

MAR08-2007-020225

Abstract for an Invited Paper  
for the MAR08 Meeting of  
the American Physical Society

### Imaging ferroelectric polarization by electron holography

HANNES LICHTER, Technische Universitaet Dresden

Understanding solids means analysis of the arrangement of the different atoms, e.g. at interfaces, and the intrinsic electric and magnetic fields, as well as the resulting charge distribution. This is particularly important for functional materials, such as semiconductors, ferroelectrics and ferromagnetics. There is a variety of tools answering these questions partially. In particular since correction of aberrations [1], Transmission Electron Microscopy (TEM) offers a lateral resolution below 0.1nm hence can locally analyze position and species of atoms e.g. at interfaces. The most severe drawback is that the phase of the electron wave is not accessible by conventional imaging methods, and therefore phase-modulating peculiarities of the object such as electric and magnetic fields are invisible. However, these are measurable by TEM-holography rendering both amplitude and phase distributions produced by the object. For an overview see e.g. [2]. The electron phase  $\varphi$  is modulated by the electric potential  $V(x, y, z)$  as  $\varphi(x, y) = \sigma \int_{object} V(x, y, z) dz$  with interaction constant  $\sigma$ . In ferroelectrics,

the polarization  $\vec{P}$  contributes with a phase shift  $\varphi_{pol}(\vec{r}) = \frac{\sigma}{\varepsilon_0} \int_{object} \left[ \int_{\vec{r}0}^{\vec{r}} \vec{P}(x, y, z) d\vec{r}' \right] dz$  with respect to a reference point  $\vec{r}0$ , chosen in field-free space;  $\vec{r} = (x, y)$  is the coordinate perpendicular to  $z$ -direction. Therefore, the projected in-plane polarization  $\vec{P}_{proj}(\vec{r}) = \int_{object} \left[ \int_{\vec{r}0}^{\vec{r}} \vec{P}(x, y, z) d\vec{r}' \right] dz$  would be determined from a phase image. However, the polarization is partly compensated by *compensating charges* at surfaces, interfaces and domain boundaries, which contribute with a corresponding potential distribution. The net effect is found in the phase image reconstructed from an electron hologram. Meanwhile, specific ferroelectric effects are found on micrometer and nanometer, even at atomic dimensions. [1] M. Haider et al., Nature 392 (1998) 768. [2] H. Lichte et al., Ann. Rev. Materials Research 37 (2007), 539