metal dichalcogenides WSe2 are layer compounds consisting of sandwiches with strong covalent/ ionic intralayer bonds and weak Van der Waals interlayer interactions. These MX2 (M = W and X = X, Se) are of interest for many technological applications. They are suitable for use as high-temperature lubricants, hydrogenation catalysts, and batteries due to weak van der Waals interactions between adjacent layers in the MX2 lattice [1-2]. The single crystal of WSe2 grown by Direct vapor transport technique. The structural properties of WSe2 single crystals have been studied [3-5].

II. EXPERIMENTAL TECHNIQUE

The thermoelectric power measurements for all the samples were carried out in temperature range of 318 K to 408K with the help of thermoelectric power measurements setup. It consists of two blocks: (1) Sample holder with heater and pick up probes and (2) Electronic circuit controlling temperature and temperature gradient across the sample.The sample holder consists of two low power heaters A and B. The temperature T of the heaters A and B are measured by K type thermocouples (TC1 and TC2). The sample under investigation is mounted directly on the heaters, and is held by two pick up probes, which are of copper. These probes also measure the Seebeck voltage developed across the two ends of the sample. The second block consists of temperature indicator, proportional controller and two-heater control circuit which drive the two heaters A and B. With the help of this electronic control circuit it is possible to generate a stable temperature gradient between the two heaters. It is possible to control the temperature from 298 K to 573 K with $\triangle T$ of ±5 K simultaneously with better than ±1 K stability. The problems usually encountered in making thermoelectric power measurement are stray thermal emf. The sample and the electronic circuit have been incorporated into one unit. Use of low power heaters and electronic controllers makes the operation very easy and Seebeck coefficient of the sample can be measured very conveniently.

III. RESULT AND DISCUSSION

The measurement of thermoelectric power as a function of temperature is one of the important method for investigating electronic properties of solids. The thermoelectric power (S) provides useful information about the mechanism of electrical transport. As pointed out the quantity S can be used to determine the mobility ratio, the concentration of carriers, the position of Fermi level etc. in addition, the sign of S indicated the type of dominant carriers or the type of dominant electronic conduction. For the study of temperature dependent thermoelectric power 'S' of a p typesemiconductor the following expression [6] can be used.

$$S = \frac{k}{e}\left[A + \frac{EF}{kT}\right]$$

Where k is Boltzman constant, e is the electronic charge, A is the constant determined by the dominant scattering process and EF is the separation of the Fermi level from the top of the valance band.

Table: 1
Result of Thermo-electric Power Measurement

Sample: $W_{0.85}Se_2$ Thickness t = 0.004cm △T = 5K

Temp T K	$\frac{1}{T}$ x 10^{-3} k^{-1}	Voltage mV	S= $\frac{\mu V}{K}$
318	3.14	2.90	580
323	3.09	2.80	560
328	3.04	2.72	544
333	3.00	2.50	500
338	2.95	2.45	490
343	2.91	2.35	470
348	2.84	2.29	460
353	2.83	2.17	435
358	2.79	2.08	416
363	2.75	1.97	396
368	2.71	1.80	360
373	2.68	1.75	350
378	2.64	1.66	332
383	2.61	1.70	340
388	2.57	1.45	290
393	2.54	1.34	268
398	2.51	1.28	256
403	2.48	1.10	220
408	2.45	0.90	180

Table 1. The variation of thermoelectric power with 1000/T for $W_{0.85}Se2$ single crystals

For a small temperature range, EF is fairly constant and hence if the thermoelectric power (TEP) is plotted against the temperature, a straight line is expected. Table 1 shows the variation of TEP with temperature for WSe_2 single crystal. The values of EF and A were determined from the slope and intercept respectively, and listed in Table 2 for samples. The values of constant 'A' is given

$$A = \frac{5}{2} - S \qquad (1)$$

where's' is the scattering parameter. Revolinsky and Beernsten express the thermoelectric power,

$$S = \frac{k}{E}\left[A + \ln \frac{NA}{\rho}\right] \qquad (2)$$

Where NA is the effective density of states an d is given by

$$NA = 2\left[2\pi mh^* kT / h^3\right] \qquad (3)$$

Where mh* is the effective mass of electrons. Using the values of carrier concentration obtained from the Hall Effect measurement, the effective density of state NA for the as grown crystals can be calculated with the help of the formula

$$P = N_A \exp(-EF/kT) \qquad (4)$$

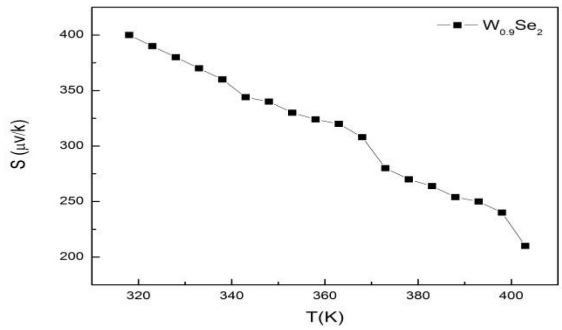

Table2: The Values Of The Seebeck Parameters For Wse2 Single Crystals

Parameters	Obtained Values
A	1.16
Scattering parameter 's'	1.34
Fermi energy 'EF' (eV)	0.028
Effective mass of electron mh* (mh)	5.54×10^{35}kg
Effective density of state 'Nc' (cm^{-3})	7.65×10^{16}

Where EF is the Fermi energy at room temperature. The values of effective density of state thus obtained for as grown crystals. Using this value of effective density of state, the effective mass of electron for WSe2 single crystal was calculated.

IV. CONCLUSION

The positive sign of Hall co-efficient reveals that grown crystal is p-type in nature and majority charge carriers in it is holes, which confirms the nature obtained by TEP measurement. It is seen that in all cases thermoelectric power increases linearly with increasing temperature confirming the typical semiconducting behavior of all crystals. The variation of thermoelectric power with temperature shows that the charge impurity scattering predominates in Tungsten diselenide single crystals.

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