Properties of Low Gap Amorphous Silicon-Germanium Alloys

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ABSTRACT

We report on the growth and properties of high quality, low bandgap, a-(Si,Ge):H alloys. The materials were made using ECR plasma growth techniques. We found that plasma chemistry had a significant impact on the material and device properties. Films with significantly better H bonding microstructure were produced when there was significant ion flux incident on the surface. In contrast, non-homogeneous films and porous microstructure was produced when ion flux density was decreased. The defect density was measured using space charge limited current, and was in the low 10^{16} /cm ^{3}-eV range for materials with low bandgaps (~1.2-1.3 eV) and in the 5 x 10^{15}/cm ^{3}-eV range for a-Si. The device fill factors ranged from 70+% for a-Si to ~53% for a-Ge:H. The properties of the a-Ge;H devices could be improved significantly by using chemical annealing during growth.

INTRODUCTION

a-(Si, Ge):H alloys are an important class of materials for photovoltaic(PV) energy conversion. Unfortunately, the properties of this material generally degrade as we increase the amount of Ge content in the alloy. In this paper, we will show that by carefully controlling the plasma chemistry, one can make good quality alloys across the entire bandgap spectrum, from a-Ge:H to a-Si:H. We will show that H bonding depends critically upon the plasma chemistry and that the films tend to be non-homogeneous when sufficient ion flux is not present during growth.

GROWTH TECHNIQUE

The materials were grown using a low pressure, remote ECR plasma technique described earlier.[1]. All the materials were grown using significant hydrogen dilution (dilution ratio of 20:1 or greater). The source gases were germane and silane.

H BONDING

For studies of H bonding, the materials were deposited on Si wafers. In Fig. 1, we show the H bonding spectra for two materials deposited under identical conditions (same silane, germane and hydrogen flows and same temperature and power conditions), except for the deposition pressure. From Fig. 1, it is obvious that the materials deposited at higher pressures (15 mT) has a significant shoulder at 2100 cm-1, indicating the presence of SiH_2 bonds and therefore, a poor microstructure. But, when pressure is reduced, the SiH_2 bond density reduces significantly. We have shown previously [2] that under low pressure conditions, ion flux is higher by a factor of 3 compared to the high pressure conditions, and that the properties of the films significantly better. Therefore, one can conclude that ion flux plays a major role in promoting homogeneous growth of the material.

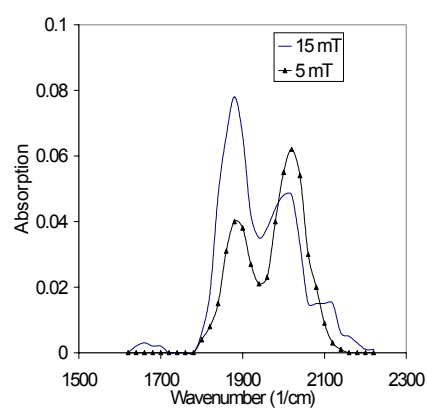

Fig. 1 H bonding for films deposited at 15 and 5 mT pressures under otherwise identical conditions.

DEFECT DENSITY

The midgap defect density was measured using SCLC techniques.[3]. The measured midgap defect density vs. bandgap is shown in Fig. 2. While the defect density is higher for lower gap materials than for a-Si:H, it is within the range to produce devices with acceptable properties.

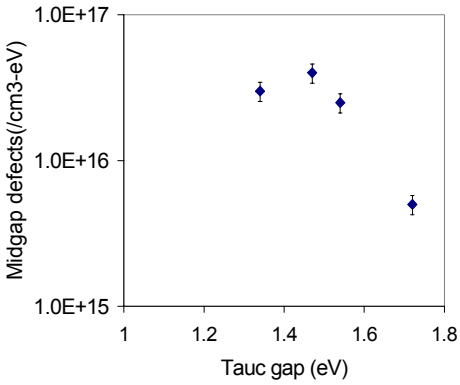

Fig 2. Defect density in a-(Si,Ge) films

DEVICE PROPERTIES

p-i-n substrate type devices were made on steel substrates. The devices had semi-transparent Cr top contacts. There was no back reflector. The device curve for a 1.26 eV cell is shown in Fig.3, The fill factor for 1.26 eV cell is 56%, indicating good material properties. Subgap quantum efficiency data yield a low value for Urbach energy of valence band tails, 44 meV. indicating very good material properties. The results for a-Ge;H cell are shown in Fig.4, for two growth conditions, a normal uninterrupted growth, and a chemical annealed growth. The fill factor and the voltage are improved significantly for the a-Ge:H cell when the i layer of the cell is made using chemical annealing {a layer-by-layer growth technique where a thin film(~ 3 nm) is grown and then subjected to anneal by a H plasma}. Thus, chemical annealing significantly improves the properties of the low gap cell.

CONCLUSIONS

In conclusion, we have shown that plasma properties such as ion flux have a profound effect on the fundamental material properties, such as H bonding, in a-(Si,Ge):H alloys. We

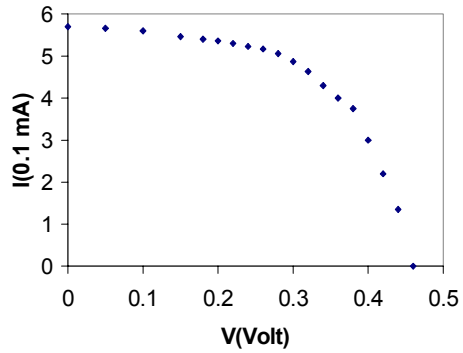

Fig. 3 I(V) curve of 1.26 eV cell. F=56%

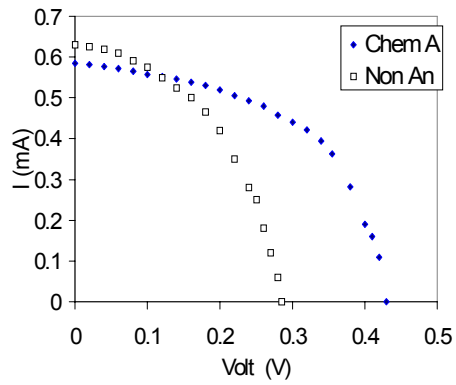

Fig. 4 Influence of chemical annealing on device properties of a-Ge:H cell

have shown that by controlling the plasma, we can produce good devices even for the lowest bandgaps (1.1 eV). The properties of the cells are improved by chemical annealing.

ACKNOWLEDGEMENT

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REFERENCES

1. S. Kaushal et al, J. Non-Cryst. Solids, 198-200, 563(1996)
2. V. L. Dalal et al, J. Non-Cryst. Solids, 227,1257(1998)
3. W. den Boer, J. de Physique(Paris),42, C-4, 481(1981)