Microcrystalline Silicon Thin Films Prepared by Hot-Wire Chemical Vapour Deposition

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I declare that this thesis is my own account of my research and contains as its main content work, which has not previously been submitted for a degree at any tertiary educational institution.

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ABSTRACT

Silicon is widely used in optoelectronic devices, including solar cells. In recent years new forms of silicon have become available, including amorphous, microcrystalline and nano-crystalline material. These new forms have great promise for low cost, thin film solar cells and the purpose of this work is to investigate their preparation and properties with a view to their future use in solar cells.

A Hot Wire-Deposition Chemical Vapour Deposition CVD (HW-CVD) system was constructed to create a multi-chamber high vacuum system in combination with an existing Plasma Enhanced Chemical Vapour Deposition (PECVD) system; to study the amorphous to crystalline transition in silicon thin films. As the two chambers were linked by a common airlock, it was essential to construct a transfer mechanism to allow the transfer of the sample holder between the two systems. This was accomplished by the incorporation of two gate valves between the two chambers and the common airlock as well as a rail system and a magnetic drive that were designed to support the weight of, and to guide the sample holder through the system.

The effect of different deposition conditions on the properties and structure of the material deposited in the combined HW-CVD:PECVD system were investigated. The conditions needed to obtain a range of materials, including amorphous, nano- and microcrystalline silicon films were determined and then successfully replicated.

The structure of each material was analysed using Transmission Electron Microscopy (TEM). The presence of crystallites in the material was confirmed and the structure of the material detected by TEM was compared to the results obtained by Raman spectroscopy. The Raman spectrum of each sample was decoupled into three components representing the amorphous, intermediate and crystalline phases. The Raman analysis revealed that the amorphous silicon thin film had a dominant amorphous phase with smaller contribution from the intermediate and crystalline phase. This result supported the findings of the TEM studies which showed some medium range order. Analysis of the Raman spectrum for samples deposited at increasing filament temperatures showed that the degree of order within the samples increased, with the evolution of the crystalline phase and decline of the amorphous phase. The Selected Area Diffraction (SAD) patterns obtained from the TEM were analysed to gain qualitative information regarding the change in crystallite size. These findings have been confirmed by the TEM micrograph measurements.

The deposition regime where the transition from amorphous to microcrystalline silicon took place was examined by varying the deposition parameters of filament temperature, total pressure in the chamber, gas flow rate, deposition time and substrate temperature.

The IR absorption spectrum for μc-Si showed the typical peaks at $2100cm^{-1}$ and $626cm^{-1}$, of the stretching and wagging modes, respectively. The increase in the crystallinity of the thin films was consistent with the evolution of the $2100cm^{-1}$ band in IR, and the decreasing hydrogen content, as well as the shift of the wagging mode to lower wavenumber. IR spectroscopy has proven to be a sensitive technique for detecting the crystalline phase in the deposited material.

Several devices were also constructed by depositing the μc-Si thin films as the intrinsic layer in a solar cell, to obtain information on their characteristics. The p-layer (amorphous silicon) was deposited in the PECVD chamber, and the sample was then transferred under vacuum using the transport system to the HW-CVD chamber where the i-layer (microcrystalline silicon) was deposited. The sample holder was transferred back to the PECVD chamber where the n-layer (amorphous silicon) was deposited.

The research presented in this thesis represents a preliminary investigation of the properties of μc-Si thin films. Once the properties and optimum deposition characteristics for thin films are established, this research can form the basis for the optimization of a solar cell consisting of the most efficient combination of amorphous, nano- and microcrystalline materials.

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