Effect of internal stress on the chemical texturing of sputtered Al:ZnO layers for light-trapping in thin film solar cells

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1. Introduction

The main properties that Transparent Conducting Oxide (TCO) layers for solar cells need to possess are both high transparency and high conductivity. For thin film silicon solar cells, an additional requirement for the front TCO layer is that it must also scatter the light in order to increase the effective light path in the cell. The tandem cell made of amorphous and microcrystalline silicon as absorber is a good example where light trapping plays a decisive role for device performance. Understanding the key parameters controlling the TCO texturization is therefore crucial to create the proper roughness and features sizes that maximize large angle scattering of the visible as well as near infra-red light [1,2]. Besides the crystalline orientation of the TCO [3], its internal stress, originating from the deposition process itself as well as from differences in thermal expansion coefficient within the complete cell structure is another of those key parameters. Here we focus on aluminum doped zinc oxide (Al:ZnO) layers since this TCO is made only of abundant elements and it can be easily textured by a wet-chemical etching step.

3. Stress evolution during Al:ZnO sputtering

The glass or Si/SiO₂ substrates were free to bend and (while rotating) their curvature evolution was monitored in-situ using a multi-beam optical stress sensor (MOSS) [5]. The curvature is the glass or Si/SiO₂ substrates having respectively larger and smaller linear expansion coefficient with respect to Al:ZnO, the thermal stress arising upon cooling at the end of the deposition add 180MPa either towards the compressive or the tensile direction.

6. ICP ex-situ + SEM

- Al:ZnO with large tension (unheated) is etched very rapidly but only leads to moderate rugosity
- Al:ZnO with low internal stress is etched slowly with moderate rugosity
- Al:ZnO with large compressive stress is etched rapidly with a high rugosity

7. Optical properties

• Beyond the crystalline orientation, which was here kept constant, the internal stress level has a strong influence on the etching mechanism.
• To obtain highly textured layers i.e. high rugosity, high level of internal compressive stress is favourable.
• In-situ ICP chemical analysis during the etching step is a powerful tool to follow the texturation step. A large and sudden increase in the etching rate is indicative for the formation of a high rugosity.

9. References