# Over 10% Efficient Wide Bandgap CIGSe Solar Cells on Transparent Substrate with Na Pre-Deposition Treatment


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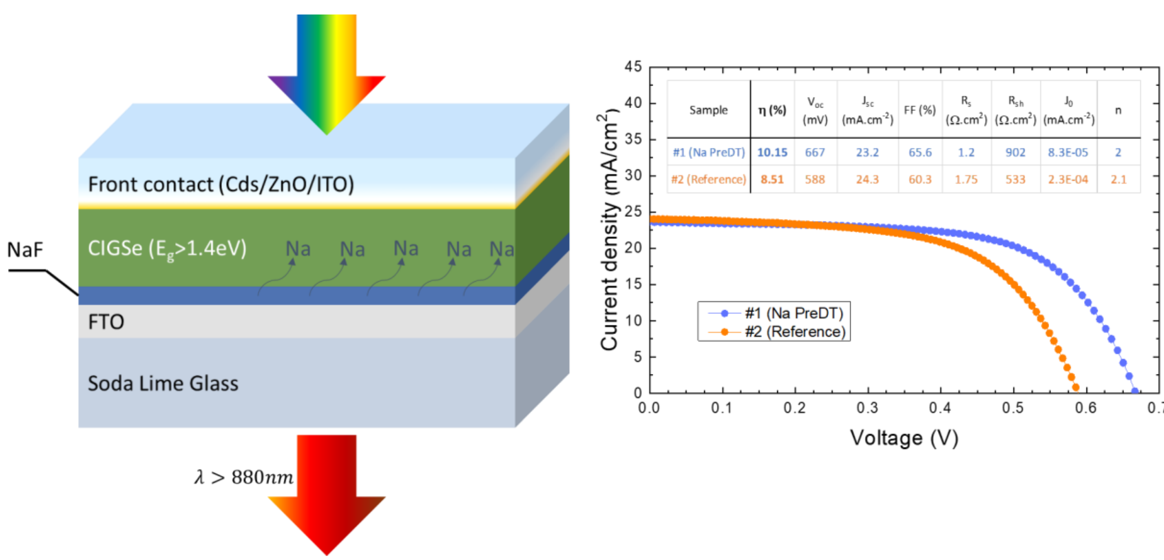
With the recent rise of new photovoltaic applications, it becomes necessary for thin film technologies such as $Cu(In,Ga)Se_2$ to develop specific optoelectronic properties and take advantage of their high degree of tunability. The feasibility of efficient wide bandgap absorbers on transparent conductive oxide substrates is in that context of critical importance. Using an original approach based on a pre-deposition sodium treatment, $Cu(In,Ga)Se_2$ absorbers fabricated by sputtering and reactive annealing with a Ga to (Ga+In) content over 0.7 and an optical bandgap above 1.4eV are deposited on transparent fluorine-doped tin oxide films, with the insertion of an ultrathin $MoSe_2$ layer preserving the contact's ohmicity. A sample pretreated with NaF is compared with a reference CIGSe absorber, and different material characterizations are performed. While Glow Discharge Emission Spectroscopy does not show any appreciable difference between the both sample, the X-Ray diffraction analysis reveals that in the absence of sodium, a clear phase segregation occurs with a Ga-poor and a Ga-rich phase coexisting. The sample including a sodium pretreatment on the other hand exhibits a single phase CIGSe with well-defined XRD peaks, thus indicating a much better homogeneity in the Ga incorporation. A thorough Raman analysis of the absorber reveals that the sodium pre-treatment significantly enhances the Ga incorporation into the chalcopyrite matrix toward the surface, along with markedly improving the film's morphology and crystalline quality. This translates in a remarkable increase of the photovoltaic performance for the resulting solar cell as compared to a reference device without Na, specifically in the voltage and fill factor. The external quantum efficiency measurement confirms the bandgap widening when using a Na pretreatment, with a measured value of 1.42eV. Eventually, an efficiency exceeding 10% is obtained without antireflection coating, a record value bridging the gap with the state of the art wide bandgap CIGSe solar cells on non-transparent substrates.


| Sample | η (%) | $V_{oc}$ (mV) | $J_{sc}$ ($mA.cm^{-2}$) | FF (%) | $R_s$ ($\Omega.cm^2$) | $R_{sh}$ ($\Omega.cm^2$) | $J_0$ ($mA.cm^{-2}$) | n |
|---|---|---|---|---|---|---|---|---|
| #1 (Na PreDT) | **10.15** | 667 | 23.2 | 65.6 | 1.2 | 902 | 8.3E-05 | 2 |
| #2 (Reference) | **8.51** | 588 | 24.3 | 60.3 | 1.75 | 533 | 2.3E-04 | 2.1 |