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APPLICATIONS

# Low Temperature Poly-Silicon (LTPS) Technology: Excimer Laser Annealing (ELA*) Process Control by Spectroscopic Ellipsometry (SE**)

The strong development of AMLCD based on amorphous silicon relies a common sense for laptop computer. But for some applications, such as displays for handy cam recorder or for Global Positioning System (G.P.S.), the amorphous silicon properties are not sufficient. For example driver integration requires an higher mobility specifications, the opening ratio requires smaller transistors. To fulfil this needs, polysilicon have the good electrical properties. Polysilicon can be obtained from amorphous silicon by two different way : by conventional annealing in an oven, SPC (Solid Phase Crystallisation), but it requires high temperature for a long time and so Quartz plate as substrate because of the softening temperature point of fused silica; the second way is by using UV light issued from an Excimer laser(*). The light is absorbed by the amorphous layer which is melt and crystallise in polysilicon while cooling.

The goal is to obtained a material which must be very homogeneous in its quality, i.e. silicon grain size must be as large as possible (up to 1 µm). For **precise optimisation of the laser annealing process** and **on line quality control** a non destructive tool capable to provide at the same time the crystallinity, the thickness and the roughness of the polysilicon layers is of great interest.

**Spectroscopic Ellipsometry(**)**, which is **contactless, non destructive and allows on-line control**, is an excellent technique to perform such characterisation.

Figure 1 shows refractive indices of silicon (from the amorphous to the crystalline silicon) and displays in the UV part of the spectrum, two absorption peaks due to the optical band gap of silicon and which give direct information on the amount of amorphous silicon mixed with crystalline silicon.

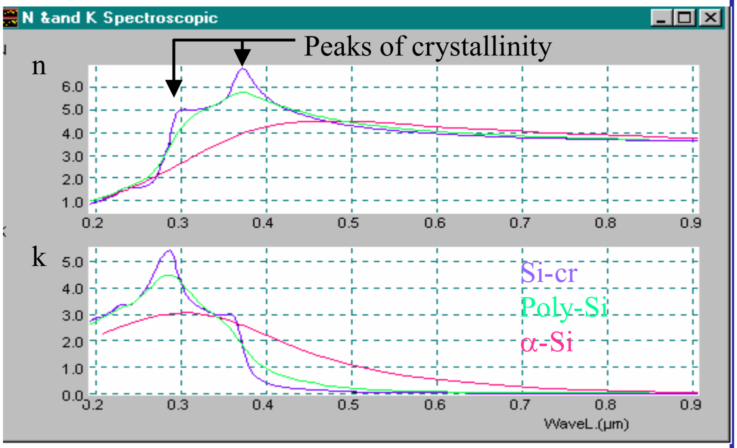

**Figure 1 : optical indices of amorphous, poly and crystalline silicon**

To characterise the poly-Si structure, we use a regression and we **define the poly-si layer** as a **composite mixture** of amorphous silicon and crystalline silicon following the **Bruggeman EMA** (Effective Medium Approximation) model.

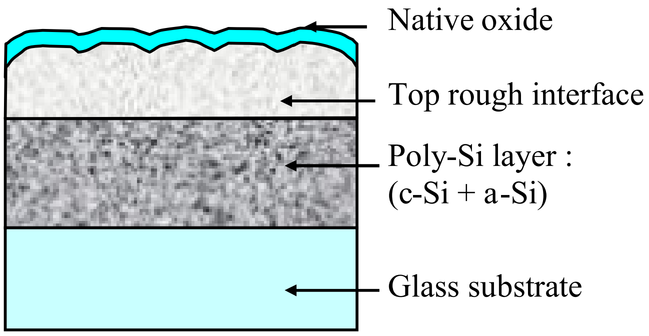

**Figure 2 : Model used for the characterisation of Poly-Si layers**

With only this **unique model** for the analysis, SE allows a **total characterisation of the poly-Si** layer **by the simultaneous determination of thickness, roughness and composition** (c-Si fraction) versus different laser annealing process conditions (environment, laser energy…).

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(*)Refer to SOPRA web page ( www. SOPRA-SA.com) for further information on SOPRA's Excimer laser.

(**)Refer to SOPRA web page ( www. SOPRA-SA.com) for tutorial on SE principles, terminology and products.

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The figure 3a shows the evolution of the c-Si fraction in the poly layer versus the laser energy. To demonstrate the reproducibility of SE results we have repeated three times the measurements during one month ( Scan 1, Scan 2 and Scan3). We have also compared these results with SEM results; the figure 3b displays pictures taken at different laser energy.

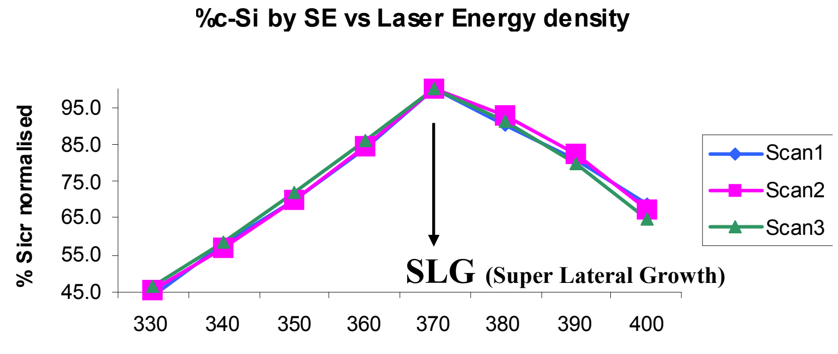
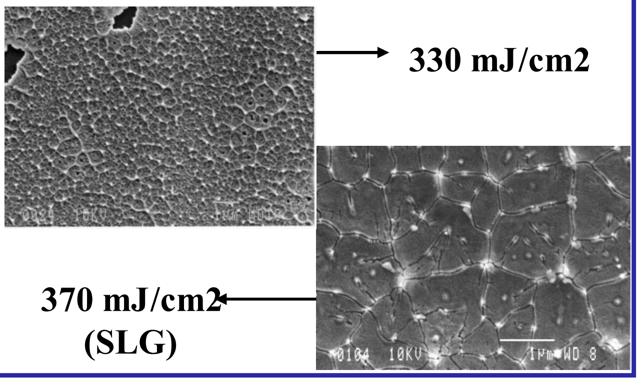
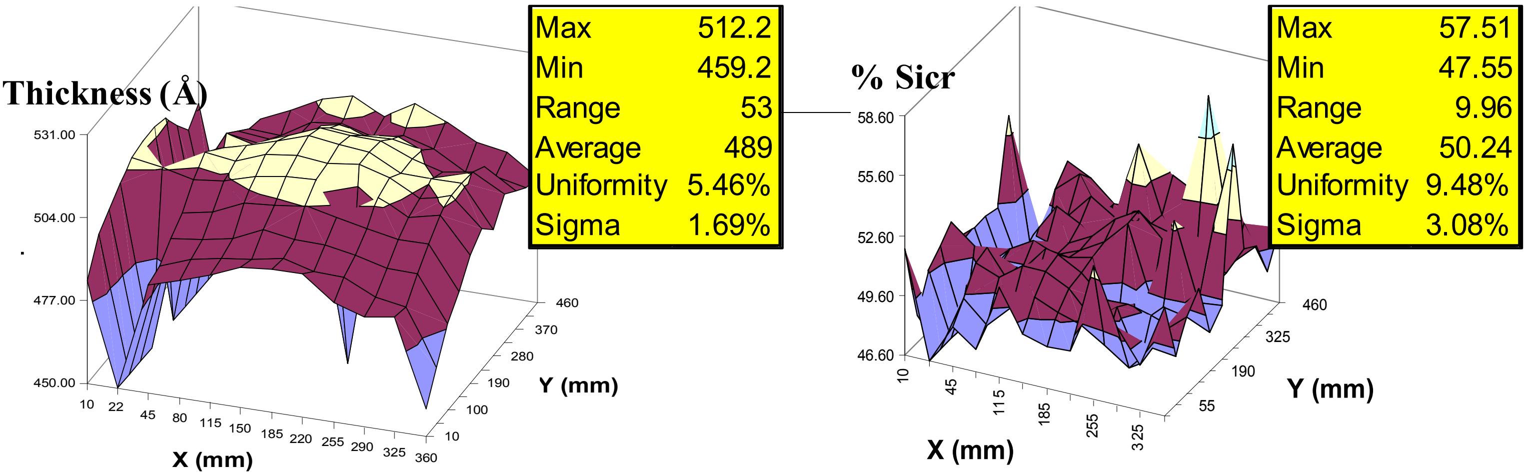


**Figure 3a** : c-Si fraction determined by SE versus laser energy

**Figure 3b** : Comparison with SEM results



These results demonstrate that **SE can describe a reproducible behaviour of crystalline silicon fraction in the poly-Si layer versus the laser energy** and thus to **determine the optimum laser energy density**. The **SEM data confirmed these results**: The maximum grain size measured by SEM corresponds to the SLG area determined by SE. These measurements has been taken **with our fast CCD spectrometer** dedicated for the **mass production control.** The figure 4 presents mappings of crystalline silicon fraction and thickness of poly-si layer.



| | |
|---|---|
| Max | 512.2 |
| Min | 459.2 |
| Range | 53 |
| Average | 489 |
| Uniformity | 5.46% |
| Sigma | 1.69% |

| | |
|---|---|
| Max | 57.51 |
| Min | 47.55 |
| Range | 9.96 |
| Average | 50.24 |
| Uniformity | 9.48% |
| Sigma | 3.08% |

**Figure 4** : c-Si fraction and thickness mappings

**From non destructive measurements and using Bruggeman EMA, Spectroscopic Ellipsometry is capable to characterise completely poly-Si layers by determining simultaneously and independently the thickness and the c-Si fraction. Using SOPRA's fast CCD spectrometer, SE is suitable for ELA process control allowing the monitoring of laser optimal energy and poly-Si material uniformity.**