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A DIGITAL IMAGING SYSTEM FOR QUANTITATIVELY MEASURING TRITIUM CONCENTRATION IN METALLOGRAPHIC SAMPLES

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Mark H. Ransick*   Gene L. Downs*

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ABSTRACT

The development of the Video Intensified Microscope coupled with digital image processing techniques offers a new way to quantitatively measure tritium concentration in metallographic mounts. Beta particles from the decay of tritium strike a scintillation film placed on the sample causing photons to be generated. The photon signal emitted from the sample is digitized and stored in an array of pixels within a digitizing board. The time required for the acquisition of these images is on the order of minutes instead of the hours or days normally required for traditional photographic autoradiography techniques. By utilizing the techniques of digital image processing and analysis, tritium concentration can be statistically analyzed. Depth profiling of tritium into a material and two dimensional concentration gradients can be plotted and analyzed. These images are also saved to optical disks for later recall and comparison and archiving.

* EG&G Mound Applied Technologies, Miamisburg, Ohio 45343 USA

INTRODUCTION

The most common method for performing tritium autoradiography utilizes a photographic emulsion technique to indicate the location of tritium. While this technique yields high quality images and can be quantified, it is a time consuming process, that sometimes requires more than a day to complete the analysis of one sample.

Advances in digital imaging techniques and improvement in light detection capacities of video cameras has produced a new method to quantitatively determine tritium concentration in a metallographic mount in minutes. The development of the video intensified microscope (VIM) has greatly improved the ability to rapidly analyze tritium concentration gradients within a material. As described by Downs[1], a scintillation film is produced on the surface of a polished metallographic sample that has been exposed to tritium. The decay of the tritium releases a beta particle which in turn strikes the scintillating compound, emitting photons. The intensifier on the VIM detects the position and intensity of the photons and records this information in the digitizing board. The number of photons generated is directly related to the tritium concentration. By analyzing the data stored in the digitizing board, depth profiles of tritium in the sample can be measured. With the use of known standards, the concentration of tritium can be quantitatively determined. All of this information can be generated in minutes, instead of the hours or days normally required by film autoradiography methods.

BASIC SYSTEM DESCRIPTION

The primary equipment for detecting the photon emission is performed by a Hammamatsu camera and video intensifying unit. This camera system is installed onto a Zeiss Axioskop microscope equipped for reflected light observation. Low magnification observation can be performed by installing a lens on the camera and viewing the sample directly by the camera. The camera is connected to a Hammamatsu computer and digital imaging system.

The computer uses a Motorola 68000 microprocessor to perform all of the operations. CPM is the operating system and the operations of the photon counting are controlled by a menu based software package. The digital imaging operations are performed by four digitizing boards, each with a resolution of 512 X 485 pixels, with a maximum gray level of 16,392.

Imaging of the sample is performed by two different methods. The first is to desensitize the intensifier and image the sample using a low intensity, standard light source. This yields a standard metallographic image, which although limited by the resolution of the system, is very useful for correlating features in the sample such as sample edges or grain boundaries to tritium locations. This image is also digitized and is available for standard image analysis procedures and image processing.

The primary method for viewing the sample is with the video intensifier acquiring the photon emission. Each photon that strikes the video intensifier is converted to a digital signal and its position is recorded in the digitizing board. For each photon detected, the gray level in the corresponding location in the 512 x 485 array is increased by one. Thus, if a particular pixel has a gray level of three, this means that three photons were detected at this location. By summing all of the gray levels for a given region the total number of photons emitted can be determined. Since there are four separate digitizing boards within the computer it is possible to store a standard metallographic image in one board and the photon image in a different board. These two images can be combined creating a composite image in a third digitizing board.

The operation of the VIM is controlled by a menu driven software package that contains many different image processing and analysis routines. Operations that are very helpful for the standard metallographic images are background subtraction, image averaging, and sharpening filters. Many other types of routines are also provided, such as image convolutions, image store and recall, and many different types of filters.

But the most important feature of the software is the ability to perform image analysis on the photon count images (figure 1). The actual number of photons detected in a defined area can be counted. The particular regions of interest can be defined as rectangles, circles, or any type of geometrical shape. A mouse can be used to define unusual shapes and measure the concentration within this region. Line profiles of tritium concentration can be measured and plotted by counting the photon intensity over an integrated area. And the actual tritium levels in an unknown sample can be calculated by comparing it to the photon intensity in a standard with a known tritium concentration.

MODIFICATIONS TO THE SYSTEM

The VIM system as purchased is a very powerful tool for tritium measurement. However, in order to perform routine analysis on a specific task, certain hardware or software modifications are usually required to maximize the capability of any system. There are two main drawbacks in using the unmodified VIM for the tasks at EG&G Mound. The first is the software. The menu driven software provided with the unit can perform all the tasks required at EG&G Mound, but repetitive tasks are very difficult when attempting to use menus. Many of the operations use similar commands that require entering the same commands repetitively. To use the system most efficiently, software must be written specific to the application.

The second drawback of the VIM is the speed of the main processor. As earlier mentioned it is a Motorola 68000 processor which is considerably slower compared to the Motorola 68030 or the Intel 80386 processors. The VIM computer is constructed so that all of the image analysis and image processing are performed using the microprocessor and not by an on-board processor on the digitizing board. An analysis of the entire field of view can take approximately a minute with the VIM, while the same operation on an 80386 can be accomplished in less than ten seconds.

Several options existed for customizing the existing VIM system. One was to modify the software on the existing system. As previously stated, the operating system used on the VIM is CPM, with the supporting libraries written in "C". While there is considerable experience at Mound in "C" programming, no real programming is done in the CPM environment at Mound. Developing software for a nearly dead operating system was not a very appealing option. Another drawback of using the existing system was its lack of disk space. Since the data is recorded in a digital format, a desired option was to store the images to disk. However the system as it was purchased contained only two floppy disks, and recording data on these is too lengthy with each image exceeding 500 bytes. Adding a hard disk was not a long term solution since that disk would be filled rapidly with images. Optical disk is the most cost effective solution but developing a method to record data to optical disk for a CPM and 68000 based system also appeared to be a lengthy undertaking.

The second choice for modifying the system to EG&G's needs was to use the VIM for acquiring the data and attach a second computer to the output of the VIM and process the data on this system. Considerable experience has been gained at Mound in the development of digital imaging systems based on PC systems[2,3]. A PC based system has been in operation at Mound for several years, digitizing the image from a metallograph and storing the image to an optical disk. After experimenting with the existing PC system on the VIM, the decision was made to process the data with an 80386 PC. This system has several advantages over the existing VIM processor. The operating system on the PC was more familiar to all the operators of the unit and considerable support at EG&G exists for PC computers. All the image processing and analysis routines that rely on the main processor could be performed on the 80386 system in a fraction of the time required on the existing VIM system. And since the system that was installed on the metallograph used the same file formats, images could be interchanged and software developed on one system could be used on the other. And finally the images could be readily stored to optical disk for archiving and later recall and analysis. There are numerous manufacturers of optical disk drives designed specifically for DOS based machines.

The system installed onto the VIM is constructed around a Compaq 386/20 PC (figure 2). Installed within the computer is an Imaging Technologies PCVison Plus frame grabber capable of digitizing an image to a 640 by 480 pixel image with each pixel storing 256 gray levels. An NHance write once read many times (WORM) optical disk drive capable of storing 115 Mbytes of data per side is installed for storing the digital images. Current prices of the disk are about $158 for 230 Mbytes which means each image costs about $0.23 to store or about 1/7 the cost of film. To output the images to film, a Matrix film record unit was attached to the video signal from the either the PC or the VIM directly. This unit is a high resolution record CRT with a film back attached to the front of the CRT. Any video signal can be transferred to film and is much higher quality than taking a picture of the curved TV monitor.

The image from the VIM system is transferred to the 386 PC by taking the RS-170 video signal from the output of the VIM digitizing board and grabbing this image with the input of the digitizing board in the PC. The image can be transferred in a 1/30 of second. The image in the VIM system is converted from a digital signal back to an analog signal and then the digitizing board on the PC reconverts this signal back to a digital image. Because of these conversions there is a loss of resolution in the image. But since all of the images analyzed will be measured by going through this conversion process, all the images will be effected the same. A more accurate method for acquiring the images would by to connect the computers by a serial interface. But the amount of time required to transmit an image at 9600 baud would take over 50 seconds.

Software to control the system was written in the "C" programming language. Several programs have been written to control the storage and recall of images from optical and magnetic media and also to count the total number of photons per given area. To determine the number of photons, the image can be segmented into smaller areas and the values plotted as a three dimensional plot or contour map.

APPLICATIONS

One of the more useful applications of the VIM at EG&G Mound is determining the depth of penetration of tritium into container materials (figure 3). Since all of the photons detected are stored as digital bits of information, it is a relatively simple process for the computer to sum the data and plot it versus the depth into the sample.

One technique for graphically examining the depth of penetration is by dividing the field of view into areas of equal size and summing the total value of the photons detected (figure 4). The standard VIM system can perform this task, but the position and size of the region of interest has to be manually entered for each area measured. And typically the number of regions measured per sample is 320. Measuring a sample with this many regions would take an inordinate amount of time using the menu based software provided with the system. With the addition of the 386 PC and software developed on this computer, the task of measuring the counts in 320 separate areas takes less than 10 seconds. Also this data can be stored to a PC ASCII file that can be read by most spreadsheet and database software for further analysis or plotting.

This type of application is very useful in comparing not only the relative diffusion rates for different types of container vessel materials, but also for examining different conditions within the same material. Hydrogen diffuses at different rates through delta ferrite in a weld than through austenite in the base metal. Thus it is important in containment vessels that have a weld to compare the rate of diffusion in the weld to the base metal.

Another useful application of the VIM system is examining hydrogen segregation within different materials. Since the optical metallographic image and the photon image are both digital, they can be summed together creating a composite image (figure 5). The sites that hydrogen preferentially segregates can be located relatively easy.

Some materials cannot be examined using film autoradiography because of their reactivity. They may reactive with the silver bromide in the film and not produce a true image of the tritium location within the sample. But since the VIM system relies on photon emission from a scintillation solution, the tritium locations can be successfully imaged on these type of samples.

CONCLUSIONS

The development of the video intensified microscope and its adaptation to the examination of tritium in metallograhic mounts has greatly simplified and improved the quantification of autoradiography. Quantitative analysis of tritium can be measured in a matter of minutes and not hours or days that is normally required utilizing the standard film process.

Figure 1.

Typical photon image from the Video Intensified Microscope. This is a 304 stainless steel containment vessel. The box drawn on the image is the region of interest that is being counted. The area measured can be any shape or size.

Figure 2.

Schematic drawing of the modified system showing the added 80386 PC and optical disk drive.

Figure 3.

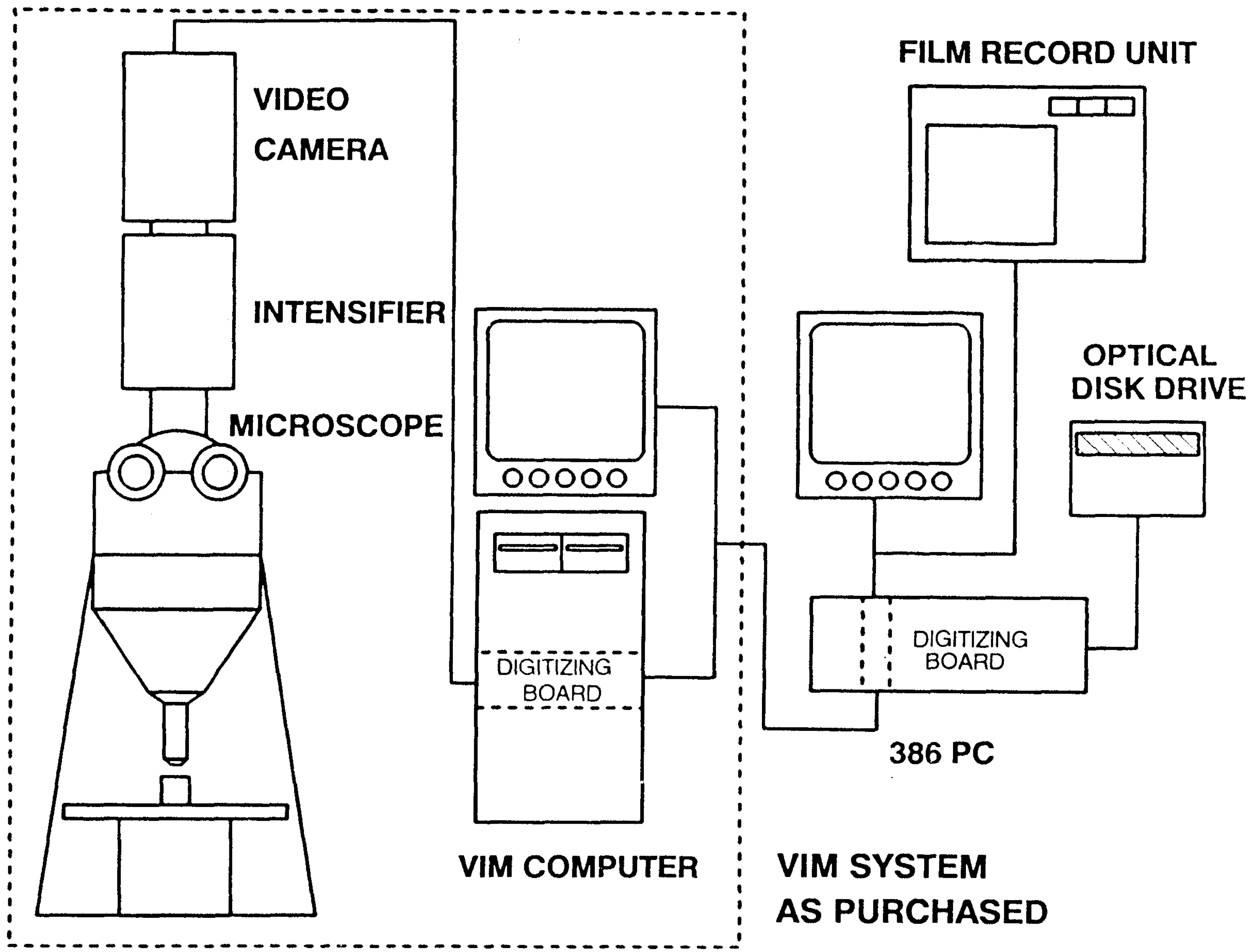
Photon count of a 304 stainless steel containment vessel. This image was acquired on the VIM and transferred to the PC and stored to optical disk.

Figure 4.

Contour plot of figure 4. The sample has been segmented into a 32 by 40 matrix and the total photons detected in each of the areas has been summed. The lighter colored regions indicate higher levels of tritium concentration.

Figure 5.

Composite image of an optical metallographic and a photon image of copper exposed to tritium. Some of the tritium locations can be correlated to twin boundaries, but many appear to have no preferential site.



VIDEO
CAMERA
INTENSIFIER
MICROSCOPE
DIGITIZING
BOARD
VIM COMPUTER
FILM RECORD UNIT
OPTICAL
DISK DRIVE
DIGITIZING
BOARD
386 PC
VIM SYSTEM
AS PURCHASED

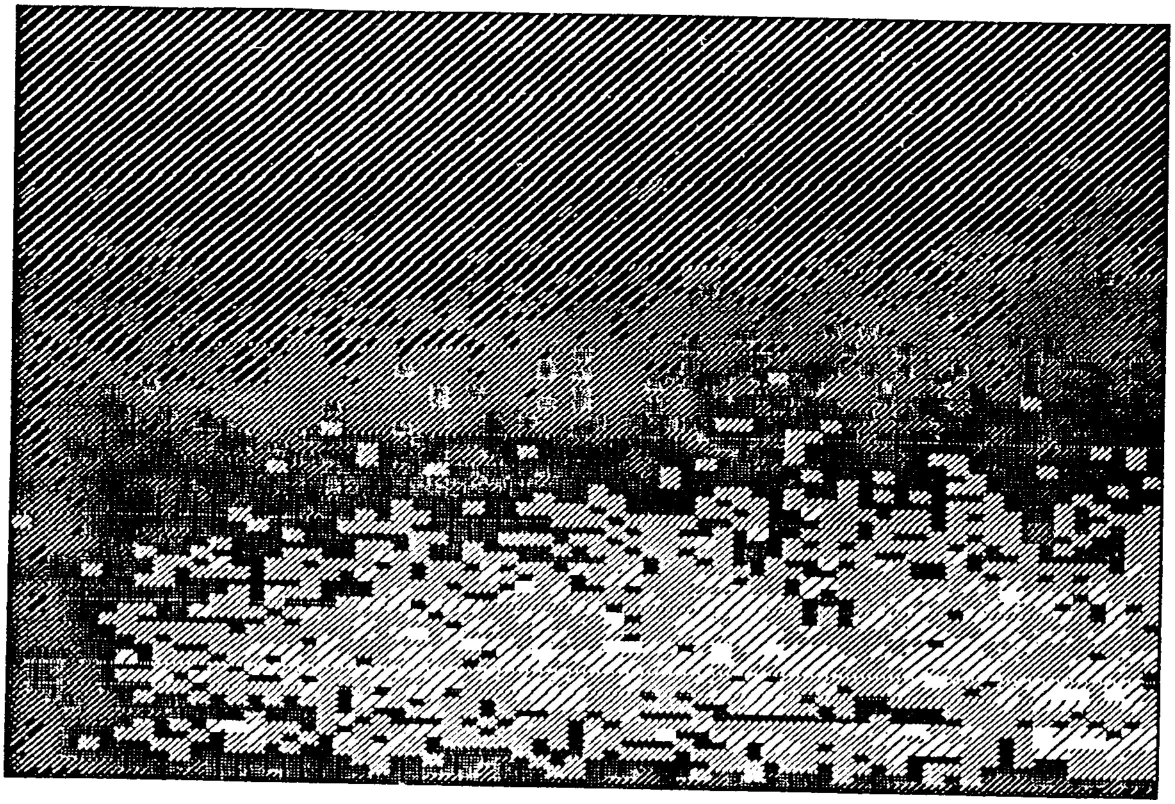


Figure 4