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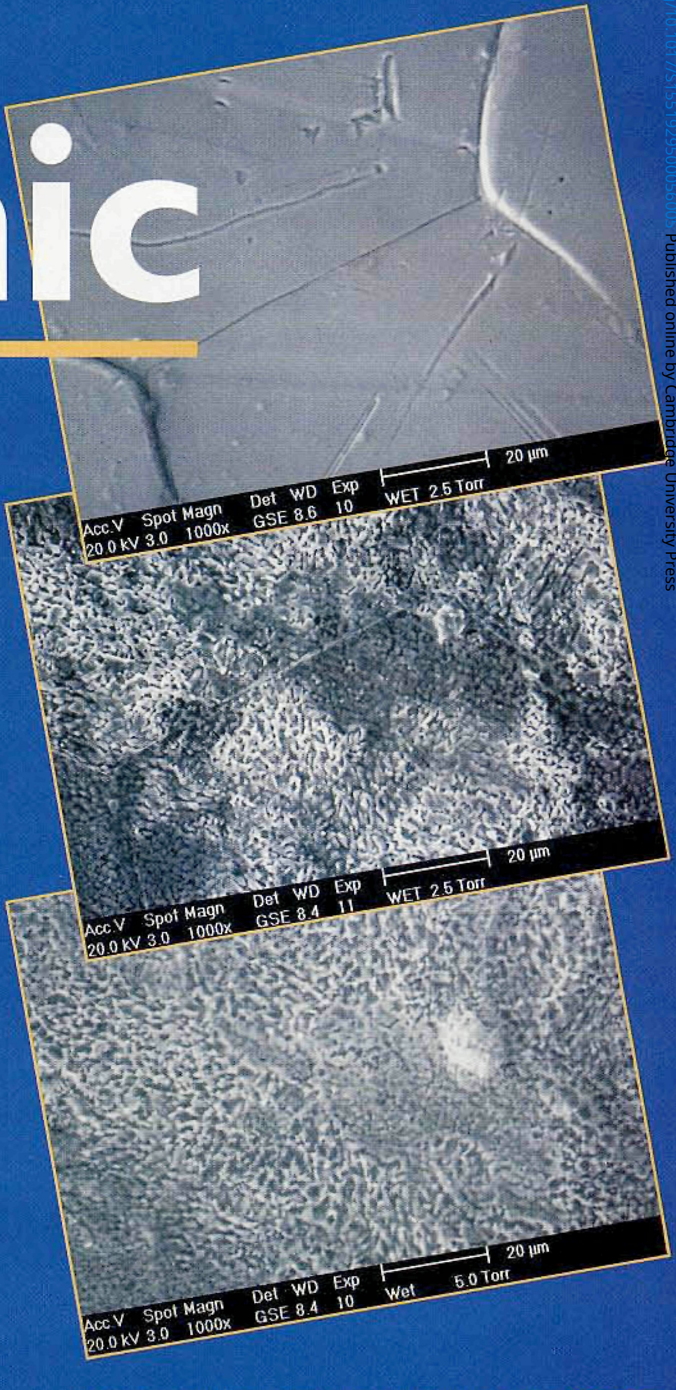

In-situ recrystallisation experiment performed in the ESEM-FEG using the optional heating stage. A titanium stabilised interstitial free steel galvanised with 0.15 wt% Al-Zn coating was heated to 500° C. Recrystallisation of the coating occurred, destroying the previously visible grain boundary structure.

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AN ELECTRON OPTICAL ACHROMAT

Stephen W. Carmichael,[1] Mayo Clinic

Spherical and chromatic aberrations have been the bane of optical lenses ever since they were first ground from a piece of glass. As light travels through a convex (converging) lens, the rays at the center of the optical axis are refracted (bent) less than the peripheral rays, so that the central rays are focused behind the peripheral rays. This is the essence of spherical aberration. Light of differing wavelengths (colors) interact differently with the lens so that longer wavelengths (red) are focused behind shorter wavelengths (blue). This is chromatic aberration. In the early days of light microscopy, these two inherent flaws seriously limited the quality of images. Over two centuries ago, it was first appreciated that these aberrations could be corrected by mating a convex lens with an appropriate concave (diverging) lens of glass having different refractive properties. What this accomplished was to introduce aberrations that were equal and opposite, effectively canceling the original aberrations. This combination of convex and concave lenses is known as the achromat, and is present in every optical microscope, except the cheapest toys. Of course, you can appreciate that this review is a gross simplification, as achromatic lenses are more complicated (therefore expensive) than I have described. But the general principles hold.

Electromagnetic and electrostatic lenses behave as a convex lens, converging a beam of electrons toward its focal point. As you know, the resolution is limited by spherical and chromatic aberrations. Spherical aberration follows the same principle as an optical lens, and chromatic aberration varies only by substituting variations in the energies of individual electrons for wavelength. Manufacturers of electron optical equipment have minimized these aberrations by limiting the beam size and narrowing the energy spread in the electron beam, but the lenses are still of the uncorrected type. Obviously, what is needed for further improvement is a divergent lens, but apparently no such thing exists. A solution for this problem was recently demonstrated by Gertrude Rempfer, Denis Desloge, and Walter Skoczylas of Portland State University and Hayes Griffith of the University of Oregon.[1] Their ingenious solution was to insert an electron mirror into the optical path, introducing aberrations that are equal and opposite.

What is an electron mirror? In this case it's a converging hyperbolic electrostatic mirror. The key element is a conical electrode that creates a retarding electric field and turns the electrons back (reflects) at a curved equipotential surface in front of the electrode. The electrons in the peripheral part of the beam are less strongly focused than more central electrons. This is the opposite of what happens in a lens, thereby correcting spherical aberration. An electron of higher energy penetrates more into the field of the mirror than an electron of lower energy, and therefore is focused more strongly. Again, this is the opposite of what happens in a lens, and this corrects for chromatic aberration.

Introducing a mirror into the optical path meant that a method for separating the incident and returning beams has to be provided. Rempfer *et al.* devised a Y-shaped optical bench with the electron source on one limb of the Y, a separating magnet where the limbs converge, the electron mirror at the base of the Y, and the final image on the other limb. They performed tests with the optical bench by putting a fine copper grid near the final image and casting a shadow pattern. In a remarkable series of illustrations with uncorrected lenses, they showed "pin cushion" and "barrel" distortions of shadows of the grid made with both visible light and electrons. These esthetically-pleasing images were chosen for the cover of the journal, but the astonishing thing about the images was how similar the distortions were, regardless of whether they were formed by light or electrons. Additional experimental demonstrations showed how the electron-generated images could be corrected with the mirror.

Rempfer *et al.* further explain how improvements in resolution resulting from aberration correction will be more readily demonstrated in electron probes and emission microscopes than in transmission electron microscopes because the aberrations are larger in these instruments than in transmission microscopes. However, I would anticipate that this electron optical achromat will prove to be a breakthrough in improving the resolution of all electron optical instruments. I, for one, can't wait to see the improved results! ■

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[1] The author gratefully acknowledges Dr. Gertrude Rempfer and Dr. Hayes Griffith for reviewing this article.

[2] Rempfer, G.F., D.M. Desloge, W.P. Skoczylas, and O.H. Griffith, Simultaneous correction of spherical and chromatic aberrations with an electron mirror: An electron optical achromat, Microscopy and Microanalysis 3:14-27, 1997.

Front Page Image

SEM Photograph of a Black Fly (Simuliidae)

Imaged on an ETEC SEM at 5 kV using the SEM Wideband Multi-Detector Color Synthesizer (designed, built and patented by David Scharf). Then acquired digitally at 2,048 X 1,538 pixels directly into a Macintosh Power PC as a TIFF file, using Digital Micrograph software and Digiscan hardware. Then output to a CELCO film recorder, using Ektachrome 100+ film, to produce a 4 X 5 transparency.

As one of a series, this image is available at 350X as a 19" X 23" high quality, lithographic print.
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Don Grimes, Editor