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Research Paper

Resistivity Measurement of Nanocrystalline Lead Selenide Under High Pressure

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Resistivity of nanocrystalline lead selenide prepared by sonochemical process is studied under high pressure using opposed Bridgman Anvil Cell upto 10 GPa. The high pressure studies are carried out both at room and at high temperature upto 300°C using an external heating arrangement. On application of pressure and temperature a remarkable change in the resisitivity curve is observed. The resistivity of the nanocrystalline lead selenide increases and then drops down under high pressure. The sharp increase in the graphs indicates the structural phase transition of the lead selenide. The bulk PbSe is transformed from B1 to B16 structure at pressures of 4.2 GPa whereas, the same transition is obtained at 6.2 GPa for nanocrystalline PbSe. Further increase of pressure results in decrease of resistivity which indicates the transition from semiconductor to metallic nature of nanocrystalline PbSe. The high temperature results in shifting of pressure required for the transition towards lower values. According to the result obtained for both bulk and nano PbSe, an enhancement in the transition pressure with decreasing grain size is observed.

Key Words: High Pressure and High Temperature; Phase Transition; Semiconductors; Nanocrystalline

Introduction

Semiconductors of nanosize have been the focus of scientific research in the past two decades because of their special properties such as surface-volume ratio, increased activity, special electronic properties and unique optical properties as compared to those of the bulk materials [1, 2]. Among them selenides have attracted considerable attention due to their interesting properties and potential applications. They have been widely used as thermoelectric cooling materials, optical filters, optical recording materials, solar cells, super ionic materials, sensors and laser materials [3-6]. PbSe is one of the most attractive selenides for a wide variety of applications in IR detectors, photographic plates, selective and photovoltaic absorbers [7]. Many conventional methods are reported for the preparation of selenides and have some limitations [8-13]. The sonochemical method is an attractive method used extensively to generate novel materials in nanosize. PbSe nanocrystals have been successfully prepared via sonochemical route from an aqueous solution [14]. It is found to be a convenient and efficient route to produce mono dispersed PbSe nanoparticles with controllable morphologies in a single step.

The application of high pressure and high temperature brings a change in the lattice spacings that leads to the discovery of new phenomena, new phases and new forms of electronic order [15]. Here the nanocrystalline PbSe prepared by sonochemical method is studied for its properties upto a maximum pressure of 10 GPa and a maximum temperature of 300°C. The variation of electrical resistivity of nanocrystalline PbSe is compared with that of the bulk PbSe. It is found that the transition is pressure

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enhanced and as the temperature is increased the transition pressure shifted towards the lower pressure value.

2. Experimental Procedure

The high-pressure electrical resistivity measurements for PbSe are carried out using the standard two-probe method by using Bridgman Opposed anvil device. The sample is placed between the two anvil face using a gasket material pyrophyllite of 10 mm diameter with 2 mm hole drilled at the centre. Steatite is used as pressure transmitting medium. The overall thickness of the sample cell is about 0.5 mm. Two copper leads are used to measure the resistivity. The resistivity measurements are carried out up to a pressure of 10 GPa. In order to produce high temperature a circular heating coil made up of Kanthal wire over laid with brass shield is used [16]. The temperature is sensed with the help of K-type thermocouple and a temperature controller is used to maintain the temperature. The coil is heated using 220 V power supply. The temperature stability obtained was ±2°C. The experiment is carried out in steps of 100°C for different pressures up to a temperature of 300°C.

3. Results and Discussion

The high temperature and high pressure studies were conducted for the nanocrystalline PbSe of 8 nm in size at temperatures 100°C, 200°C and 300°C. The observed data is shown in the Fig. 1. The resistivity of the sample is found to be few kilo ohms cm at normal temperature and pressure. From the graph it is inferred that the resistivity remained almost unchanged up to a pressure of 5.4 GPa. At 6.2 GPa the onset of the transition starts and there is a sharp rise in the value of resistivity. On further increase of pressure the resistivity increases up to 8.45 GPa and then it decreases. The sudden rise in the resistivity shows that the PbSe undergoes a structural transition from low pressure phase (B1) to high pressure phase (B16). Bulk-PbSe undergoes a phase transition from NaCl (B1) to orthorhombic phase (B16) at a pressure of 4.2 GPa [17, 18]. The transition pressure of the nanocrystalline PbSe obtained at room temperature is compared with that of the bulk PbSe and it is found that there is an increase in the transition pressure. When the temperature is increased from room temperature to 300°C in steps of 100°C the resistivity follows the same path as that of the previous result. From the graph, we infer that the transition pressure decreases towards the lower pressure range on increase of temperature. Fig. 2 shows the temperature and pressure phase diagram for different temperatures and pressures. Above 300°C the nanocrystalline PbSe will have the nature of bulk PbSe by undergoing a transition at 4.2 GPa. At high temperature and high pressure the nanocrystals coagulate to form crystallites of larger size. The result obtained is consistent with the most recent studies on the finite size effects on the transition pressures of nanocrystals reported earlier [19, 20]. For nanoparticles, the surface to volume ratio is large and the surface energy plays a vital role in the enhancement of transition pressure.

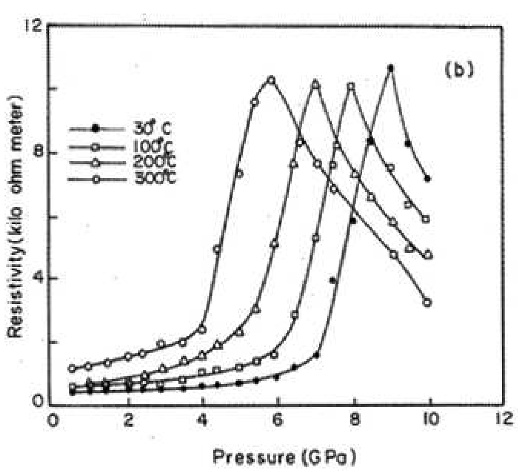

Fig. 1: Resistivity *vs* Applied Pressure at different temperatures for nano PbSe

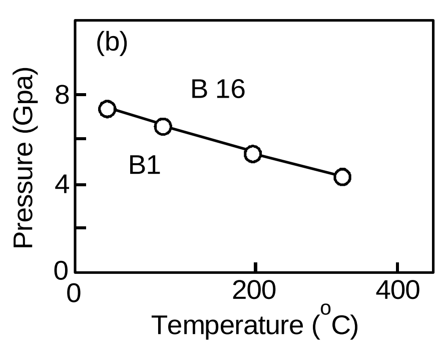

Fig. 2: Temperature-Pressure phase diagram of nano PbSe

Conclusion

Thus, the effect of reduced particle size in PbSe nanocrystals elevates the transition pressure and increase the sluggishness of the transition. The transition pressures are largely controlled by the surface energy of the particles associated with any given phase of the nanocrystalline particles. The transition pressure decreases with increase in temperature.

Reference

1. Henglein A *Chem Rev* **89** (1989) 1861
2. Agfeldt A and Gratzel M *Chem Rev* **95** (1995) 49
3. Mongellaz F, Fillot A, Griot R and De Lallee *J Proc SPIE-Int Soc Opt Engg* **156** (1994) 2227
4. Wang WZ, Geng Y, Yan P, Liu FY, Xie Y and Qian YT *J Am Chem Soc* **121** (1999) 4062
5. Lakshmikumar ST and Rastogi AC *Sol Energy Mater Sol Cells* **32** (1994) 7
6. Korzhuev MA and Fiz *Khim Obrab Mater* **3** (1991) 131
7. Mulik RN, Rotti CB, More BM, Sutrave DS, Shahane GS, Garadkar KM, Deshmukh LP and Hankare PP *Indian J Pure Appl Phys* **34** (1996) 903
8. Metcalf HC, Willams JE and Caskata JF *Modern Chemistry*, Holt, Reinhart, Winston (eds), New York, 919820 pp 54
9. Coustal RJ *J Chem Phys* **38** (1958) 277
10. Lokhande CD, Patil PS, Tributsch H and Enaoui A *Sol Energy Mater Sol Cells* **55** (1998) 379
11. Steigerwald ML, Alivisatos AP and Gibson JM *J Am Chem Soc* **110** (1998) 3046
12. Ptatschk V, Schreder B and Herz K *J Phy Chem B* **101** (1997) 8898
13. Suslick KS *Ultrasound: Its Chemical, Physical and Biological Effects*, VCH, Weinhein, Germany, 1998
14. Jun-Jie Zhu, Wang H, Xu S and Chen HJ *Langmuir* **18** (2002) 3306
15. Samara GA and Drickamer HG *J Chem Phys* **37** (1962) 1159
16. Jaya Arun TK and Victor Jaya N Proc of Advances in High Press *Sci and Tech* 2001
17. Chattopadhyay T, Von Schnering HG, Grosshans WA and Holzapfel WA *Physica B & C* **139-140** (1986) 356
18. Ovsyannikov SV, Shchennikov VV, Popova SV and Derevshov Yu A *Phys Stat Sol(b)* **235** (2003) 521
19. Murray CB, Norria DJ and Bawendi MG *J Am Chem Soc* **115** (1993) 8706
20. Tolbert SH and Alivisatos AP *Science* **265** (1994) 373.