# MICROCRYSTALLINE SILICON: PREPARATION AND PROPERTIES

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## ABSTRACT

The plasma parameters controlling the deposition of crystalline and amorphous silicon are discussed and illustrated by examples [1]. The control of the structural properties achieved enables one to perform a systematic study of the transition from the crystalline to the amorphous phase during deposition, as well as a better understanding of some properties of a-Si such as its Raman scattering spectrum [2]. It is shown that the microcrystalline phase becomes thermodynamically unstable with respect to the amorphous phase at a lower limit of the crystallite size of ~30Å [3]. The effect of reversible adsorption of air constituents on the electrical conductivity, electron spin density and on changes observed in the X-ray Photoelectron Spectra of μc-Si will be described and discussed [4].

The results can be summarized as follows:

A post-deposition exposure of μc-Si films to air results in an irreversible incorporation of oxygen with the formation of Si-O bonds as detected by infrared spectroscopy. In addition, a reversible chemisorption of oxygen (and possibly also of moisture) occurs, resulting in a decrease of the electrical conductivity $\sigma_{R.T.}$ at room temperature and in an increase of its activation energy. After annealing at $\geq 200°C$ under high vacuum ($\leq 10^{-6}$ torr), the conductivity increases and its activation energy decreases returning to their original values. The extent of such reversible changes in $\sigma_{R.T.}$ depends on the deposition conditions, reaching a factor $\geq 10^{7}$ for samples deposited at low temperatures and only a factor 2-5 for those prepared at ~ 400°C. Table 1 shows, as an example, the effect of the residual pressure of oxygen on the activation energy, $E_{act}$, on the pre-exponential factor, $\sigma_o$, and on the room temperature conductivity, $\sigma_{R.T.}$ of a sample deposited at 265°C. The kinetics of both, the

| $P_{O_2}$ (torr) | $E_{act}$ (eV) | $\sigma_o$ ($\Omega^{-1}cm^{-1}$) | $\sigma_{RT}$ ($\Omega^{-1}cm^{-1}$) |
|---|---|---|---|
| $<10^{-6}$ | 0.15 | 2 | $6\times10^{-3}$ |
| 1 | 0.37 | 58 | $3\times10^{-5}$ |
| 100 | 0.89 | $4\times10^{8}$ | $4.5\times10^{-7}$ |

Table 1 (see text)

adsorption and desorption have been studied and will be reported.

Samples exposed to air for a long period of time show an esr signal with g ± 2.0055 and a density of spins of the order of $10^{17}cm^{-3}$. This signal vanishes (detection limit $5x10^{15}cm^{-3}$) after the vacuum annealing as described above; however, it does recover again after long term exposure to air.

An XPS study has revealed only an insignificant shift of the Si 2p binding energy due to the repeated adsorption - desorption process indicating that the observed changes in $E_{act}$ of the electrical conductivity are not dominated by a shift of the Fermi level. The accompanying, reversible appearance of a weak Si 2p signal shifted by ~1.5eV to lower energy from the pure Si-signal is attributed to a reversible, chemisorbed state on the grain boundaries which obviously influences the charge transport properties of μc-Si as observed by the changes in σ. Further details can be found in the quoted references.

## REFERENCES

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