# Applied Low Current Microscopy

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Since the DoE funded TEAM project ended in the United States with the development of spherical and chromatic aberration correction in 2009 single atom sensitivity is established for transmission electron microscopy (TEM) imaging. Theoretically, every material could be imaged in full atomic resolution, and every atom could be resolved within all material structures. In an experimental setup, however, electron beam sensitivity of a given material determines which original structures can be resolved. Therefore, our focus in the last decade has been on minimizing electron beam induced material damage, and to find alternative ways to image beam sensitive materials without altering their original structure. At least, if a material is altered under the electron beam the dynamics of this behavior should be recorded, too. Such dynamic considerations led to the development of current-controlled TEM.

Low dose rate and pulsed electron beams were applied to image pristine properties of $MgCl_2$, a Ziegler-Natta catalyst which is both air and electron beam sensitive. The choice of pulse and delay times allowed to mitigate damage caused by phonon accumulation. The total electron dose can be extended more than ten times before material alterations set in. Changing electron currents while imaging polymers or various catalytic nanocrystals by varying dose rates and / or the irradiated areas had similar effects. Using direct electron detectors facilitated those experiments, and allowed for the use of ultra-low currents where single electrons are delivered to interact with the material under investigation. The importance of reproducible imaging and sample preparation conditions will be discussed.

With the application of current-controlled TEM the onset of material changes is found to be generally delayed. The experimental setup may be used in combination with cryo-microscopy, and could further postpone material alterations, even in soft materials.

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