DEVELOPMENT OF A TRANSPARENT PROTECTIVE BARRIER LAYER VIA PECVD FOR FLEXIBLE THIN FILM SOLAR CELLS

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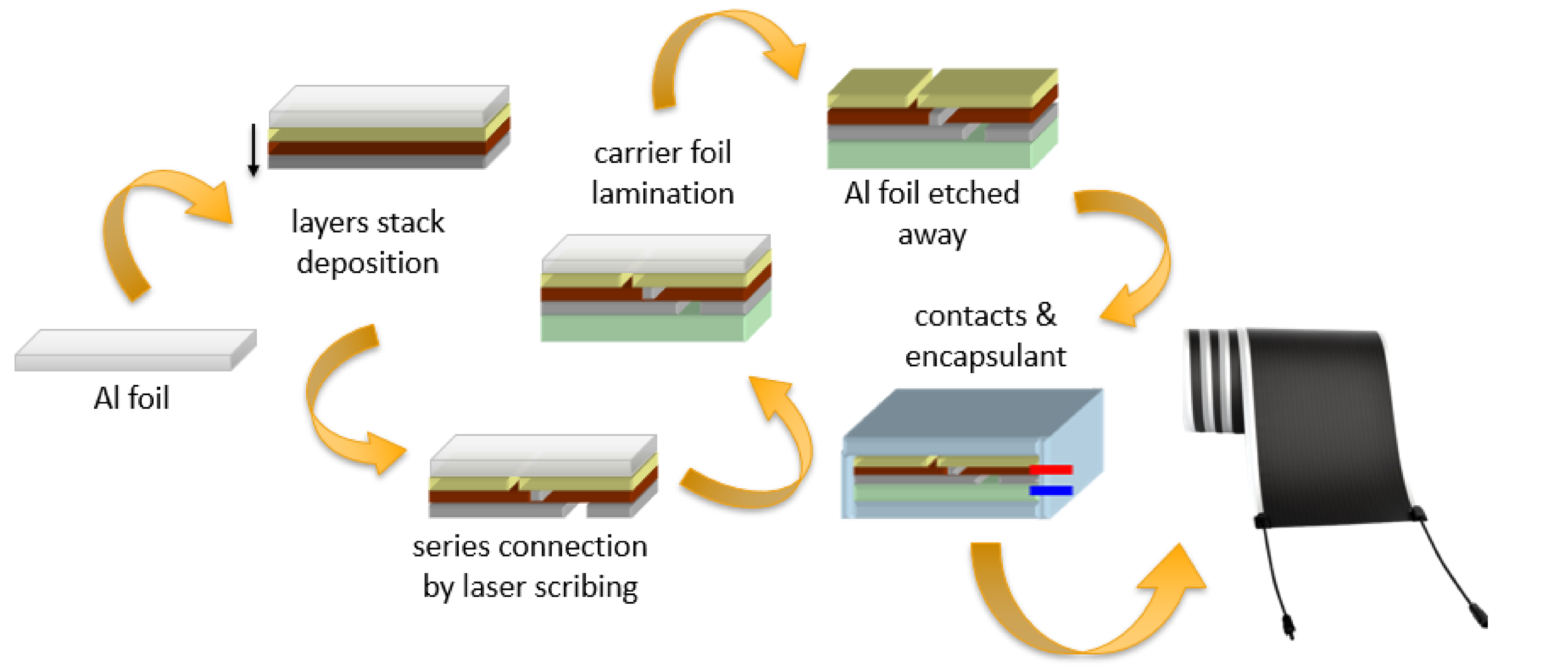
MOTIVATION & OBJECTIVES

- Thin-film flexible solar panels have many advantages such as light-weight, adaptability and low costs.
- To have good quality layers (especially TCO), the process happens at high temperature on a temporary Al substrate.
- After the PV layers are deposited, the Al foil is chemically etched.
- A protective barrier layer is needed between the Al foil and TCO to protect the PV stack.

Requirements of the barrier layer:

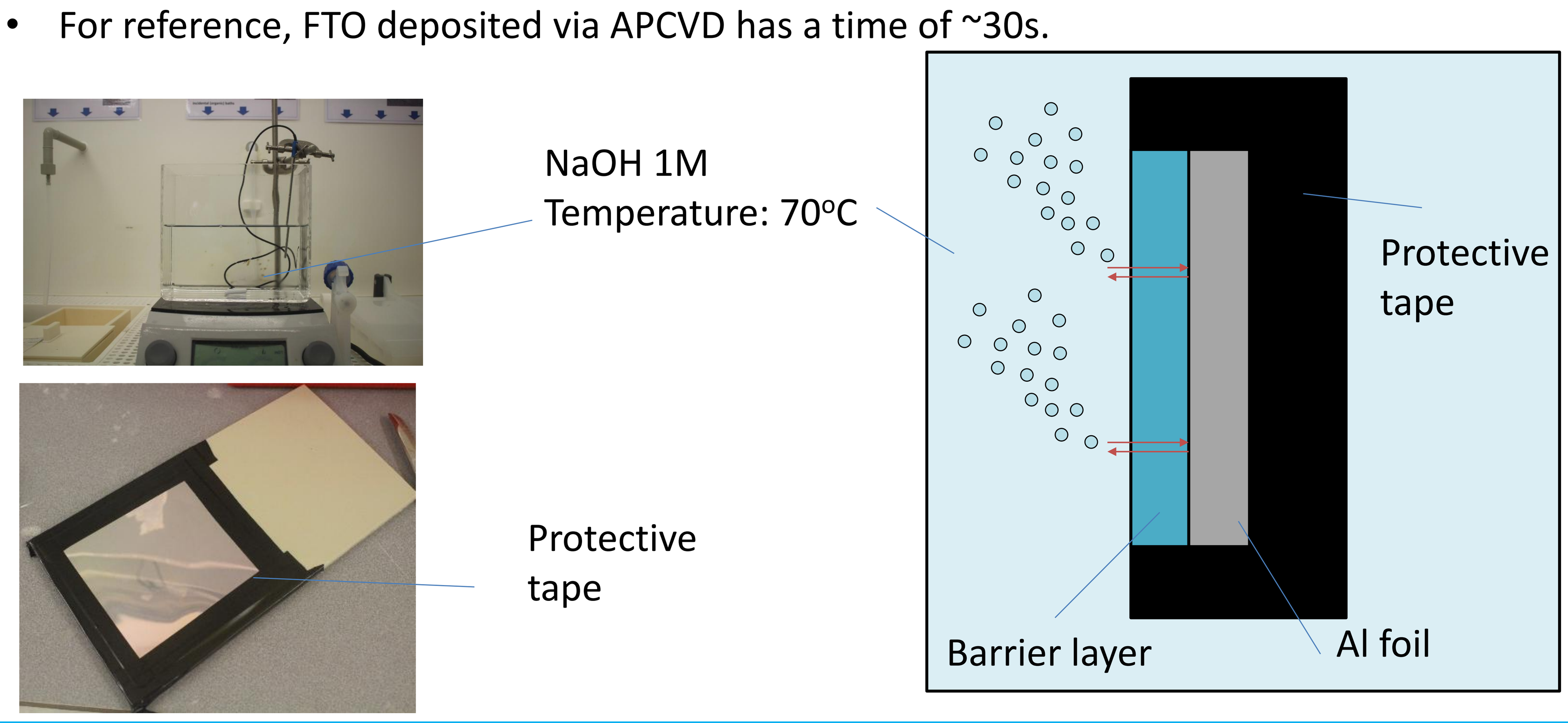
- It should be optically transparent
- It should protect the PV stack from the chemcial etch of the Al foil
- It could potentially act as a water ingression barrier
- It could smoothen out rough features on the Al surface
- It could potentially have anti-reflection properties
- It can be used as a dielectric material to avoid leakage currents



An example of a thin film flexible solar cell process on a temporary substrate, i.e. Hyet Solar

ETCH LEAK TEST

- To determine the chemical etch resistance, a test was developed.
- The sample was immersed in a NaOH 1M solution at 70ºC, with the barrier layer exposed.
- The time that it takes for bubbles to appear is recorded (the solution has reached the Al foil).
- For reference, FTO deposited via APCVD has a time of ~30s.

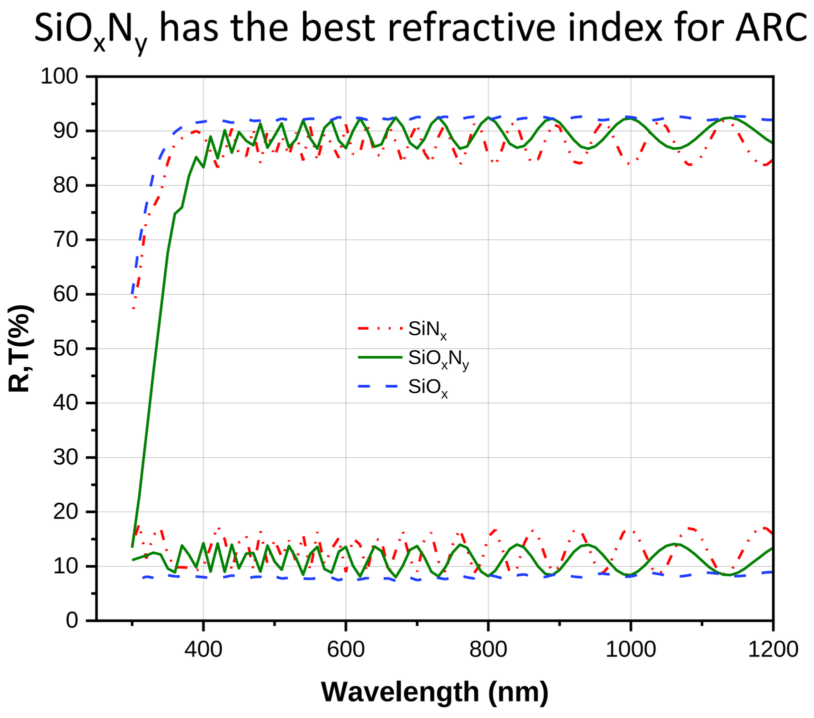


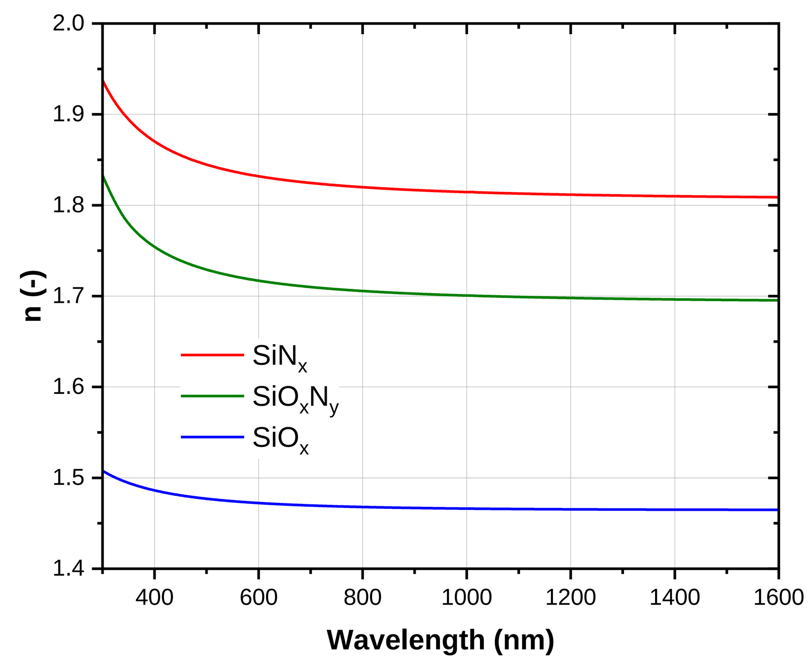
MATERIAL CHOICE

- The available materials are silicon-based alloys, mostly SiO_x, SiO_xN_y and SiN_x.
- They are deposited by PECVD at 400ºC. The high temperatures makes the materials more dense and chemically resistant.

OPTICAL PROPERTIES

- All materials tested were very transparent, with over 80% transparency in the visible range (400-1200nm).
- The function as an antireflection coating (ARC) usually needs a refractive index between that of the front encapsulant and the solar cell stack (usually between 1.6-1.7 is optimal). SiO_xN_y has the best refractive index for ARC purposes.

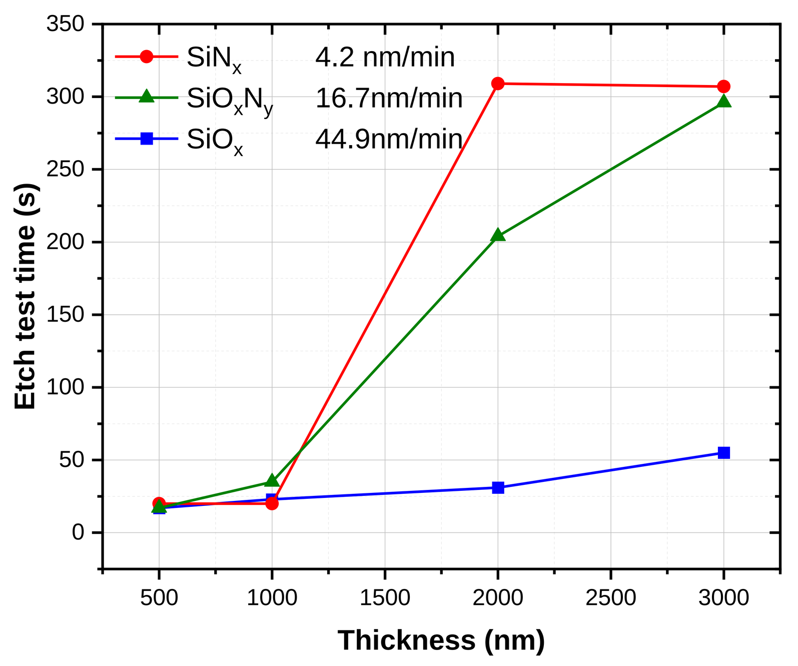




CHEMICAL RESISTANCE

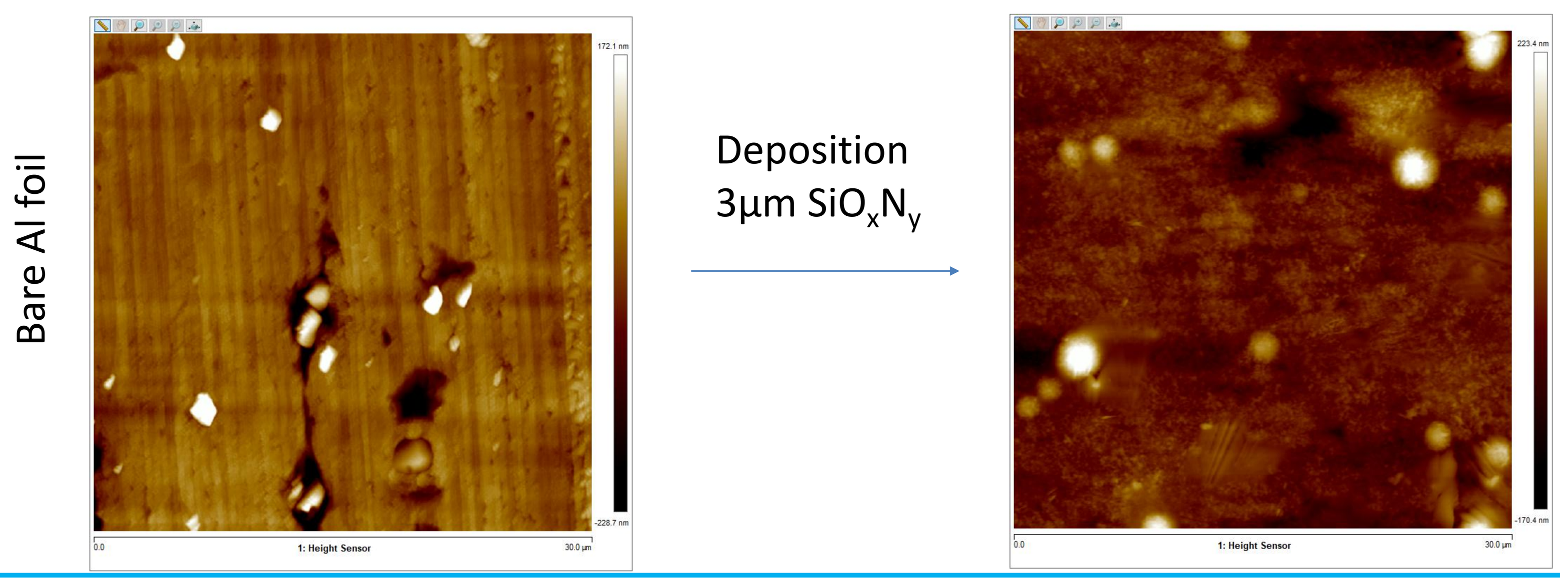
- Higher thicknesses achieve better chemical resistance. The relation seems to be non-linear, which suggests there are complex mechanisms at play.
- The best performing material is SiN_x, with over 5 min at 2 µm thickness. However, SiO_xN_y can also achieve good results at a much higher deposition rate.

Note: the tape started detaching after 5 min of exposure, limiting the accuracy of the test at times over 5 min.



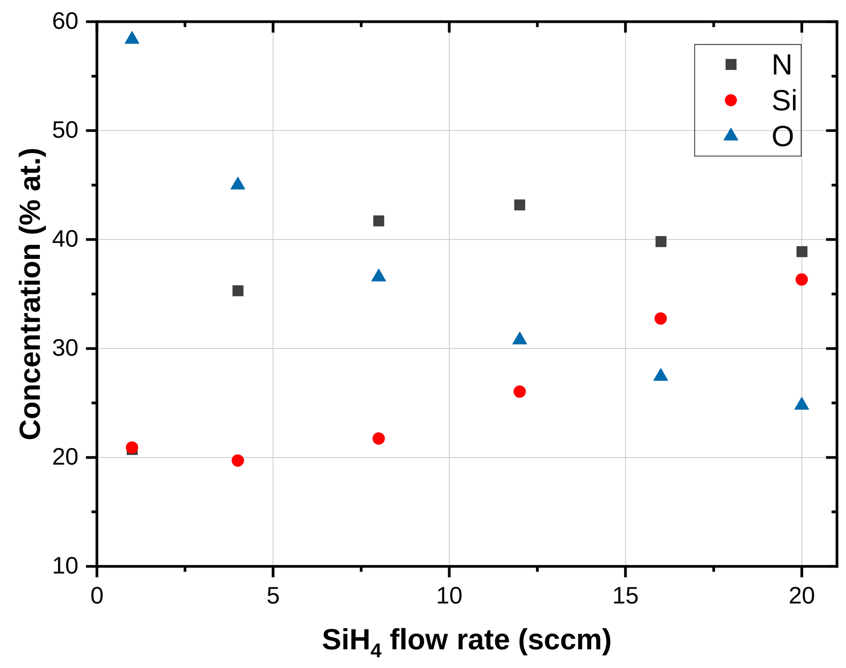
SURFACE MORPHOLOGY

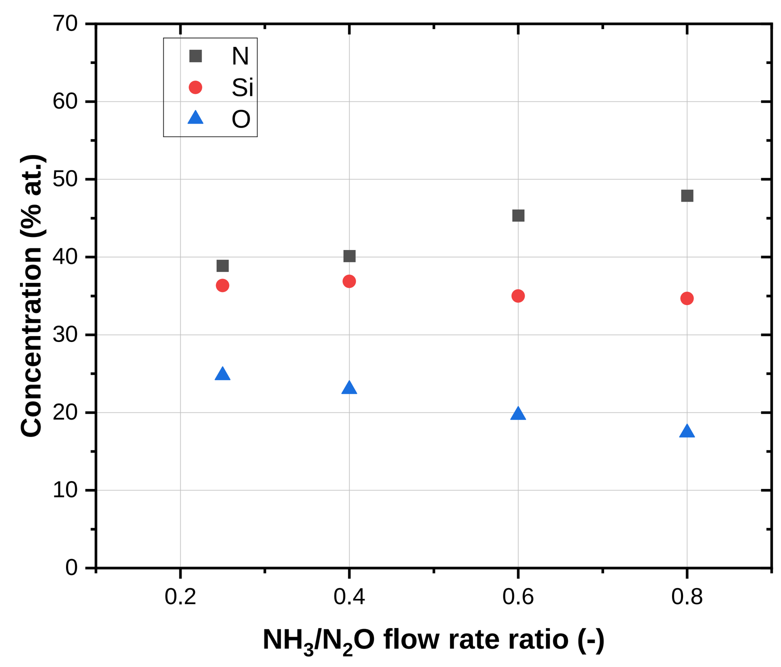
- A 3 µm layer smoothen out the milling tracks, but it does not cover the particles and bigger features at the surface of the Al foil. This happens in all the different materials.



SILICON OXI-NITRIDE OPTIMIZATION

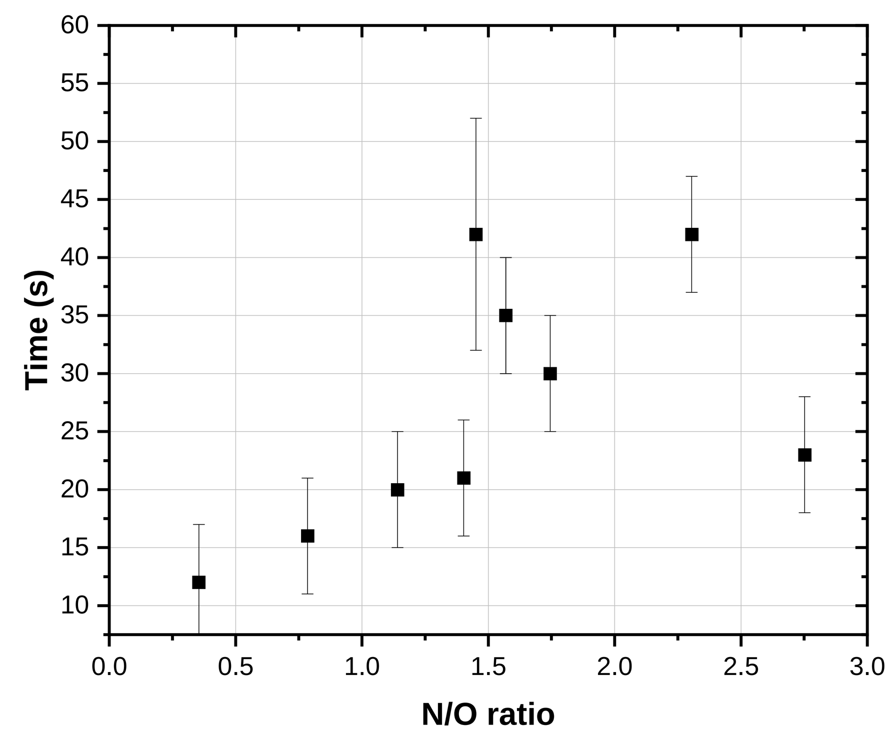
- Silicon oxi-nitride (SiO_xN_y) is chosen as the best combination of optical properties, chemical resistance and deposition rates compatible with industry processing.
- To better understand what the role of the nitrogen and oxygen is, different concentrations of oxygen and nitrogen are tested, especially on the chemical resistance.
- The two ways in which changing chemical composition is achieved is by
  - Changing the SiH_4 flow rate
  - Changing the NH_3 to N_2O precursor gases ratio
- It was observed that there is a balance between the oxygen and nitrogen that can be present in the material. The more nitrogen present, the less oxygen, and vice versa.





CHEMICAL RESISTANCE

- The samples for this experiments were done with a thickness of 1 µm.
- All samples were comparable in terms of transparency and dielectric properties.
- Including more nitrogen in the matrix increases the chemical stability and etch barrier layer properties.
- The most etch resistant layers have an N/O ratio between 1.5 and 2.5.
- The dominant way in which the etch leak test fails for this material seems to be through localized pinholes. It is expected that the presence of oxygen slightly increases the solubility of the layer, degrading the chemical resistance of the layer.



CONCLUSIONS

- A transparent etch resistant layer was designed. The best material was found to be a SiO_xN_y layer deposited at 400ºC via PECVD with an N to O ratio between 1.5 and 2.5.
- There is a minimum thickness for the barrier to be effective. It is recommended for the thickness to be between 2 and 3 µm.
- It is speculated that the etching mechanism is dominated by pinholes, although the dissolution of oxygen could also play a role.
- The barrier layer also has antireflection properties for a typical flexible solar cell configuration, as well as a flattening effect on smaller features on the Al foil.

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Website: https://luminosity-project.eu/