# In situ observations of electron beam induced nanocrystallization of an amorphous tungsten foil

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We analyzed ultra-thin amorphous tungsten (W) foils made by electron beam physical vapor deposition. The samples consist of an amorphous W layer (2 nm in thickness) supported by an amorphous carbon foil (3 nm).

The samples are studied by high resolution electron microscopy in an aberration corrected low voltage transmission electron microscope and by high angle angular dark field (HAADF) imaging using our Nion, an aberration corrected dedicated scanning transmission electron microscope (STEM). During observation the amorphous W structure changes to a nanocrystalline structure with grain sizes of about 2 nm to 5 nm under the influence of the electron beam. We observe the formation of different crystalline phases for different acceleration voltages: Imaging with acceleration voltages of 30 kV and 60 kV, respectively, leads to the formation of mainly $WC_{0.82}$ nanocrystals and also some $W_2C$ nanocrystals. The time to form these nanocrystalline structures depends on the radiation dose of the electron beam. To achieve a high electron dose a small region of the sample (50 nm x 50 nm) was irradiated for 1 hour at 80 kV acceleration voltage. This treatment leads to the formation of pure tungsten nanocrystals (with a grain size of about 5 nm).

During the continuous STEM in situ observation of the sample irradiated by the electron beam the movement of bright dots is observed in HAADF image series. We interpret this phenomenon as the observation of surface diffusion of W atoms. By tracking W surface atoms in the HAADF image series we are able to estimate the diffusion constant for this electron beam enhanced W surface diffusion.

Initial changes of the amorphous structure by the influence of the electron beam at the start of image acquisition are measured by applying the method of electron correlation microscopy in the HAADF image series.

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