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COMMUNICATION

Patterned growth of nanocrystalline silicon thin films through magnesiothermic reduction of soda lime glass

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A low-cost and green method of producing nanocrystalline silicon thin films is presented. Using a magnesiothermic reduction process, we have successfully converted the surface of soda lime glass directly into silicon thin film. Furthermore, by varying reaction time, the amount of silicon produced in thin film form (or layer thickness) can be controlled. The nanocrystalline silicon thin films on glass were characterized using scanning electron microscopy, energy dispersive spectroscopy and Raman spectroscopy. Finally, the optical properties of the thin films derived at different reaction times were also measured. The band gaps of the synthesized thin films were within the range of 2.3–2.5 eV.

Thin films based on silicon are still the mainstream technology for applications ranging from microelectronics, photovoltaics, optoelectronic to micro-electro-mechanical systems. Current technologies for silicon thin films involve a variety of processes and can be categorized as: 1) amorphous silicon (α-Si), 2) polycrystalline silicon (poly-Si) and 3) nanocrystalline silicon (nc-Si). The first prospect (α-Si) offers a relatively low-cost process, better electrical uniformity and low leakage current of transistor devices. However, α-Si suffers from low carrier mobility, which results in a lower absorption coefficient and poor reliability of its electronic properties. In contrast, the second prospect (poly-Si) offers superior reliability with high carrier mobility due to its larger grain size.[1] In spite of this, poly-Si, due to the current industrial fabrication, is limited by its poor electrical uniformity.[2] This is largely due to the need for excimer laser annealing for crystallization, which also limits the scalability of poly-Si-based devices.[1] Furthermore, the cost of poly-Si production is usually very high owing to the complexity of the process, which requires laser equipment and high temperature. On the other hand, the third prospect (nc-Si) exhibits a structural feature and characteristic property in between the other two aforementioned technologies. Overall, nc-Si combines the advantages of both α-Si and poly-Si technologies and would give the optimum qualities for future optoelectronic devices.[1]

This study aims to look for alternative means of developing a thin film process for fabricating nc-Si. Current methods of fabricating nc-Si thin films involve re-crystallization of α-Si thin film and direct deposition of nc-Si.[3] Re-crystallization techniques reported in the literature include laser melt recrystallization,[4,5] chemical induced recrystallization[6] and rapid thermal annealing.[7] On the other hand, a deposition process usually uses the decomposition of chemical gas, like silane, through plasma-enhanced chemical vapor deposition (CVD),[8,9] hot wire CVD,[3] glow discharge CVD,[10,11] radiofrequency magnetron sputtering,[12,13] and other similar deposition methods.[14] The re-crystallization process has difficulties in controlling the crystallite size and crystalline volume.[3] Moreover, the post annealing treatment required in this process is over 1000 °C, which limits its potential applications. In contrast, vapor deposition has been the process of choice in most literature due to improved film stability, higher deposition rates and good optoelectronic properties.[3] But, the deposition process almost always uses silane or silane-derivatives as the precursors, which are dangerous and toxic.[15,16] An alternative fabrication process, which can offer an environmentally friendly and reasonable quality material, is ideal.

With the various environmental problems that concern our world today, recent research is trying to take into consideration the potential effect of new methods towards human health and the overall ecosystem. The increasing interest towards environmentally benign processes shows that people are taking this matter seriously.[17] An ideal protocol requires production of materials in an environmentally benign manner. This includes minimal waste and environmentally safe and sustainable products.[18]

This study offers a novel, green and alternative process in fabricating nc-Si thin films. The process follows the chemical equation:

$$SiO_2\ (s) + 2Mg\ (g) \rightarrow 2Si\ (s) + 2MgO\ (s) \qquad (1)$$

$$\Delta_r G = -375.01\ \text{kJ mol}^{-1}\ (\text{at } 520\ ^\circ\text{C})^{19} \qquad (2)$$

Previous studies have demonstrated that silicon dioxide starting from different structures (diatoms,[20] sand[21] and microparticles[22]) can easily be converted into elemental silicon following

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