Analysis of amorphous-nanocrystalline silicon thin films by High Resolution Transmission Electron Microscopy and Time-of-Flight Elastic Recoil Detection Analysis

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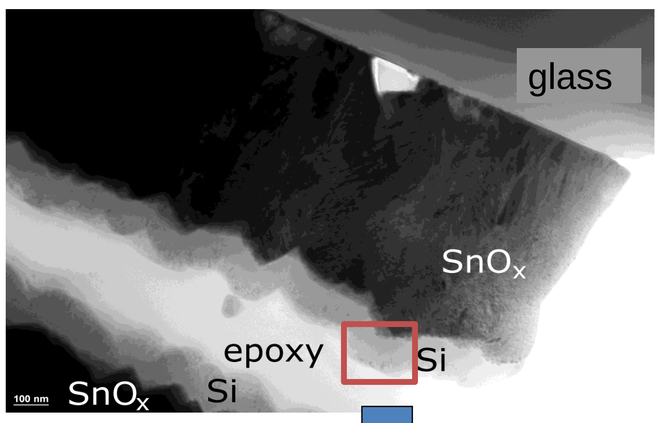
INTRODUCTION

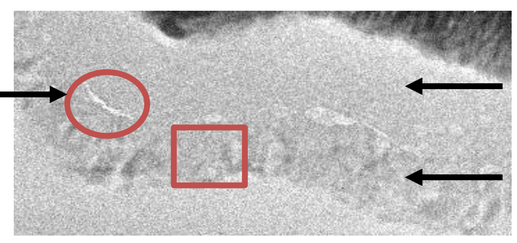
- SAMPLES: amorphous-nanocrystalline silicon thin films
  - thickness = 100 nm
  - Method of preparation: PECVD

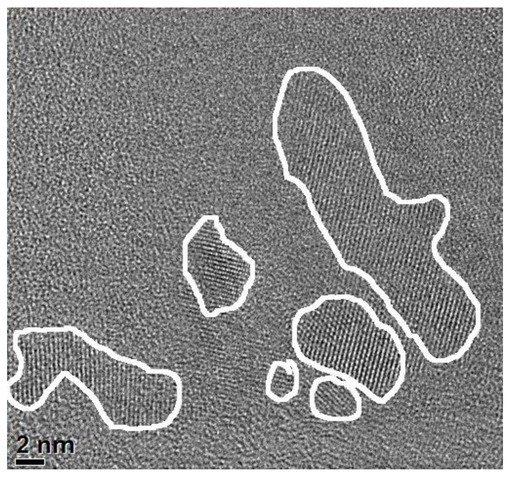
    a-Si:H - 90% SiH_4 + 10% H_2 (50 nm)

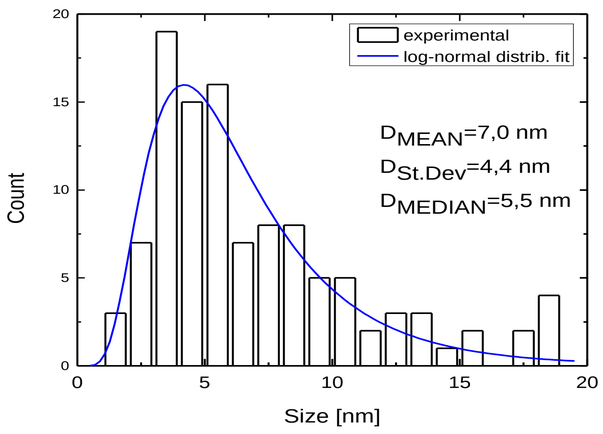
    a-nc-Si:H - 5%SiH_4 + 95% H_2 (50 nm)
  - thermal treatment in vacuum chamber at 400°C for 1h

High Resolution Transmission Electron Micoroscopy (HRTEM)





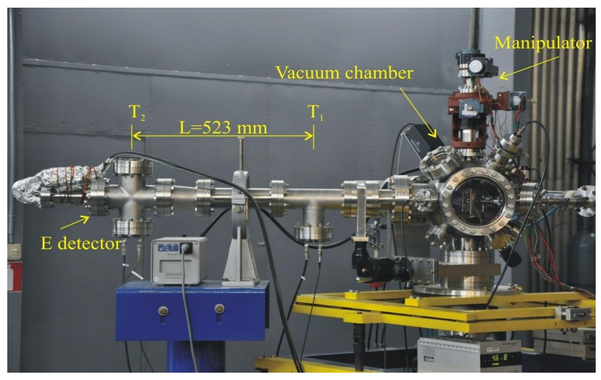


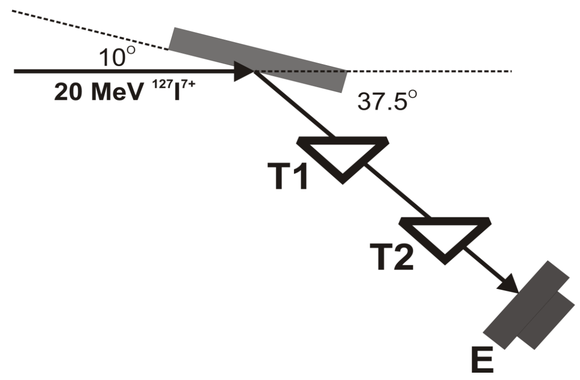


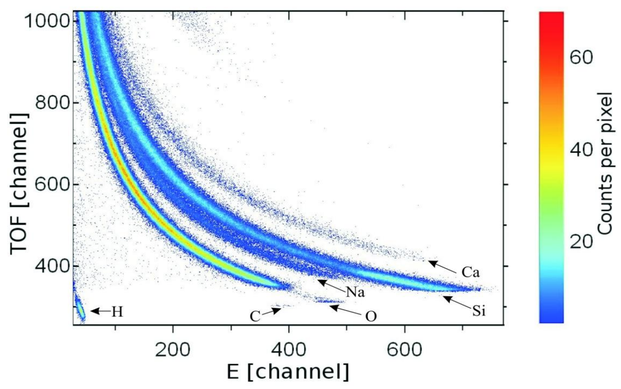
As seen by high resolution transmission electron microscopy (HRTEM), the films contained nanocrystals of silicon embedded in amorphous Si:H matrix. The size of crystals and crystal to amorphous fraction increased starting from substrate towards surface of the film. Amorphous matrix looked uniform except in the area where nanocrystals start formation where spots brighter than average appeared. These areas can be attributed to less dense material, presumably voids. It is assumed that the surface of voids is "decorated" with hydrogen that saturates silicon "dangling bonds"

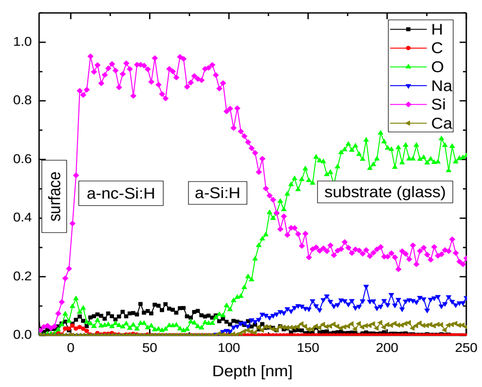
Time-of-Flight Elastic Recoil Detection Analysis (TOF-ERDA)

6 MV Tandem Van de Graaff accelerator located at Ruđer Bošković Institute



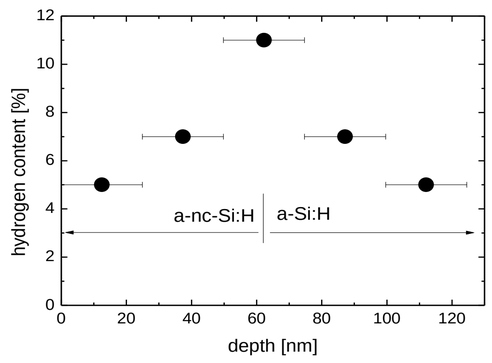




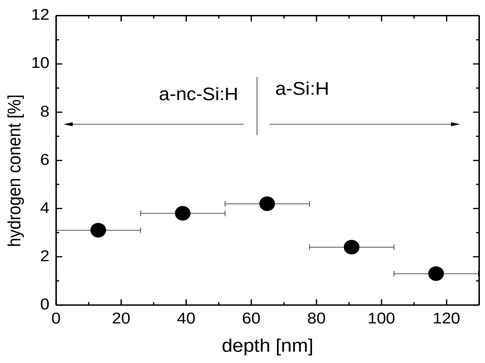


The distance 100 nm from the surface correspond to the interface between glass substrate and beginning of amorphous silicon. The distance 50 nm from the surface correspond to the position where nanocrystals start to growth. At this point, concentration of silicon atoms decrease while hydrogen concentration increase. This is consistent with model where nanocrystals are formed in the areas rich with voids filled with hydrogen that make increase of pressure and enables crystallization.

BEFORE THERMAL TREATMENT



AFTER THERMAL TREATMENT



After heat treatment at 400°C, the distribution of hydrogen remained the same, while total hydrogen concentration decreased. This indicated that the type of hydrogen bonding was the same across the amorphous network and assumed that areas of less density materials consist of agglomerates of smaller voids.

CONCLUSIONS

- Si nanocrystals embedded in a-Si:H matrix
- size of nanocrystals and crystal to amorphous fraction increased starting from substrate to surface
- non-uniform hydrogen distribution across the depth with the maximum on the interface a-Si:H/a-nc-Si:H
- less dense material – probably agglomerates of small voids

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