Front- and Rearside Plasma Texturing of Crystalline Silicon Wafers for PV Applications

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Motivation

Inductive Coupled Plasma (ICP) surface textures offer a significant improved absorption for front side textured solar cells (Fig. 1).

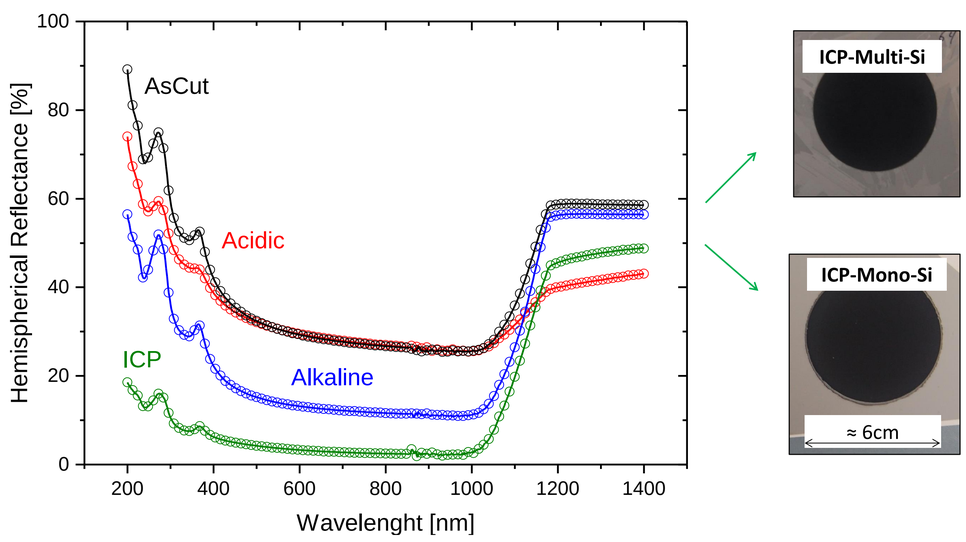

Fig. 1: Hemispherical reflectance of front side ICP textures (green) compared to alkaline (blue), acidic (red) and AsCut wafers (black)

Perform front and rear side ICP textures in crystalline silicon an improved light trapping?

µ-Structure & Moth-Eye-Effect

The excellent optical properties of ICP textures are caused by the Moth-Eye-Effect (Fig. 2).

(I) Structure width & wavelength are in the same magnitude
(II) Determined through the Effective-Medium-Theory (EMT)
(III) Gradual transition of the effective refraction index

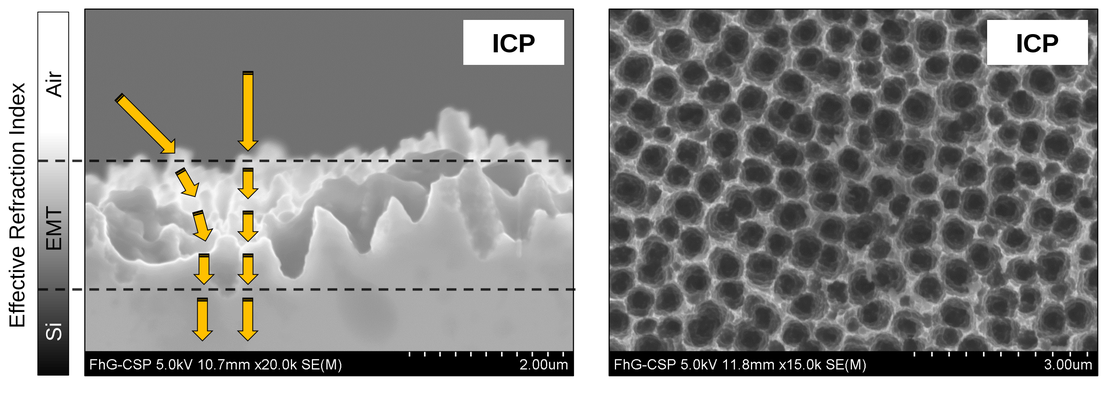

Fig. 2: Side view (left) and top view (right) of ICP textures with regard to the effective refraction index

Improved absorption through the Moth-Eye-Effect over a wide angle of incidence

Conclusion & Outlook

Inductive Coupled Plasma (ICP) surface textures are recommended as front side textures, because

(+) Improved Absorption through Moth-Eye-Effect (Fig. 2)
(+) Sufficient surface passivation through Atomic-Layer-Deposition (Fig. 4)
(-) Reduced rear side reflectance by gradual refraction index (Fig. 3)

Further planed studies at ICP textures are

- Adjustment of PECVD passivation to ICP structures
- Investigation of the Potential-Induced-Degradation (PID) on ICP textures on cell and module level

Front- and Rearside Plasma Texture

Investigation of one-sided & two-sided plasma textures compared to AsCut wafer results (Fig. 3)

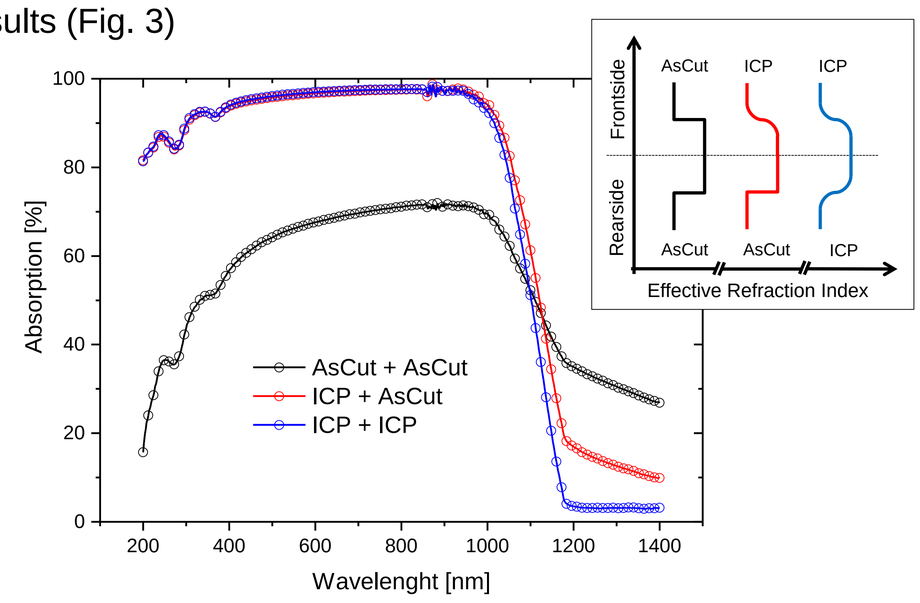

Fig. 3: Absorption of one-sided & two-sided plasma textures and AsCut wafers with regard to their effective refraction index

The gradual transition of the effective refraction index at the front side leads to a significant improved coupling of light into the crystal. But the same effect reduces the rear side reflection (Tab. 1).

Tab. 1: Overview of the coupling of light and the rear side reflectance of selected front and rear side textured crystalline silicon

	Frontside Coupling of light	**Rearside Reflectance**
AsCut - AsCut	Average	Average
ICP - AsCut	Strong improved	Reduced
ICP - ICP	Strong improved	Strong reduced

ICP Textures are well suited through their Moth-Eye-Effect for solar cell front sides. However, this effect increases the rear side transmission by the gradual effective refraction index.

Effective Lifetime

Comparison of the reached effective charge carrier lifetimes of ICP textures after Atomic-Layer-Deposition (ALD) or Plasma-Enhanced-Chemical-Vapour Deposition (PECVD) (Fig. 4).

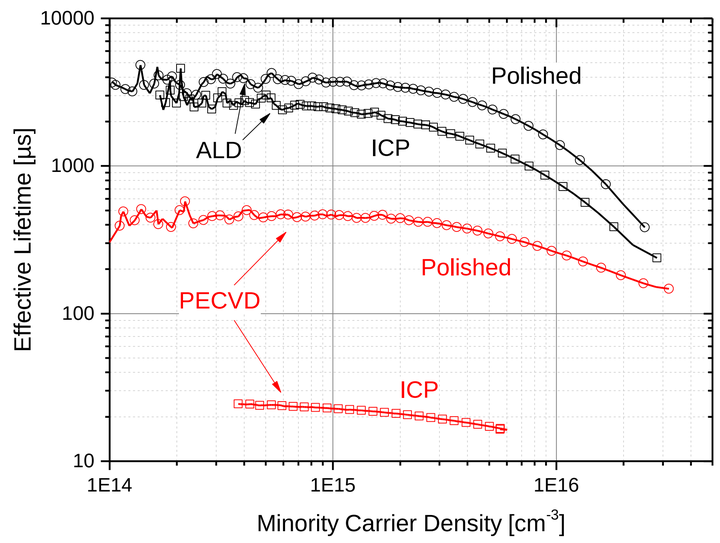

Fig. 4: Effective charge carrier lifetime over minority carrier density for ALD (black) and PECVD (red) passivated ICP probes

Sufficient surface passivation by Atomic-Layer-Deposition, but PECVD passivation must be adjusted.

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