Thermoelectric performance improvement in engineered amorphous Silicon

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Abstract— This report presents exciting advances in the field of engineered thermoelectric materials that are clean and which involve techniques compatible with standard Silicon processing. We observe thermoelectric figure of merit ~0.2 at room temperature for n-doped amorphous(a)-Si brought about by enhancement of the electrical conductivity while the inherently advantageous attributes of a-Si are retained in terms of low thermal conductivity and high Seebeck coefficient .

Keywords: amorphous Silicon, thermoelectric, figure of merit.

1 Introduction

IMPROVED performance from Silicon based thermoelectric (TE) materials for operation near room temperature may prove to be a decisive breakthrough for harvesting waste heat to generate electricity or achieve active cooling in integrated chips. Nonetheless, Si has a rather poor figure of merit, $ZT(=\sigma S^2 T/\kappa)$ which will require substantial improvements to achieve practically usable levels of performance. This may be achieved by enhanced TE power factor (σS^2) or reduced thermal conductivity (κ) or both.

2 Aim of the study

In the present work, we seek to improve the ZT of a-Si brought about by enhancement of σ while maintaining the advantage of suppressed κ and higher S of the amorphous phase.

3 Methods

The amorphous Silicon film is grown by low pressure CVD technique followed by implantation with Arsenic and dopant activation by thermal annealing. We could avoid crystallization of the a-Si by suitable optimization of the thermal annealing temperature and time.

We used non-invasive Raman thermometry for evaluating the Seebeck coefficient, the Van der Pauw geometry to determine the electrical conductivity and 3-ω method to ascertain the thermal conductivity.

4 Results

Figure 1 shows the cross-sectional scanning electron microscope (SEM) image of the a-Si sample on thermal SiO_2 and crystalline Silicon substrate. The micro-Raman spectrum shows the broad peak around 480 cm^{-1}: signature of the amorphous phase, shown in Fig. 1 (inset).

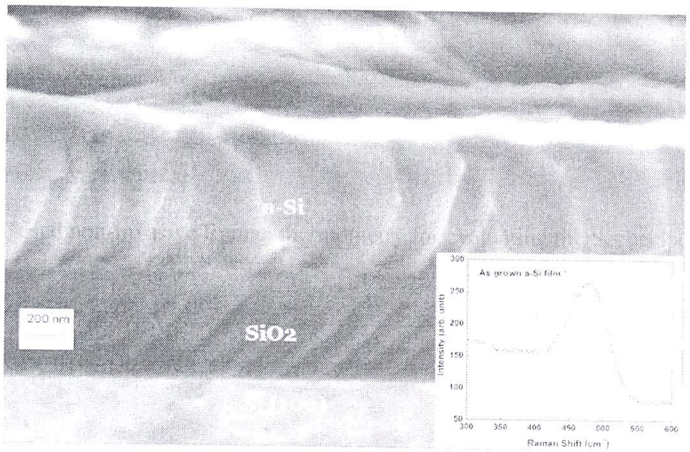

Fig. 1. The cross-section SEM image of a-Si on SiO_2 and c-Si substrate. The inset shows the Raman spectrum of the a-Si film.

The ZT obtained for the optimized n-doped a-Si is ~ 0.2 at room temperature. Other thermoelectric properties for this sample are listed in the table below. For perspective, the polysilicon films with nano-patterning have only achieved ZT of 0.035 [1] and Bi_2Te_3 bulk nanopowders show a value of 0.25 at room temperature [2].

Table 1: Thermoelectric properties of the optimized n-doped a-Si

σ(S/m)	κ(W/m·K)	$S(\frac{mV}{K})$	ZT
1550	1.49	0.75	0.17

We will further present physical, electrical (σ) and thermal (κ and S) characterization results of other n-type samples. Additionally we will present the results of the p-doped a-Si prepared likewise.

5 Conclusion

We observe orders of magnitude enhancement of ZT of a-Si by doping and activation while preserving the benefits of the disordered phase. This method is attractive since it does not require complex processing steps and has the potential to be replicated and scaled.

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