Temperature dependencies of c-Si Raman spectra on alumina and glass ceramic substrates

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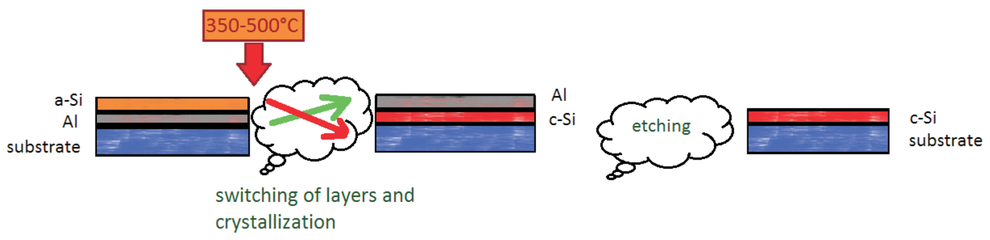
Motivation

Thin film solar cells ⟶ material and energy savings during its production

- Cheap and quick preparation of thin c-Si layer (seed layer) – aluminium induced layer exchange (ALILE):



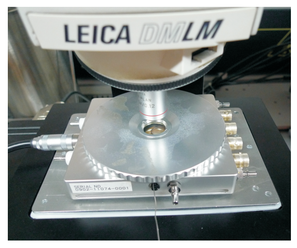
- In this manner prepared seed layer is then used as a substrate for **epitaxial grow** of high quality c-Si film ⟶ requires minimal number of defects in the seed layer ⟶ low stress in material is needed

Objective:

- What type of seed layer is the best for epitaxial grow?
  ⟶ **We are able to determine the amount of stress in material originating in deposition according to the type of substrates from Raman shift.**

Experimental setup

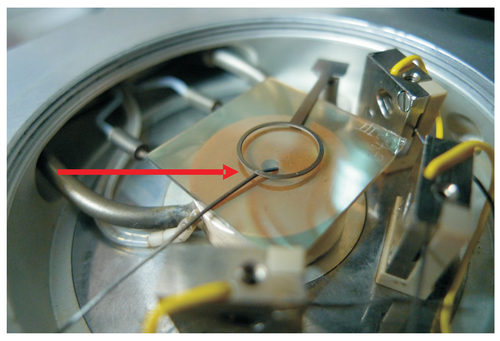
- InVia Reflex Raman microspectroscope from Renishaw equipped by HeCd dual laser with **325 and 442nm** excitation wavelengths.
- Temperature stage Examina 600 from Linkam, enebling us to observe Raman spektra between **-196°C and 600°C.**
- Thermocouple



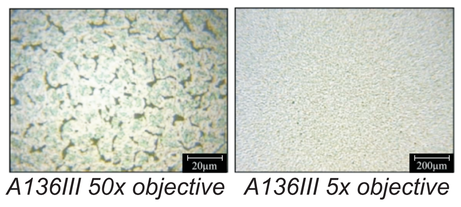
Samples

There are two types of the seed layers studied in this work; Alumina (A136III) and glass ceramic (G43III). On each layer thin c-Si film were grown epitaxially; sample A126 on alumina seed layer and G43 on glass ceramic seed layer.

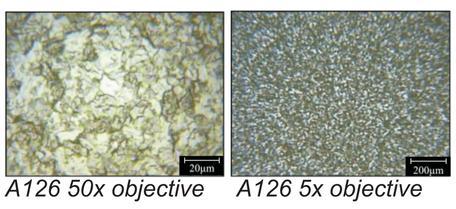
Type of sample	seed layer	epi grown film
AIC on alumina	**[A136III]**	**[A126]**
AIC on glass ceramic	**[G43III]**	**[G43]**



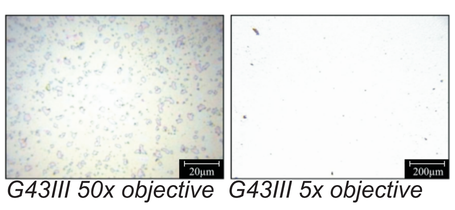
Transparent G43III sample (seed layer) placed on heating pan, thermocouple (red arrow) contact detail



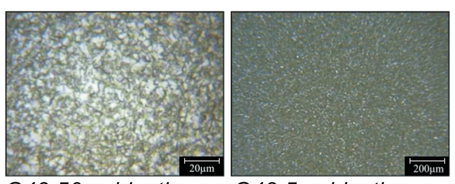
A136III 50x objective *A136III 5x objective*



A126 50x objective *A126 5x objective*



G43III 50x objective *G43III 5x objective*



G43 50x objective *G43 5x objective*

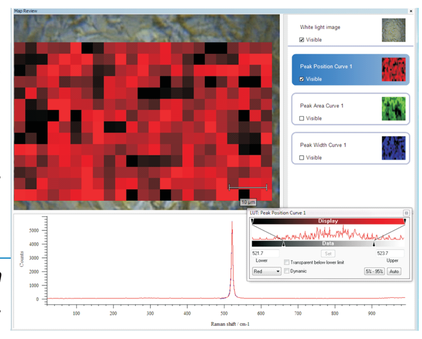
Measurement

The idea was to warm the sample up near to the deposition temperature, where only stress originating in deposition would be visible. Stress caused by different expansion coefficients of the layers etc. would disappear.

- All samples were warming from 25°C up to the 600°C in 50°C steps and then cooling back to the 50°C;
- 5min accumulation on each level, 20min after reaching 600°C;
- Real surface temperature of the sample was monitored during measurement with thermocouple;
- Raman spectra were measured on each level with 442 nm excitation laser, collection depth ~ 50 nm;
- 5x zoom objective

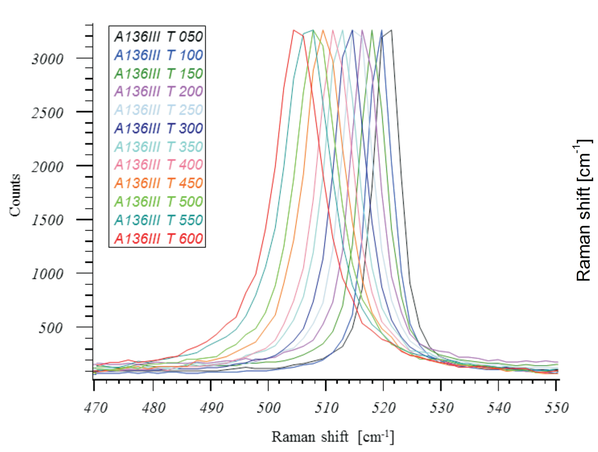
Samples are inhomogeneous as illustrated by Raman mapping.

- 50x zoom objective – differences 2cm^{-1} in Raman shift from spot to spot
- 5x zoom objective – differences only from 0,2cm^{-1} to 0,4cm^{-1}
  ⟶ suppression of inhomogeneity, but supreme optimization for sufficient signal intensity was needed.

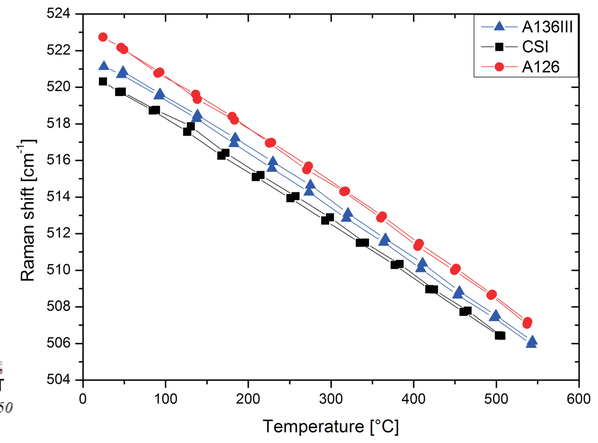


*Raman map, **A126** , 50x objective, colour on the map expresses 2cm^{-1} difference in Raman shift of the c-Si peak because of different levels of stress in the material.*

Results

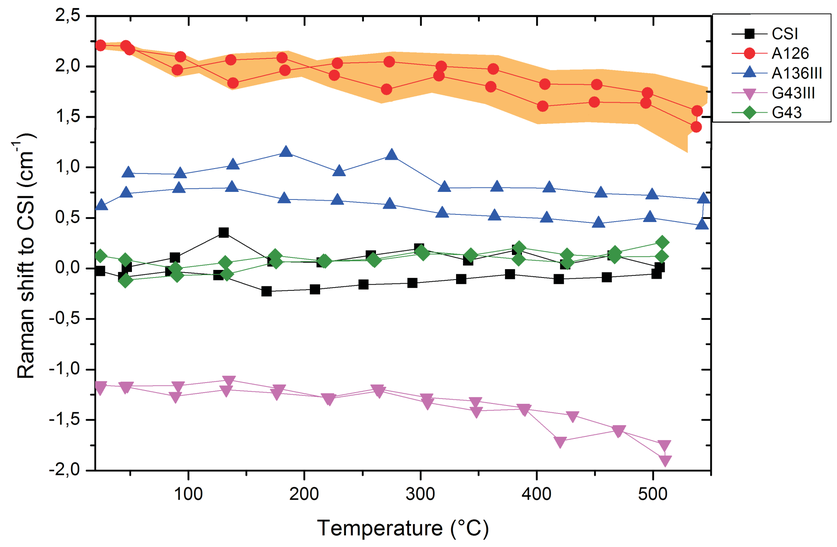


Raman spectrum shifts as we change the temperature. This is in great agreement with theory.



Central wavelength is subtracted from prev. fig. and shown here as a single point.

⟶ We are looking for deviations from this behavior, as we are interested in differences in shift of c-Si compared to the deposit layers according to the temperature change.



Comparison of measured samples to CSI (rate of CSI slope shown in fig. above is defined here as 0). Discrepancy between CSI data and 0 represents error of the measurement. Orange area expresses how the curve is affected by temperature error ± 8°C.

<u>The slope of A126 could be given by thermal stress</u>

Reality:

$1cm^{-1}\ shift\ in\ figure\ above \sim 500MPa$

Theory:

- From equations for linear thermal expansion and Hooke's law with neglecting the influence of thin CSI layer to the substrate:

$$P = G_{alumina} * (\alpha_{alumina} - \alpha_{CSI}) * \Delta T_{A126}$$

$$P_{513°C} = 862MPa$$

P..... pressure applied to the object
G.....Young's modulus (modulus of elasticity)
α.....coefficient of linear thermal expansion
ΔT..... change of the temperature

- The real temperature stress may be significantly lower due to the stress relaxation on grain boundaries in the material.

Theoretical value of thermal stress is of the same order as observed phenomenon, but considering inaccuracies of the measurement we cannot confirm the hypothesis.

Conclusion

- We have undertaken all possible steps for the maximal precision of our experiment. (Raman mapping, 5-times magnifying objective to suppress the inhomogeneity, Raman depth profile measurement, calibration before and after measurement, laser plasma line calibration, thermocouple on the surface of the sample)
- Temperature measurement precision is crucial for this experiment and significantly affects our results. Comparison of the Raman stress measured on two samples (temperature has to be measured twice – doubles the error) cannot be done with necessary precision.
- We were expecting no stress at the deposition temperature (500°C for ALILE, 1000°C for epi grow film). Relaxed stage would be expressed as an intersection of "the curve of the sample" with c-Si curve. However, we do not observe these phenomena. (Stress from deposition? Inaccuracy of the measurement?)

Acknowledgment

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