Chapter 1
Introduction

1.1 Introduction

Hydrogenated amorphous silicon (a-Si:H) has vast applications in our modern civilisation today. This material is now used extensively in many large-area device applications such as solar cells[1], photoreceptors[2], flat panel displays[3], page-wide document scanners[4,5], printer heads[6] and many others that need a high quality semiconductor possible of being processed on large, curved and flexible substrates. The advantages of using a-Si:H for devices are the wide range controllability of material properties and flexible design capability of the device structures. A low defect density in the material, thus making it behave like a true semiconductor that exhibits doping effect[7] contributes to the success of a-Si:H in modern microelectronics technology.

Since the presence of hydrogen in amorphous silicon is crucial in producing device-quality material, the determination of hydrogen content in a-Si:H is of paramount interest. Various techniques for determining hydrogen concentration in the material have been proposed in literature. Some of the established techniques using expensive equipment like Nuclear Magnetic

Resonance (NMR) and Secondary Ion Mass Spectroscopy(SIMS) are not available in most laboratories. Other methods like heating the sample in a vacuum and observing the presence due to the hydrogen evolution[8,9,10] and counting the count-rate of characteristic γ–rays produced from nuclear reaction between hydrogen and high energy ions[11,12] are also frequently used to determine hydrogen content in film but these methods fail to establish the bonding sites of these hydrogen relative to the silicon atoms. Since the effectiveness of hydrogen in reducing defects depends strongly on the way it is incorporated, rather than the hydrogen content itself, a technique which can determine the H content and also its bonding site is necessary. The determination of H content from the integration of absorption areas under the Si-H peaks obtained from the FTIR transmission spectrum enables one to identify the bonding sites of the hydrogen in the film. However, problem arises when an absorption band is broad due to the overlapping of two absorption bands, as in the Si-H_x stretching bands located at ~ 2000 cm^{-1} in this work. Tedious mathematical procedures need to be carried out to identify the H content at the monohydride and polyhydride bonding sites, which also could worsen the resolution of the magnitude of the H content. However, this technique is widely used by researchers in this field but different absorption bands are taken for determining the hydrogen content in the a-Si:H film. Some researchers use the integrated absorption areas of the Si-H_x stretch peak at ~ 2000 cm^{-1} only[13,14] or the integrated absorption areas of the Si-H wagging peak at ~ 600 cm^{-1} only[15,16] while others used the total integrated areas of these two peaks[17] to determine the H content in the film. This technique which is referred

to as the chemical bonding infra-red model(IRM) in this work is one of the two techniques used to determine H content in the a-Si:H film, where the total integrated absorption areas under the Si-H_x stretching and Si-H wagging peaks are used as the total H content in our film. The second technique, referred to as the valence electron model(VEM) which is introduced in this work is a method to determine H content in our films by combining the J.C. Manifacier[18] method, for obtaining the dispersion curve of refractive index versus wavelength from the optical transmission curve in the visible region, and the model proposed by C. Ance et al[19],for detemining the H content in a-Si:H film from the dispersion curve.

In this thesis, an attempt is made to test the feasibility of the valence electron model by comparing this H content to the H content determined by the chemical bonding infra-red model and also by studying the effect of the H content calculated by these two techniques on the optical energy gap, dc room temperature conductivity and density of states at the Fermi level, $N(E_f)$.

Chapter 2 of this thesis presents a review on the a-Si:H material. Various deposition techniques are presented and described in Section 2.2 followed by the structural, transport and optical properties presented in Sections 2.3, 2.4 and 2.5 respectively. The role of hydrogen in a-Si:H material as found in literature concludes the chapter.

The home-built dc glow discharge system used to prepare the a-Si:H film in this work is presented in Chapter 3. Section 3.2 describes the system in detail while Section 3.3 presents the deposition procedures. The deposition parameters that are usually quoted in the literature to affect the structural,

electrical and optical properties are mentioned in Section 3.4. Section 3.5 briefly describes the process of annealing the various a-Si:H film samples used in this work.

Chapter 4 gives a detail account of on the measurement and calculation techniques carried out on the a-Si:H film. Details on the FTIR system and its usage to analyse the chemical bonding configurations in the film, the electrical and optical characterisation are also presented in this chapter.

The experimental results are presented and described in Chapter 5. Section 5.2 presents the preparation conditions of all the a-Si:H film samples studied in this work. FTIR, optical and electrical characterisation results are presented and described in Sections 5.3, 5.4 and 5.5 respectively.

Chapter 6 analyses the results of the measurements described in Chapter 5. Section 6.2 starts of by attempting to correlate results of film characterisation with respect to its deposition conditions. Details of the analytical techniques involved in determining the hydrogen content in the a-Si:H samples in this work, namely the chemical bonding infra-red model and the valence electron model, are presented in Section 6.3. This section also analyses the H content results for the as-prepared film derived by these two techniques. Section 6.4 concludes the chapter by analysing the effects of annealing on the chemical bonding structure, the optical energy gap, the electrical characteristic and the hydrogen content of the film.

Chapter 7 discusses the results from the analysis made in Chapter 6. The growth mechanism of a-Si:H film by dc glow discharge deposition and hydrogen diffusion and evolution mechanism in annealed films are described in

Sections 7.2 and 7.3 . The discussion in Section 7.4 is centred on trying to correlate characteristics of the as-prepared a-Si:H film and its H content to the growth mechanism. The H content of the annealed film calculated by both the valence electron model and the chemical bonding infra-red model are also correlated to the film characteristics in Section 7.5 followed by an attempt to identify the bonding sites of the hydrogen content calculated by these techniques.

Finally, Chapter 8 summarises this work and explores the possibility of further works in this area of research.

1.2 References

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