Defects created by chemical and laser texturization on the surface of mc-Si wafers studied by optical means

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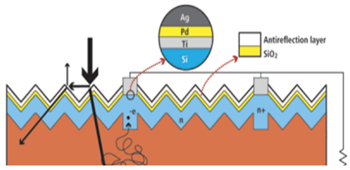
INTRODUCTION & MOTIVATION

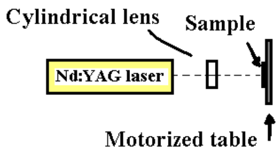
- Chemical texturization of mc-Si wafer surfaces produces different patterns, allowing for a diffuse surface which increases the light absorption and the final cell efficiency
- Alkaline chemical texturizations are typical for c-Si. Chemical texturizations based on the HF:HNO_3 solution are a general option for mc-Si, giving different surface morphology textures: pits, moth eyes, grooves, etc. Laser texturization processes have been also explored.
- Texturization processes can introduce detrimental defects in the material, e.g. laser texturization can produce residual stresses or even amorphous phases.



In this work we have studied the effect of both chemical and chemical-laser texturizations, analyzing the morphological structures produced and their impact on the optical properties.

SAMPLES UNDER STUDY

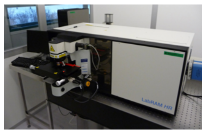
- P- type mc-Si wafers (cut in small pieces of 2 x 2 cm^2), 200 µm thick, resistivities of the order of 0.5 Ω.cm.
- KOH alkaline etching and or wet chemical acid etching with HF:HNO_3 with different diluents (H_2O, CH_3COOH, H_3PO_4 or H_2SO_4)
- Laser texturization: parallel or square grooves, 50 / 100 µm in between lines, pulsed Nd:YAG laser (1064 nm, 94.3 mJ)



Characterization techniques

Secondary electron images

UV-Vis spectrophotometry

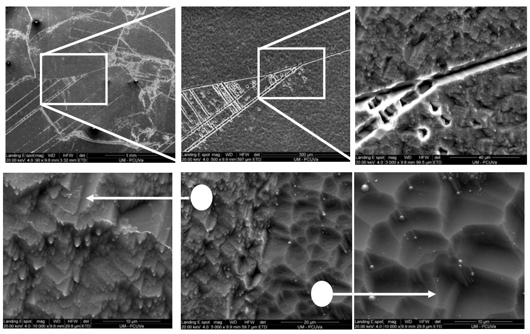


Raman spectroscopy

RESULTS AND DISCUSSION

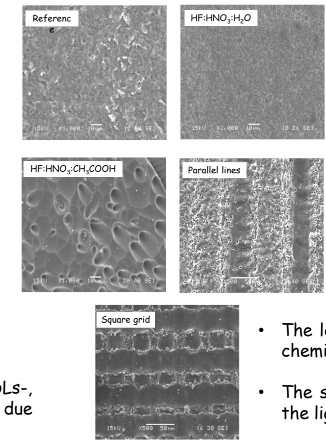
SEM & UV-Vis characterization

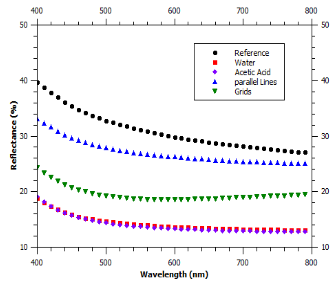
Alkaline chemical processes



- Highly anisotropic texturization
- Alkaline etching allows revealing typical defects (GBs, dislocation lines –DLs-, etc,) since they rapidly etch the areas with high defect concentrations, due to the weakening of the crystal lattice bonds in those areas.

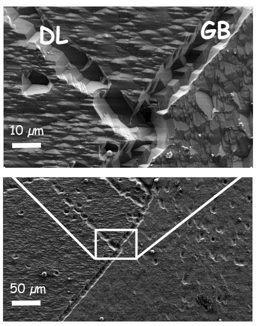
Acid chemical processes + laser texturing

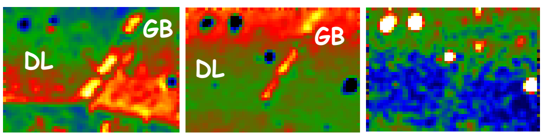




- The observed morphological differences are caused by the differences in the velocity of the etch process.
- In order to increase light trapping it is important to obtain an homogenous pattern.
- The lowest reflectivity is observed for wafers textured with HF:HNO_3 chemical etching with H_2O and CH_3COOH as diluents
- The size of the created features is a crucial parameter for optimizing the light absorption

Raman analysis

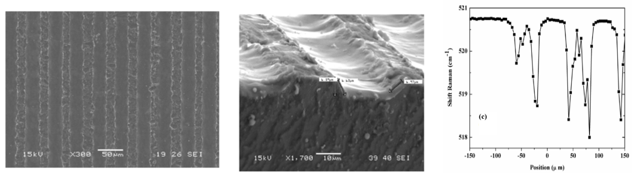




Si peak intensity | Si peak position | Si peak FWHM

- Raman spectroscopy allows to map the strain field around extended defects
- DLs show strain levels below the detection limit of our experimental setup
- GBs show a marked tensile/compressive behaviour, with large stress values (~ 50 Mpa) around the DL.

Laser texturization



- Laser texturization pattern and the reflectivity largely depend on the previous chemical attack undergone by the wafer
- Laser texturization results in poly crystalline edges and stress

CONCLUSIONS

- Acid etchings, combined with laser texturization, allows for a uniform textured surface in mc-Si
- Small features can successfully scatter light, increasing the effective optical path length and enhancing absorption
- Laser texturization produces some material degradation

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