Digital Imaging for TEM
Part 1

Anthony D. Buonaquisit, Advanced Microscopy Techniques

We are all familiar with digital imaging for SEM instruments. Digital imaging for TEM applications is not as well established. Nevertheless, it seems clear that it will not be long before digital imaging for TEM becomes common place. Systems are improving and costs are plummeting. With this in mind it is timely to review what digital imaging for TEM involves.

In normal TEM operation an electron bream is scattered through a thin section of a sample. Physical mechanisms cause the electrons of the beam to scatter, producing bright-field images, dark-field images and diffraction patterns. The operator adjusts the instrument to display one of these images on the instrument's viewing screen. A photographic record is collected by flipping the viewing screen and exposing a sheet of film held in the TEM's camera. Exposed negatives can be removed for developing and printing in batches, using standard darkroom techniques.

Digital imaging systems (Figure 1) consist of a scintillator screen, a light sensitive digital camera, a frame grabber computer card and a computer system.

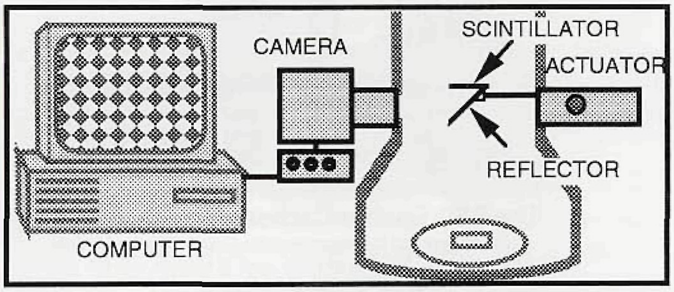

Figure 1 : Side Mount TEM Digital Imaging System

The scintillator converts the electron image into a photon image. Scintillators can be produced from phosphor powder or single crystals. Both materials have found application though the phosphor powders are said to offer the better sensitivity, especially for low dose imaging.

The digital camera is coupled to the scintillator using either a fiber optic bundle or a high quality lens system. The former provides more efficient light collection. The latter allows a much wider field of view and potentially higher resolution.

Modern digital cameras are designed around a charge coupled device (CCD). The CCD sensor is an integrated circuit (Figure 2) that is fabricated to form a two dimensional array of light sensitive cells. When a photon penetrates an individual cell it produces a small charge which is held within the cell. The amount of charge held within a cell is proportional to the number of photons that penetrated the cell while it was exposed. On-chip circuitry "reads" the amount charge that has been stored in each cell, and thus records an image frame.

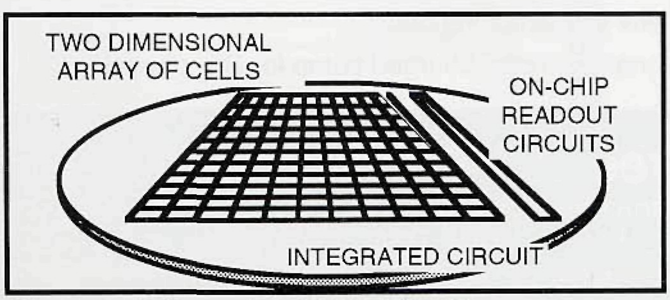

Figure 2 : Schematic of CCD Chip Camera

CCD arrays can have different formats producing square or rectangular active areas. A CCD array consisting of cells arranged in 384 rows and 512 columns would be relatively small and might be called a "500 line camera." A typical 100 line camera, might use 1317 rows and 1035 columns. Larger scale cameras such as 2000 line and 4000 line cameras are also available.

The grey scale resolution of a CCD camera is determined by the electronics of it's readout circuitry. Typical values are 256 gray levels, referred to as "8 bits deep"; 1024 gray levels, referred to as "10 bits deep"; 4096 gray levels, referred to as "12 bits deep"; and 16384 gray levels, referred to as "14 bits deep".

The reading circuitry is fast but does take a finite time to read all the cells in the CCD array. It is therefore common practice to blank off the array during readout. This is achieved by either a mechanical shutter or beam blanking.

The exposure time between data readouts can be adjusted. Today's better systems operate at rates from 10 frames per second to many seconds per frame. Shorter exposure times are useful for focusing or "driving around" a sample. Longer exposure times give best image recording. The duration of exposure is ultimately limited by the stability of the TEM and/or the sample.

Frame grabber cards are used to interface a standard PC or Macintosh with the camera system. They are the location of memory arrays referred to as "image planes", fast processing circuits and anything else the design engineer thinks might be useful for digital imaging. The idea is that computations using the frame grabber hardware will work faster than the the same thing done by software.

If the camera system and frame grabber board are designed to produce data in standard file formats, such as TIFF (Tagged Image File Format), the data are compatible with a wide world of commercial software applications programs. Indeed all aspects of desktop publishing, desktop video and desktop networking are immediately open. In addition output devices can range from the simple laser printer to the latest dye sublimation or dry film processors.

Next time we will review the pro's and con's of digital imaging for TEM. ■

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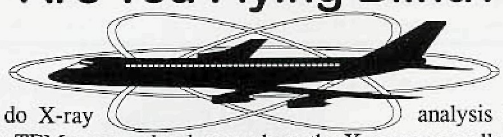

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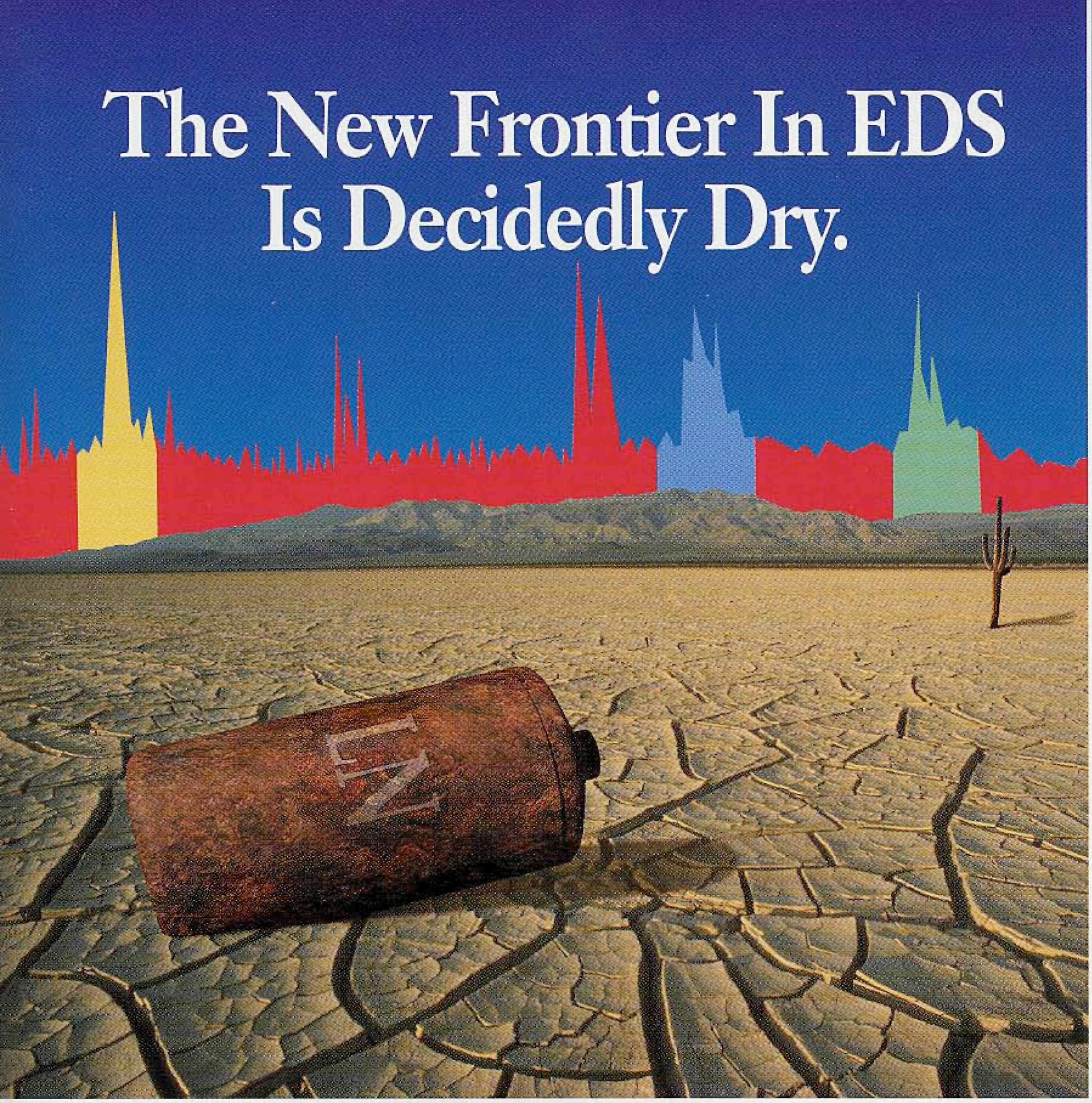

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