doi:10.1017/S1431927610062318
Microsc. Microanal. 16 (Suppl 2), 2010

5.4 nm Spatial Resolution Obtained from an Aberration-Corrected Photoemission Electron Microscope Utilizing an Electrostatic Mirror

R. C. Word,* G. Rempfer,* L. Almaraz,* T. Dixon,* P. Witham,* and R. Könenkamp*

*Department of Physics, Portland State University, PO Box 751, Portland, Oregon, 97207

We report resolution of 5.4 ± 0.5 nm for a photoemission electron microscope (PEEM) built with an electrostatic mirror that simultaneously corrects for chromatic and spherical aberration. This is a marked improvement over the 8-10 nm achieved with uncorrected PEEMs, which, unlike more familiar TEMs and SEMs, suffer particularly from chromatic aberration due to the 0 to 1-eV initial energies of the image-forming photoelectrons.

To employ an electrostatic mirror corrector in an electron microscope requires an accompanying magnetic beam separator so that the reflected beam is diverted to the imaging system. This unfortunately demands that the instrument not be cylindrically symmetric and presents many practical challenges. Our instrument design [1] employs a Y-branched beam-line. This consists of three magnetic deflectors that steer the beam over small ~17-degree angles (rather than 90- or 60-degree angles used elsewhere) with an equal number of left-hand and right-hand bends, which tend to minimize deflection aberrations. Beam alignment for a system that breaks cylindrical symmetry is, not surprisingly, difficult. We invested significant time into the development of beam alignment techniques as well as into technical solutions for the correction of imperfections in the beam lines. Additionally, in a system employing twelve lenses, small resolution-spoiling voltage instabilities are difficult to isolate and correct. To combat this complexity, the most critical of the electrostatic lenses and the mirror are powered by two shielded oil-submersed voltage dividers that minimize DC voltage instability and suppress AC noise to a few parts per million.

The entire instrument has been modeled in SIMION. This permits computer-refinement of the lens and mirror potentials to tune the spherical and chromatic aberration correction. Based on simulated and experimentally determined aberration coefficients, the expected resolution of the instrument is ~2 nm, assuming technical problems are overcome and a suitable specimen is found.

At the present resolution milestone, the specimen used to determine the resolution was sarcoplasmic reticulum (SR) vesicles extracted from rabbit skeletal muscle using the method of MacLennan [2] and air-dried from aqueous suspension on chromium-coated glass. This biological membrane, whose purpose is to sequester and release calcium, is comprised almost entirely of calcium pump protein and phospholipids. It is of interest particularly in cardiac studies. PEEMs are especially suited to imaging biological specimens and other organic materials since the microscope does not use a destructive high energy electron beam. Additionally, biological materials on chromium substrate usually generate very high contrast when illuminated by UV light. The specimen in this case was illuminated by a 100-mW 244-nm CW Ar laser. While the vesicles are very bright, they are not particularly suited for determining resolution because they are large, have soft borders, and are made of lipids and proteins that have equivalent brightness (Fig. 1). However, accompanying the SR vesicles were small, very bright particles with diameters in the order of 10 nm (Fig. 2a). We assume these are lipids, proteins, and other organic material left as impurities after the separation of SR from muscle cells. We used two methods to determine resolution of these particles: the 90%-10%

slopes of intensity profiles of select particles (Fig. 2b) and by the Fast Fourier Transform (Fig. 2a) method of Joy [3]. From these two methods we calculate a spatial resolution of 5.4 ± 0.5 nm. [4]

References

[1] G. Rempfer, *J. Appl. Phys.* 67 (1990) 6027
[2] D.H. MacLennan, *J. Biol. Chem.* 245 (1970) 4508
[3] D.C. Joy, *J. Microsc.* 208 (2002) 24
[4] This research was partially supported by NSF under grant number DBI-0352224 and by DOE under DE-FG02-07ER46406

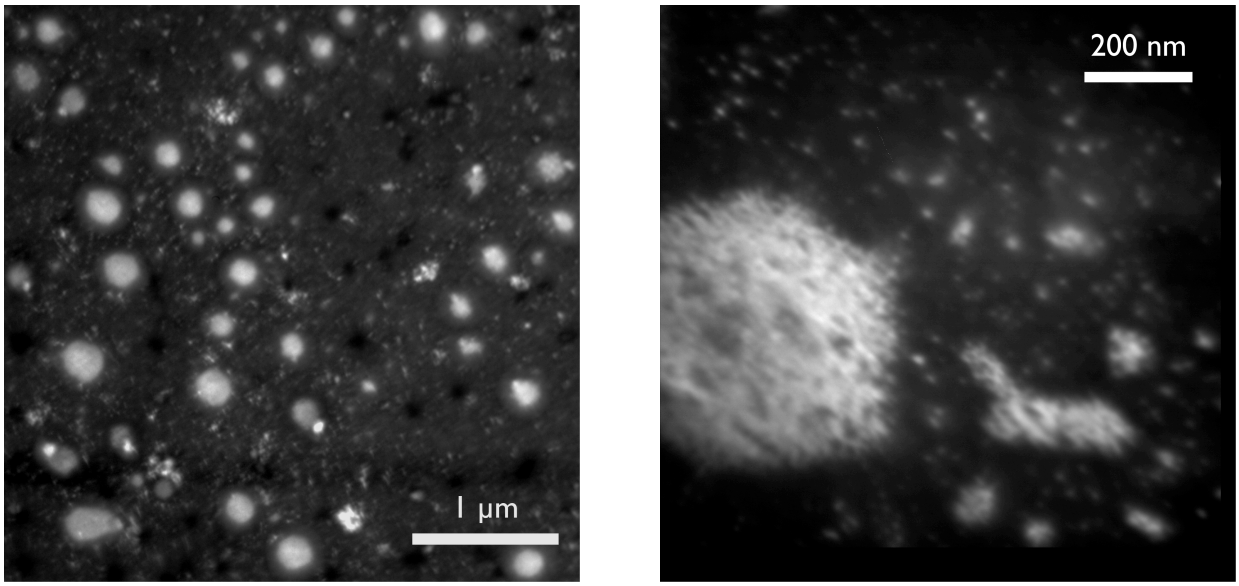

FIG. 1. PEEM micrographs of sarcoplasmic reticulum vesicles on chromium substrate. Image contrast altered to reveal substrate detail.

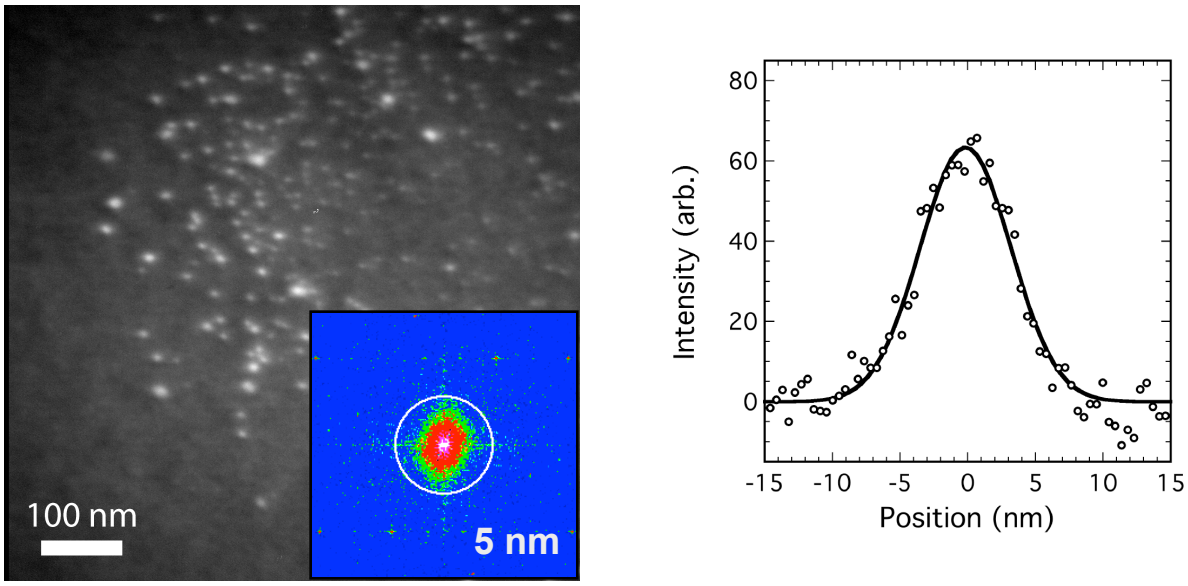

FIG. 2. (a) As-taken micrograph of bright impurity particles. Inset: center of FFT showing 5-nm spatial resolution ring. (b) Intensity profile of a particle in Fig 2a. The slope of the 10% to 90% intensity level is 5.5 nm.

https://doi.org/10.1017/S1431927610062318 Published online by Cambridge University Press