Summary

Workshop on fundamentals of a-SiN_x:H in industrial solar cell processing

3 November 2005 at IMEC (B)

Arthur Weeber and Ingrid Romijn
ECN Solar Energy
Harold Dekkers, IMEC
Giso Hahn, UKON

General Information

Workshop on the fundamentals of SiN_x:H in industrial solar cell processing

3 November 2005 at IMEC (B)

Organized within SP4 Cell Technology by:

- **Harold Dekkers (IMEC)**
- **Giso Hahn (UKON)**
- **Arthur Weeber (ECN Solar Energy)**

Participants:

- **About 85 from Asia, Australia, North America, and Europe**
- **From industry, universities and research institutes**

Contributions: 17 oral presentation

General Information

Subjects:

Deposition systems

- **Several deposition systems were discussed**

Bulk passivation

- **H diffusion in Si**
- **Defects to be passivated**
- **Bulk properties of SiN_x:H**

Surface passivation

- **Application different passivating layers**
- **Fixed charges and states at the interface**

Deposition systems

Different systems:

- **MicroWave Remote PECVD**
- **Expanding Thermal Plasma (ETP)**
- **Parallel Plate PECVD (direct PECVD, low and high frequency)**
- **Sputtering**
- **Hot Wire CVD**

Main conclusion:

All systems result in the same good bulk passivation

Bulk passivation I

H diffusion in Si and defects to be passivated

- **Direct detection of deuterium after SiN_x:H firing of Cz, mc-Si, and in pc-Si**
- **About 10^{14} H/cm^{-2} diffuses into the bulk of Si**
- **Diffusion kinetics dependent on oxygen content (trapping)**
- **Dynamic H distribution in Si modelled and showed that with trapping density of 10^{16} cm^{-3} H diffuses >>100 µm within seconds**
- **Enough hydrogen in layers to passivate dangling bonds in grain boundaries of pc-Si**
- **Firing of SiN_x:H layers and MIRPH result in passivation of extended defects within a huge fraction of the cell volume**

Under discussion / investigation:

- **Where does the hydrogen come from?**
  - **From SiN_x:H or process induced defect layer at the interface?**

Bulk passivation II

H diffusion in SiN_x:H layer and passivating effect

- **Mass density of SiN_x:H layer key parameter for bulk passivation (tested on layers with same n and different densities), best passivation found for ρ_{mass}=2.9 g/cm^3 (found for both parallel plate PECVD and sputtering).**
- **Same relations found for Si-N bond density using MW PECVD (there is a one to one relation between mass density and Si-N bond density), best bulk and surface passivation at [S-N]=1.3·10^{22} cm^{-3}**
- **Diffusion mechanism and coefficient of H depends on density (mass and/or [Si-N])**
  - **Open structures, low density: H_2 molecule diffusion**
  - **Dense structures, high density: atomic H diffusion**
- **Hydrogen effusion from and kinetics in a-Si:H presented and similarities with effusion from a-SiN_x:H shown**

Surface passivation

Layer characterization

- **Remote and high-frequency PECVD SiN_x:H give optimal surface passivation**
- **Large number of fixed charges (Q_f~$2 \cdot 10^{12}$ cm^{-2})**
  - **Q_f dependent on composition (results contradictorily)**
  - **Q_f can change under illumination (results contradictorily)**
- **Recombination in space charge region important**
- **Damaged layer about 100 nm**
- **Excellent surface passivation for a-Si:H and a-Si:H/a-SiN_x:H stacks**

Solar cell processing with SiN_x:H at the rear

- **High efficiency processing: efficiencies >19% achieved**
- **Screen-printed: results lower than Al BSF**