Abstract
Laser crystallization of amorphous or microcrystalline silicon films to obtain high-quality polycrystalline films is one of the most promising methods for diminishing costs in the microelectronic and solar cells sectors. During a laser crystallization process light is partially absorbed by the amorphous silicon, heating the sample and, if the temperature rises high enough, causing the reorganization of the film structure into a crystalline one. In this work we show results on the crystallization of non-hydrogenated silicon thin-films by a continuous wave infrared laser, as well as a study of the process with a simple finite elements method (FEM) numerical model based in the dimensional non-linear heat transfer equation with a steady heat source.

Results

Laser source and samples
Laser source
- Continuous wave (CW) at 980 nm
- Linear spot: 19.6mm (Top hat) x 2.16mm (Gaussian)

Allows the treatment of large areas

Samples (IEEE Journal of Photovoltaics, Vol. 4, No. 6, November 2014)

Heat resistant substrate
Buffer layer
Heated to 700ºC

Prevent cracks by thermal stress

Process parameters:
- Power: 300 – 1300 W
- Speed: 1 – 25 mm/s

Experiments results
Low laser intensity
Low speed
Untreated
Melting onset
Liquid phase melting
Dewetting onset

High laser intensity
High speed

FEM modelling
Finite Elements Method (FEM) model.
- 2D stationary model
  silicon film + glass substrate
- non-linear heat transfer equation
- Including phase change (1687 K)

Phase change
\[ \frac{1}{\sqrt{\pi \Delta T}} \exp \left( \frac{-(T - T_m)^2}{\Delta T^2} \right) \]

Source term
\[ S(r, z, t) = \rho(1 - R(T)) \Delta n(T) \exp(-\alpha(T)\Delta t) \]

Fluence profile
\[ F(r) = F_0 \exp \left( -2 \frac{r^2}{a^2} \right) \]

Results from the FEM model of the laser process with different process parameters.

FEM model results
- Good agreement between calculations and experiments.
- Irradiation time is a key variable in the crystallization process.
- The model can predict the start of the liquid phase crystallization process can be used to study the onset of the dewetting of the silicon.

Conclusions
- A continuous wave IR laser source emitting at 980 nm has been used to crystallize amorphous silicon (a-Si) thin films.
- Laser-annealed films with high crystalline quality (grains of several mm long) have been obtained.
- A simple thermal FEM model has been developed in COMSOL Multiphysics to simulate the process by numerically solving the two dimensional non-linear heat transfer equation with a steady heat source.
- The local temperature evolution in the irradiated area given by the FEM model shows good agreement with the experiment results.
- The model helps to determine the experimental parameters needed for crystallizing a-Si without damaging the film.

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