“Study of the failure mechanism of crystalline silicon: relation between crack orientation and failure stress”

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In the PV industry, cracking of solar cells is one of the main causes of failure and demotion. Most cracks are generated in the cutting process to obtain the silicon wafers. For this reason, the characterization of the mechanism of breakage and the behaviour of strength of silicon wafers is highly important in order to minimize the fracture rate and to optimize the process steps. In this study, monocrystalline silicon UMG wafers with different orientation of cracks generated are subjected to a 4-line bending test in order to:

1. Removing sawing damage
   - Monocrystalline silicon UMG wafers
   - 156x156 mm² dimensions (thickness of 200 mm)
   - The sawing damage has been removed by means of alkaline NaOH solution in all of them.
   - Final thickness about 150 μm.

2. Doing controlled cracks
   - The cracks are generated with a diamond tip.
   - The depth and the length (10 mm) of the crack are always the same.

3. Four-line bending test and HSC study
   - HSC Photon Fastcam SA1.1
   - Objective Samyang 135mm
   - 180 000 fps

4. Strength characterization
   - As a first step, 24 samples of set A and 24 samples of set B are prepared for the strength characterization being tested by the 4-line bending device.
   - A clear non-linear behaviour is observed for wafers without cracks due to the large displacements during the tests (Fig. 10).
   - Finite Element Models (FEM) are developed to simulate the tests (Fig.12).

5. Conclusions
   - The images collected with HSC allow to observe how the behavior of the break is different in wafers with and without cracks.
   - The thin wafers are very flexible, resulting in a non-linear behavior that complicates the model.
   - Further investigations will be carried out.