# Mapping surface plasmons in thin film solar cells using energy-filtered transmission electron microscopy


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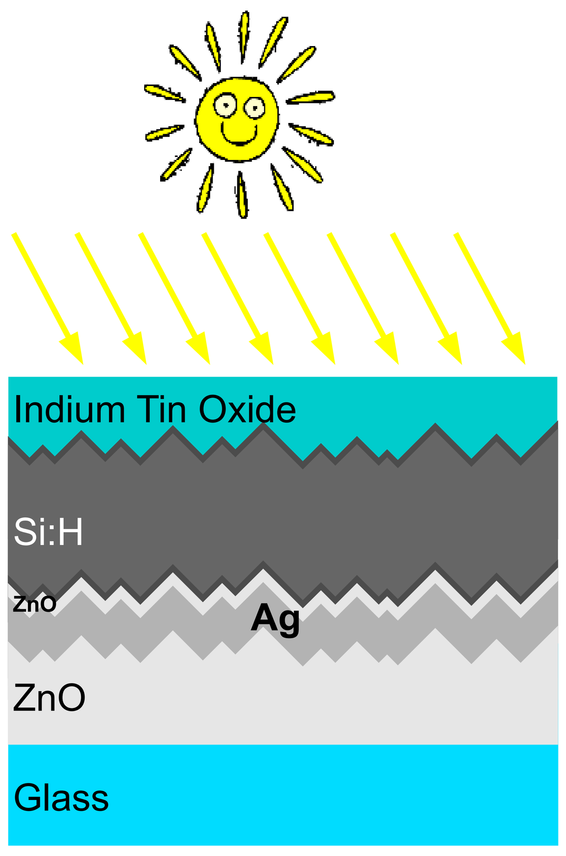
## Surface plasmons on Ag thin films

The light trapped by thin film Si solar cells is improved when they are grown on rough substrates. The use of a rough Ag reflector layer results in additional optical absorption, partly through the creation of surface plasmon polaritons [1].

In thin film solar cells, Ag surface plasmons are suspected to absorb part of the visible light in the 1-3.5eV range.

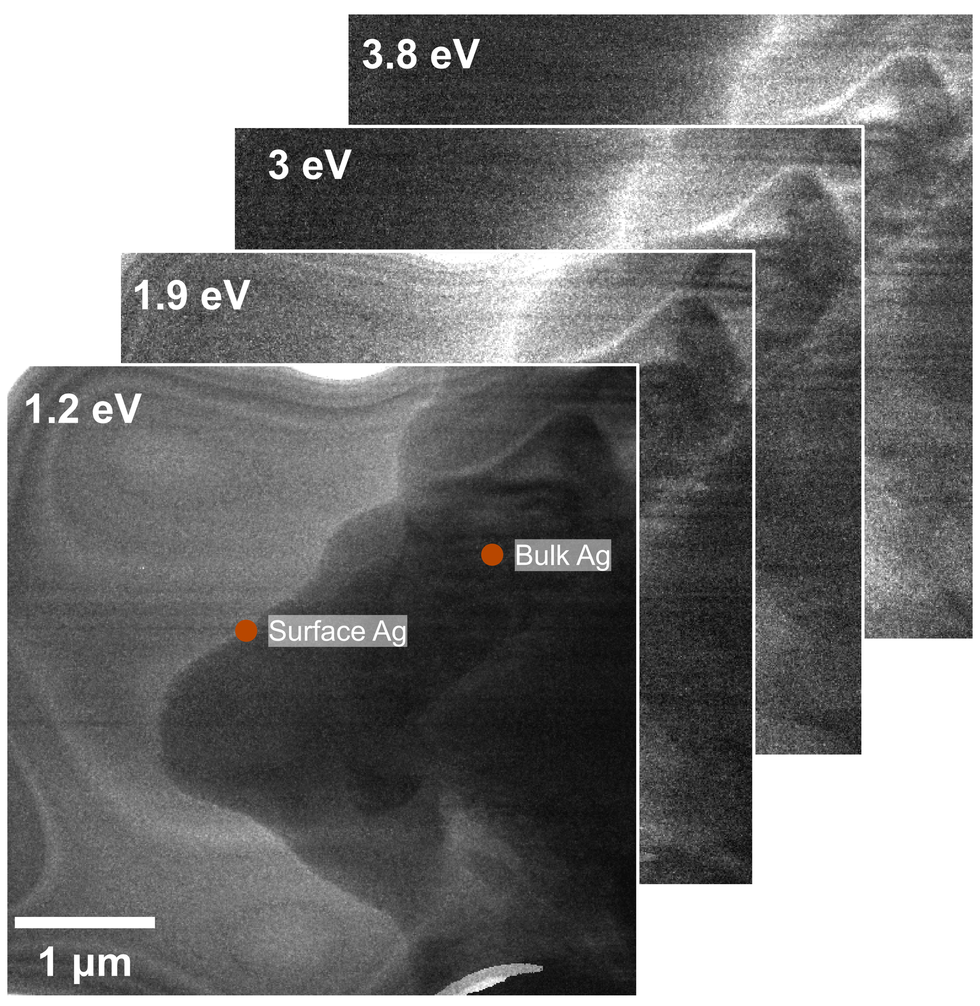



## Method

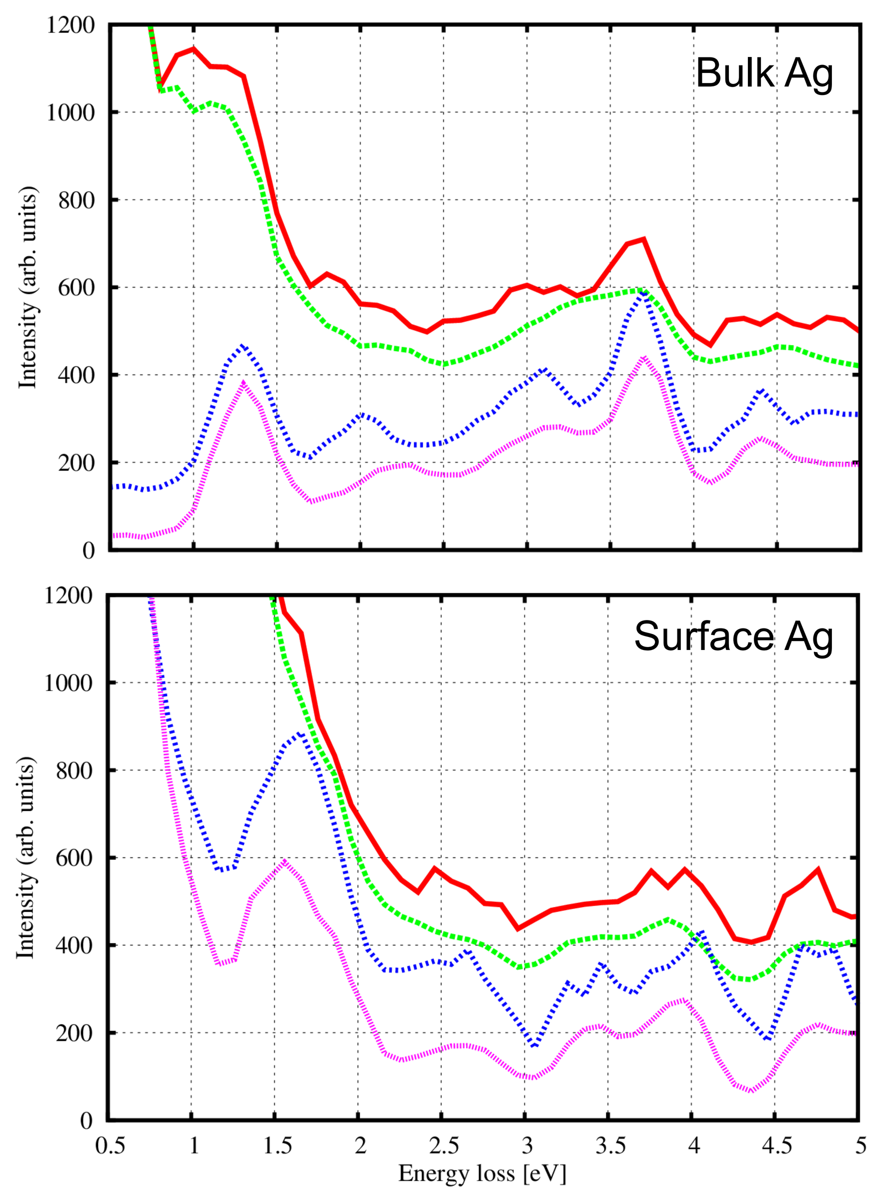
In this work, we map plasmonic absorption in Ag layers in real solar cells using energy-filtered (EF)TEM, followed by post-process noise filtering and deconvolution (using a Richardson–Lucy algorithm).

We use EFTEM images collected in a chromatic aberration corrected microscope, which results in better spatial resolution than using STEM-EELS [2].

## Improvement of signal/noise ratio using principal component analysis and Richardson-Lucy deconvolution




EFTEM series recorded with a monochromated beam, a 0.2 eV energy-selecting slit width and a 0.1 eV energy step.




→ Principal component analysis allows noise reduction before applying the Richardson-Lucy algorithm.

→ 10 iterations of the Richardson-Lucy algorithm does not introduce artifact peaks.

→ Finding peak positions and energy shifts using an automatic procedure becomes possible after the use of principal component analysis and the Richardson-Lucy algorithm.

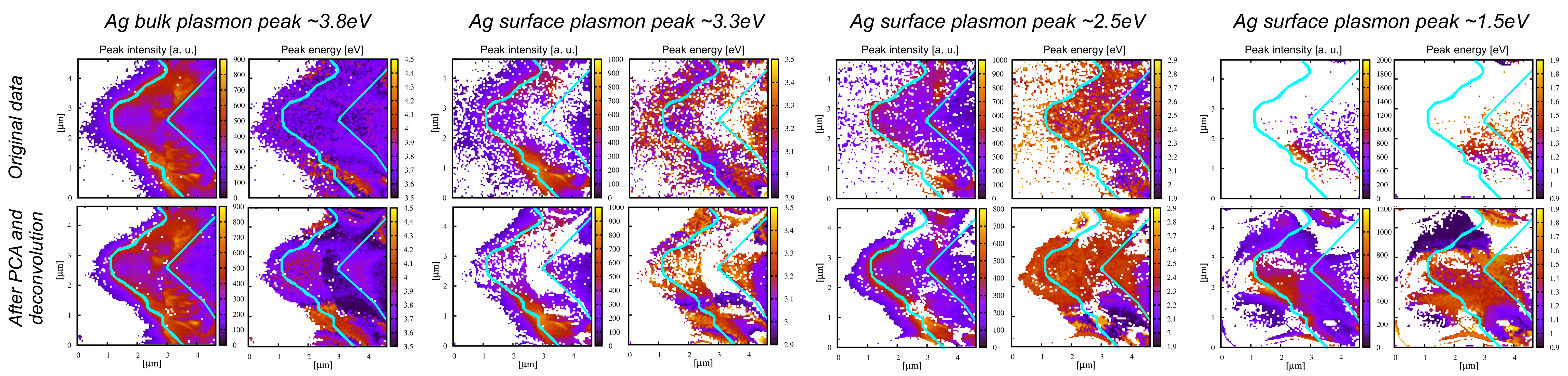
Original spectra

Spectra filtered using the 30 1st principal components

Spectra deconvoluted with 10 iterations of the RL algorithm

Spectra filtered using 30 1st principal components followed by 10 iterations of the RL algorithm

## Intensity and energy loss maps for the different Ag plasmon peaks




→ Numerical processing is beneficial for energies below 3eV

→ Plasmon peak energy across the sample can be determined with high spatial resolution

→ The three surface plasmon resonances can be resolved using a combination of EFTEM and numerical processing

→ The energy resolution is still limited by the energy steps used during acquisition and will be improved in future experiments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[1] F.-J. Haug et al. *Journal of Applied Physics 104* (2008) 064509

[2] J. Nelayah et al. *Nature Physics* 3 (2007) 348