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Investigation of Structural and Thermoelectric Properties of Lead Telluride Thin Films Deposited by DC Magnetron Sputtering

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Keyword: PbTe; Lead Telluride; Thermoelectric thin film; DC magnetron sputtering

We prepared Lead Telluride (PbTe) thin film by DC magnetron sputtering method. The powder precursors of Pb and Te purity 99.99 % ratio 1:1 were mixed. PbTe Powder was pressed using as sputtering target. DC magnetron sputtering condition, the base pressure is 3.2×10^{-3} Torr, applied the argon gas (purity 99.99%) in vacuum chamber to obtained working pressure at 50×10^{-3} Torr. The sputtering power is 25 W and sputtering time is 30 minutes. Phase identification, morphology and film thickness have been investigated by X–ray diffraction and scanning electron microscope. Electrical resistivity and Seebeck coefficient of the PbTe thin films have been investigated by four probe steady state method. The results demonstrated that the crystal phase of PbTe is face center cubic (FCC) structure. The average PbTe films yielded film thickness is around 460 nm, the average electrical resistivity is 17 Ω m and Seebeck coefficient is 8.0×10^{-5} V K^{-1}.

Introduction

Lead telluride semiconductor is IV–VI group with crystallize in the FCC NaCl–type structure. The study in theoretical and experimental have present due to the unusual characteristics such as high carrier mobility high dielectric constants and narrows band gaps, have importance in many application such as optical electronics solar cell and thermoelectric. PbTe is potentially attractive thermoelectric as thermoelectric generator, has high operate temperature, good chemical stability and height figure of merit (Z). Low dimensional materials such as thin films are of great interest for construction of high performance thermoelectric devices[3].The improvement of Te properties can be achieved by reduced the dimensionality of materials [4]. In this work the structural information and resistivity, Seebeck coefficient of PbTe films deposit on Si–wafer substrates have been studied.

Experimental

Deposition Condition

High purity Pb and Te powder (99.99 % purity Sigma aldrich) were mixed at ratio 1:1 then cold– pressing atmospheric to prepare the PbTe target. Silicon wafer was used as substrate. DC magnetron sputtering condition is, target to substrate distance 6 cm, the chamber was first evacuated to pressure 3.2×10^{-3} Torr and then applies argon gas up to 50×10^{-3} Torr base pressure. The sputtering was carried out at constant power 25 watt and sputtering time is 30 min.

Result and discussion

XRD Analysis

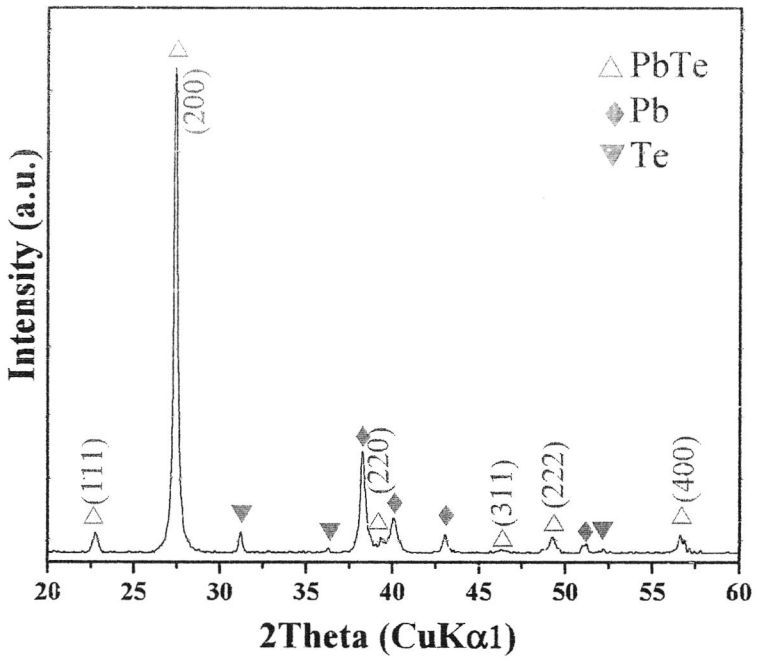

Fig. 1 The XRD pattern of PbTe thin film

The XRD pattern revealed that the target consisted of a majority FCC NaCl–type structure (PDF#00–008–0028) with relatively good crystallinity. Crystallite size and lattice constant of main peak (200) were calculated (main peak) and compare to standard as shown in table 1.The grain size was calculated by Scheerer formula Crystallite size $(D)=\frac{K\lambda}{\beta\cos\theta}$ where K is constant safe factor 0.94 for cubic structure, λ is X-ray wave length 1.540 Å , β , θ is Bragg's angle and FWHM.

Table 1. A standard and calculated comparison of PbTe crystal structure

Standard (PDF#00-008-0028)				Calculated				
2θ	d (Å)	I	h k l	2θ	D (Å)	FWHM (Å)(β)	Crystallite size (D)(nm)	Lattice constant (a)(Å)
27.59	3.23	100	2 0 0	27.94	3.19	0.35	24.44	6.38

SEM analysis

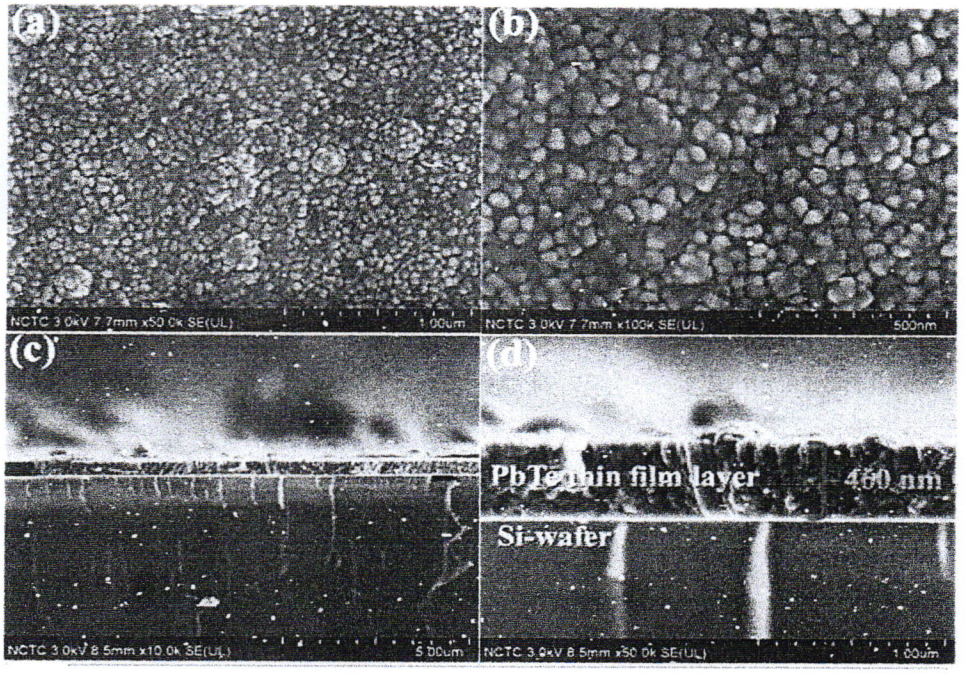

Fig. 2 The morphology of PbTe thin films

It is observed that the surface of the film have fine, smooth and uniform, (a) and (b) indicate the average grain size range from 50–100 nm. Also (c), (d) show cross-section plane and average film thickness is around 460 nm.

Seebeck Coefficient and Electrical Resistivity Analysis

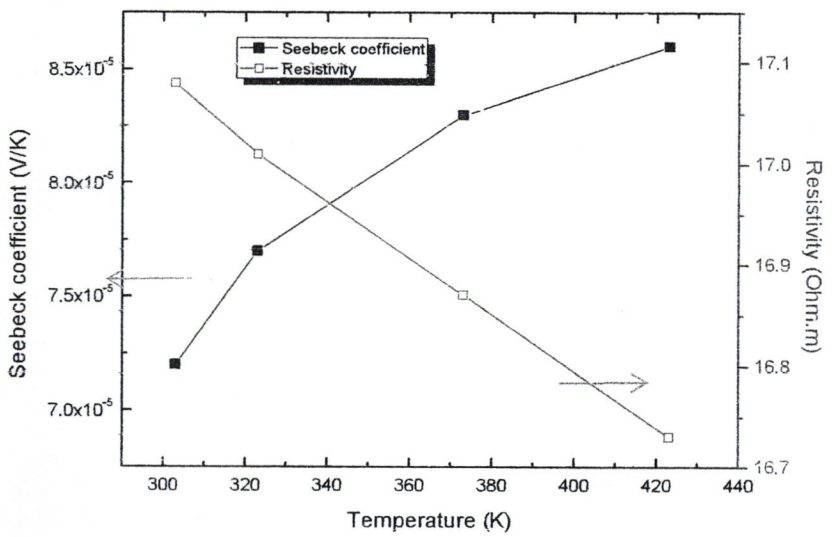

Fig. 3 The resistivity and Seebeck coefficient of PbTe thin film as function of temperature

The resistivity and Seebeck coefficient of PbTe thin film shows in Fig. 3. It is observe that Seebeck coefficient increasing with temperature shows nature of semiconductor, also electrical resistivity and corresponds to early report by S. Patil [1].

Conclusion

PbTe thin films were successfully fabricated by DC–magnetron sputtering at room temperature without annealing. The film exhibits polycrystalline nature and has a rock salt structure. The low resistivity and high value of Seebeck coefficient of the film indicates that this method possible to thermoelectric module fabrication.

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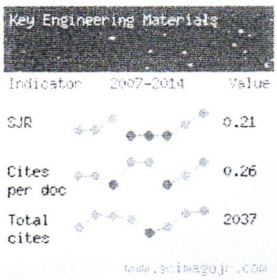

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