Depositing CIGS solar-cells on steel-substrates would allow fabrication of light flexible cells. This specificity would also give access to a roll-to-roll deposition process, i.e. a production-line process that would eventually lead to a cheaper final product. But electrical performance of this kind of cells is degraded by inter-reactions between the thin film multilayer and the steel substrate [1, 2]. To limit this drawback, a barrier layer is added between the steel substrate and the back contact layer [2]. Nonetheless, elemental diffusion may occur anyway. Consequences on the electrical properties of the cell of such a phenomenon are well described in the literature [3], but no direct observation of the altered layer has been shown. These reactions occur under the surface as deep as several hundred nanometers and maybe extremely local, what makes their analysis non-trivial. The purpose of this work is to use electron microscopy techniques to study, on the nano-scale, reactions and products between the steel substrate and the active CIGS multilayer. The analysis uses two different samples elaborated by sputtering, then annealed at 550°C for 15mn under Se atmosphere. The first sample is [Steel + Ti + Mo + Se] (Figure 1), and the second is [Steel + Ti + Mo + CIGS]. The analyses have been obtained using Transmission Electron Microscopy. SEM imaging and EDS mapping reveals surface defects spaced by several microns as well as strong changes of sample composition in the micron size defects. In order to understand the nanometric origin of this diffusion process, targeted cross-sections of the defects were prepared using the Focused Ion Beam in-situ lift-out method. TEM-BF and HAADF imaging on the first sample revealed crystals resulting from reaction between steel and Se (“C” figure1). Structural analysis using electron diffraction combined with EDS elemental mapping confirmed the formation of a second phase consisting of hexagonal CrSe whereas Fe is largely absent in these grains. Though such diffusion processes can be blocked by thick amorphous layers, the interaction between steel and thinner layer remains important for the development of future functional steel surfaces. Correct understanding of interlayer reaction may allow to control defects, thus improving the final solar-cell efficiency.

[1] P. Jackson et al. (2004), Contamination of Cu(In,Ga)Se2 solar cells by metallic substrate elements
Fig. 1: STEM High Angle Annular Dark Field (Left) and TEM Bright field (Right).

Fig. 2: Selected Area Diffraction patterns (aperture diameter 400nm, position "C" figure 1); experimental (left), simulated (right), representation of the CrSe 3D-crystal orientation (center)

Fig. 3: STEM _EDS mapping [Blue: Cr K-edge, Yellow: Se K-edge, Red: Fe K-edge] (Left); RBG compiled image (Right)