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Etching Uniformity and Profile Control in Patterned Plasma System for HJT-IBC Solar Cell Fabrication

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The patterned plasma etching technique is a promising low-cost route towards crystalline silicon heterojunction (HJT) interdigitated back contact (IBC) solar cells [1][2][3], the highest performance known single junction cell design. In this technique, the powered electrode of a RF reactor is approached close to the substrate to be etched, such that the plasma only lights within patterned slits in the electrode, thus performing a localized plasma process, as depicted in Figure 1.

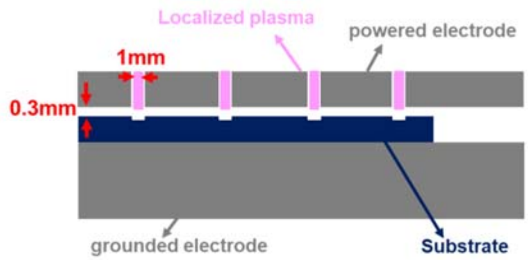

Figure 1. Depiction of patterned plasma process

Three challenges are inherent in this technique due to its use of an intense but localized plasma: (1) achieving a high electronic quality surface after etching, (2) achieving a uniform etching process throughout the wafer surface, and (3) controlling the etching profile, making it as "square" as possible. Furthermore, one must achieve all three goals simultaneously. Our recent work has shown that the first goal is possible through careful plasma surface treatments [1]. In this work, we show that the second two goals are met through the additional degrees of freedom provided by a multi-level programmable pulsed plasma source (Synertia RFG 15/13, COMET) with Automatic Frequency Tuning (AFT). First, the effectiveness of the many possibilities of this source for achieving a uniform patterned etching process everywhere on the wafer is shown in Figure 2.

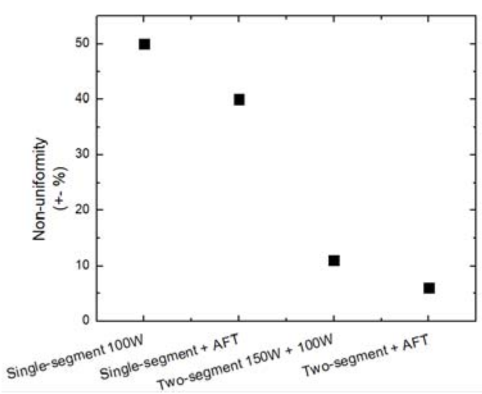

Figure 2. Etching uniformity results using different etching power segments and AFT settings.

By employing a high power "lighting" phase (150 W) along with a lower power "etching" phase (100 W), along with AFT, the non-uniformity over the wafer can be reduced from almost ± 50% to ± 6%, a fully acceptable value for this cell design. It additionally demonstrates the importance of the AFT feature – the tuning feature ensures the optimal power coupling upon ignition of the plasma, which encourages a uniform process.

The final goal – controlling the "squareness" of the etching profile – is very important as it will determine how closely together the IBC fingers can be placed in the final cell design. As shown in Figure 3, many parameters play a role in the etched profile (power, pressure, and duty cycle).

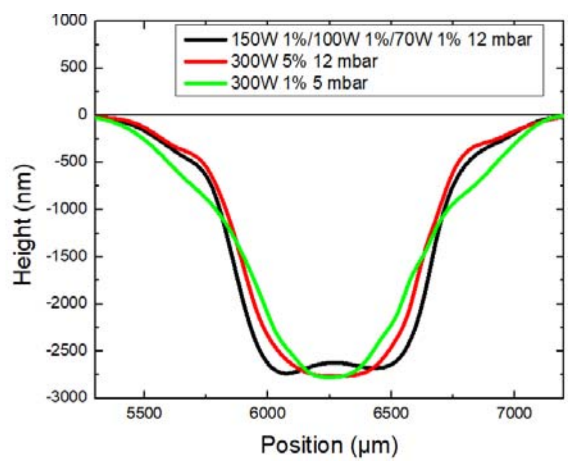

Figure 3. Etching profile for three plasma process conditions (same gas mixture).

The "300W" curves of Fig. 3 represent the limiting conditions under which the plasma will light reliably when a single power level is used, and thus also giving a predictable etching rate and uniformity. The flexibility afforded by the multi-level pulsed system (black curve) allows one to achieve three goals simultaneously: optimizing the etched profile, achieving a uniform process, and using the lowest maximum power (minimizing damage to the surface).

In summary these results show that the process window provided by this plasma source is an enabling step for the fabrication of patterned plasma HJT-IBC solar cells.

References

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