Developing aesthetically pleasant solar panels is crucial to the success of building-integrated photovoltaics. Solar panels based on black silicon are an appealing solution, and thanks to their superior absorption of light they can lead to increased efficiency. Here, we demonstrate a combination of black Si and black bus-bars that yields an all-black front surface based on conventional, screen-printed solar cells. We fabricate black Si using mask-less reactive ion etch (RIE), with averaged light reflection of less than 1.5% on Czochralski mono-crystalline wafers (Fig. 1a). As black Si does not require an antireflective coating, current work focuses on optimizing the Al₂O₃ passivation towards a high minority carrier lifetime.

We also developed a process for blackening bus-bars by combining metal coating by electroplating with chemical etching of the metal surface. The coating is completely inorganic and is thus expected to resist degradation by UV-light. The coating reduces reflectance dramatically as compared to conventional bus-bars with soldering coating - down to less than 4% in average (Fig. 1d). Fig. 1e and 1f show cross-sections of bus-bars before and after soldering, respectively. The soldering coating on the top side does not change during soldering, while the solder material on the back Si is redistributed due to surface tensions. Chemical analysis by EDS shows that the coating on the top side has not been damaged by the soldering process or the flux that was used before soldering. The small hole in the top layer on fig 1f (indicated by the blue circle) was made by one of the pins from the stringer-machine during soldering. This hole is not visible from a distance of 1 m.

Figure 1: (a) Reflectance as function of photon wavelength for black Si. (b) Minority carrier lifetime as function of excess carrier density for p-type Si after RIE (diamonds), after Al₂O₃ coating (triangles) and after annealing (circles). The lifetime of a double side polished Si reference with the same passivation is also shown (squares). Inset: photograph of a 4” Si after RIE processing; (c) Top: cross-section SEM image of nanostructures after full fabrication. Bottom: HRTEM image of the interface between a nanostructure and the Al₂O₃ coating (scale bar: 2 nm); (d) Reflectance as function of photon wavelength for black bus-bars; (e)-(f): optical microscope images of polished cross-sections of bus-bars before (e) and after soldering (f). The small hole caused by a pin during the stringing process is indicated by the blue circle.