Development of a Polarized Microscopic Image Management System for Supporting Asbestos Qualitative Analysis Utilizing Dispersion Staining

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Abstract–**This paper describes development of an automated polarized microscopic image management system for supporting qualitative analysis of asbestos. Dispersion staining is a visual observation method. Experts count all particles in the microscope view and also the number of the fibrous asbestos fibers. For supporting this work, we are developing an automated system to ease experts' burdens for efficient observation. The system takes polarized images using the microscope with an automated polarizer and registers them on the database via on-line process. A prototype system was developed. Its functional performance is also discussed.**

I. INTRODUCTION

In recent years, health damage caused by asbestos has become an important social problem. Asbestos has been shown to disperse asbestos fibers that penetrate and adhere to lung tissue when inhaled, sometimes causing lung cancer and other health problems. Nevertheless, asbestos-containing insulation, fireproofing and other materials came to be widely used in the construction of ordinary homes and other buildings. Therefore, asbestos analysis is an indispensable tool for determining whether building materials now in use contain sufficient asbestos to cause health problems [1][2][3].

Asbestos analyses of two types exist: qualitative analysis and quantitative analysis. Qualitative analysis clarifies whether a building material contains sufficient asbestos fibers to cause health damage. Quantitative analysis is calculation of the actual asbestos content of a specimen. In the qualitative analysis process, X-ray diffraction analysis and visual inspection, designated as dispersion staining, are done in experiments. Visual inspection continues to impede working efficiency because of the labor and time required. On the other hand, the recent worsening of asbestos-related problems has spurred requests for asbestos analysis and is making the need for improvements in analytical efficiency an urgent priority.

Until now, some systems have been developed for supporting asbestos analysis. Magiscan [4][5], and the Asbestos Fibers Automatic Counting System (AFACS) [6][7] are now in service. Both use image evaluation, but the targets of these systems are airborne asbestos fibers [8], and their utility is attributable to the fact that, aside from asbestos fibers, air specimens normally contain only ultrafine and mostly non-visible particles.

The purpose of this current research is to develop a system that supports dispersion staining, which is a qualitative analysis technique used for asbestos measurements in construction materials. Consequently, the system is intended to support the visual inspection process of dispersion staining.

Our previous work developed an automated microscopic system for asbestos inspection [9] [10]. It realized automated microscopic imaging including observation area detection utilizing image processing. It also stores image data in a computer. However, for effective asbestos inspection, it is necessary to implement an on-line interactive access framework.

Therefore, in this paper, we develop a polarized microscopic image management system for supporting asbestos' qualitative analysis utilizing dispersion staining. It realizes automated microscopic imaging, imaging data registration to the database and interactive browsing of registered data using a Graphical User Interface (GUI).

Fig. 1. Visual Inspection Utilizing a Microscope.
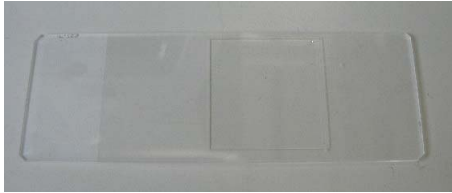
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Fig. 2. A specimen from the construction material is set on the slide glass with the refractive index liquid. It is covered by a cover slip (22 mm × 22 mm).
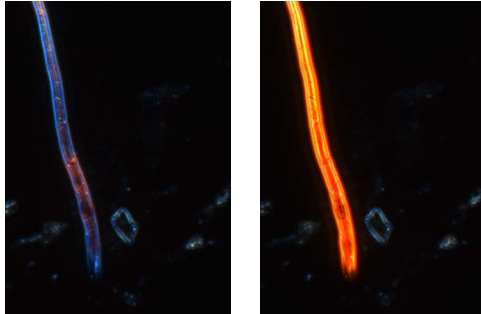

Fig. 3. Example of dispersion color change.

II. DISPERSION STAINING METHOD

Qualitative analysis is performed to determine whether a specimen contains asbestos fibers. The two primary methods of qualitative analysis are X-ray diffraction analysis [11] and dispersion staining [12]. The results obtained using both methods show whether a given specimen contains asbestos.

Here, dispersion staining is a representative visual inspection process that enables an observer to identify asbestos fibers based on dispersive colors through immersion and polarization.

Figure 2 depicts an example of the specimen from the construction material set on the slide glass with the refractive index liquid; it is covered by cover slip. In addition, Fig. 3 shows a typical example of dispersion color change of an asbestos fiber. An inspector produces a plural specimen with dispersion staining using several refractive index lipids from the material.

Here, specimens obtained from construction materials that are suspected of containing asbestos also contain other substances that are roughly equivalent in size to asbestos fibers. Therefore, for such specimens, dispersion staining is often employed because of its relative ease in distinguishing asbestos fibers from other particles. The abstract of the actual procedure used for the dispersion staining is prescribed in the Japanese Industrial Standards (JIS) [13] as follows.

1) *A specimen from the construction material (Fig. 2) is set on the slide glass with a cover slip and the refractive index liquid. It is then observed under a dispersion objective lens at ×10 magnification. The dispersion objective lens is switched to ×40 magnification if fibers with dispersive colors are found roughly.*

2) *All particles in the visual field under the eyepiece lens of ×40 magnification (up to 1,000) are counted.*

TABLE I
DISPERSIVE COLOR OF ASBESTOS FIBER

Asbestos	Refractive index	Dispersion color
Chrysotile	1.550	Red purple – Blue
Amosite	1.680	Pink
	1.700	Blue
Crocidelite	1.680	Orange
	1.690	Pink
	1.700	Blue
Tremolite / Actinolite	1.605	Golden yellow
	1.620	Red purple
	1.640	Blue
Anthophyllite	1.605	Golden yellow
	1.618	Red purple
	1.640	Blue

Observed particles might be of any substance, but if fibers showing the unique colors of asbestos are found, their types and amounts are recorded.

3) *The processing described above is performed in immersion liquids of three types, each having different refractive indexes, to determine whether there are four or more asbestos fibers with aspect ratios of 3.0 or greater in a total of 3,000 particles.*

Here, JIS prescribes asbestos' unique dispersive colors as listed in Table I.

From field interviews, it is known that it is better to observe 200–300 unit views of each specimen for reliable inspection. It is also known that, usually, few specimens can be analyzed using a single operator in a day. The inspection of a single specimen takes about one hour.

III. FUNCTIONAL REQUIREMENTS

The purpose of this research is to propose a technological development that will support efficient analysis using dispersion staining, which is currently cumbersome. While asbestos evaluation techniques that use image processing are already under investigation, the need to collect images (selecting a field of observation using a microscope) for evaluation to comply with the official procedure is burdensome in terms of time and labor.

When considering the official procedure for dispersion staining [13], it is believed that a supporting system should at least have the following functions.

1. Automatic detection/decision of an observation area (center position of a cover slip)
2. Synchronous computer control of the above automatic shutter control and control for a polarizing plate angle
3. Registration of polarized microscopic image data and imaging conditions to the database
4. Graphical User Interface (GUI) for viewing the image interactively

Issues 1 and 2 above must be considered because present JIS official procedures state that particles and asbestos fibers should be counted after the arbitrary selection of an observation field, and that the detection of dispersive color changes be used.

Using present JIS official procedures, it is difficult to specify which observation area (view) includes counted particles or asbestos fibers after inspection. Moreover, we consider that seamless imaging of the target area is necessary after the arbitrary selection of an observation field for taking more accurate (realistic) inspection used both of local view and bird's-eye view. Consequently, Issues 3 and 4 above become necessary for supporting the asbestos inspection process. Issue 3 implies management of image data with relational imaging conditions. Issue 4 means realization of a system by which an operator can select imaging data interactively. Registration to the database would be automated as managed by on-line software agents, and the GUI supports an operator's handling of registered data of the database arbitrarily. The operator must see different polarized images at the same view position detected for a dispersion color change, and also select the view position and view magnification for accurate detection and counting operations. It is necessary to implement such functions for support of asbestos inspection.

The next section presents discussion of our development of a polarized microscopic image management system that implements issues 3 and 4 as on-line processes.

IV. POLARIZED MICROSCOPIC IMAGE MANAGEMENT SYSTEM

Figure 4 presents the system configuration of the developed support system. We first briefly introduce the already developed imaging system and describe extended functions for a polarized microscopic image management system.

1. Automatic polarized microscope imaging unit [9][10]

Because the use of a dispersion microscope is prescribed for dispersion staining, we used a computer-controllable system microscope (BX61; Olympus Corp.). During system operation, a source installed under the microscope illuminates the prepared specimen for observation, which is then recorded through the microscope lenses by a system-connected CCD camera (Retiga 4000R; QImaging Corporation). Settings of camera imaging conditions are controlled using image processing library software (Image-Pro Plus; Media Cybernetics Inc.). Under current design specifications, 36-bit color (12 bits each for R, G, and B) and 24-bit color (8 bits each for R, G, and B) images can be saved in the Multi-TIFF format.

The system created here was tested to confirm its operational utility. The official procedure prescribes the counting of particles and asbestos fibers after arbitrarily selecting a visual field. After considering our ability to count
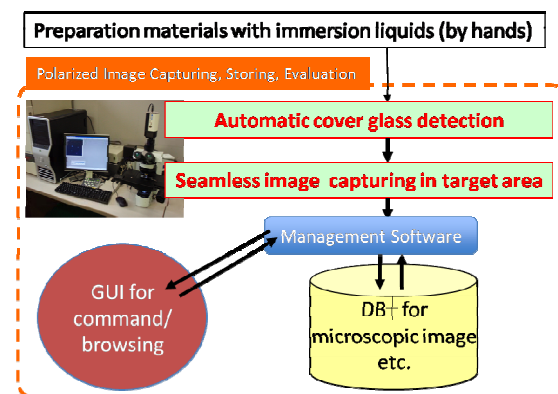

Fig. 4. System configuration of microscopic management system.
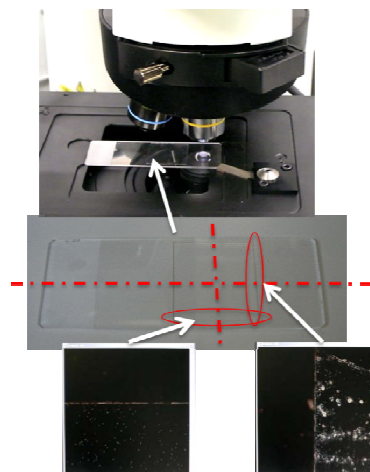

Fig. 5. Target Area Detection based on Image Processing.

all particles and asbestos fibers in the selected visual field with higher precision, we decided to take an approach of imaging the entire observation area by shifting the unit view area of the microscope. The unit imaging area observed using the microscope is 0.379 mm × 0.379 mm. The polarizing plate, XYZ stage and imaging shutter are controlled synchronously (the polarizing plate is set to 0°, 45°, 90°, and 135°). The image is usually saved in the 24-bit color Multi-TIFF format to a local storage device. Its imaging conditions are included in its own file name to be consistent with the
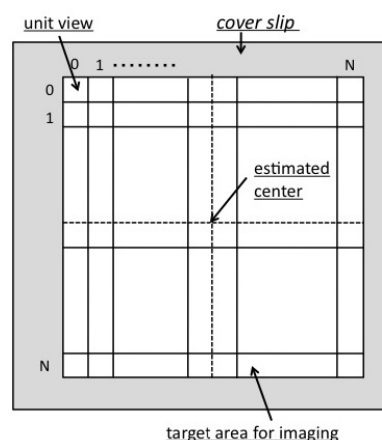

Fig. 6. Coordination of the target area for imaging.

imaging data and imaging conditions.

For automated imaging processes, it is necessary to detect a target area for imaging automatically. An automatic cover slip detection function has been proposed [10]. Functions based on image processing using a ×100 magnification microscopic image are implemented. The imaging system scans to seek the left side vertical edge of the cover slip and also seek the upper side horizontal edge after detecting the vertical edge. Edge detection is done using the thresh-holding color component of Hue, Intensity, Saturation (HIS) expression on the captured image (Fig. 5). Using this process, the imaging system can specify the original point (center position) of the cover slip and determine the target imaging area.

This imaging unit is used to polarize microscopic image management systems.

2. On-line storage device monitoring / image data registration agent unit

The developed microscopic imaging system takes only the images and stores them in its own storage device to realize interactive or on-demand type inspection, it is necessary to manage the imaging data with the imaging condition information (captured image file, imaging conditions, specimen ID, and so on).

This function is realized through the use of on-line software, which has a monitoring agent and a registration agent that register the image captured by the polarized microscope imaging unit and record it in the database. The monitoring agent monitors storage devices of a polarized microscope imaging unit via on-line processing (Fig. 7(a)). The monitoring agent monitors the storage device of the polarized microscope imaging unit for confirming whether there are new imaging data or not based on the verification result obtained utilizing the database (Fig. 7(b)). The monitoring agent calls the registration agent if a new one is detected. The registration agent registers the image file and imaging conditions (Fig. 7(c)). Imaging conditions are important information used to display the images. Here the imaging conditions include a specimen image capturing date (ID, refractive index liquid type), the unit image position on the plate (Fig. 6), and the polarizing plate angle. For conditions obtained in the file name of the image, its format is "***SpecimenID_X position ID+Y position ID_Polarizing plate angle.tif***". After registration, the registration agent waits for that and the monitoring calls again (Fig. 7(a)).

3. Graphical User Interface for browsing polarized images

This function is to show microscopic images with conditions commanded by the operator. It displays a unit image captured by the automated imaging system function and survey image. A survey image is constructed from some unit images based on imaging condition information. The GUI gathers the same ID images from the database according to specimen ID and reconfigures the survey image utilizing position / polarized angle information. Human operators can

(a)   Monitoring storage of polarized microscopic imaging system.

(b)   Confirming whether imaging data are new or not.
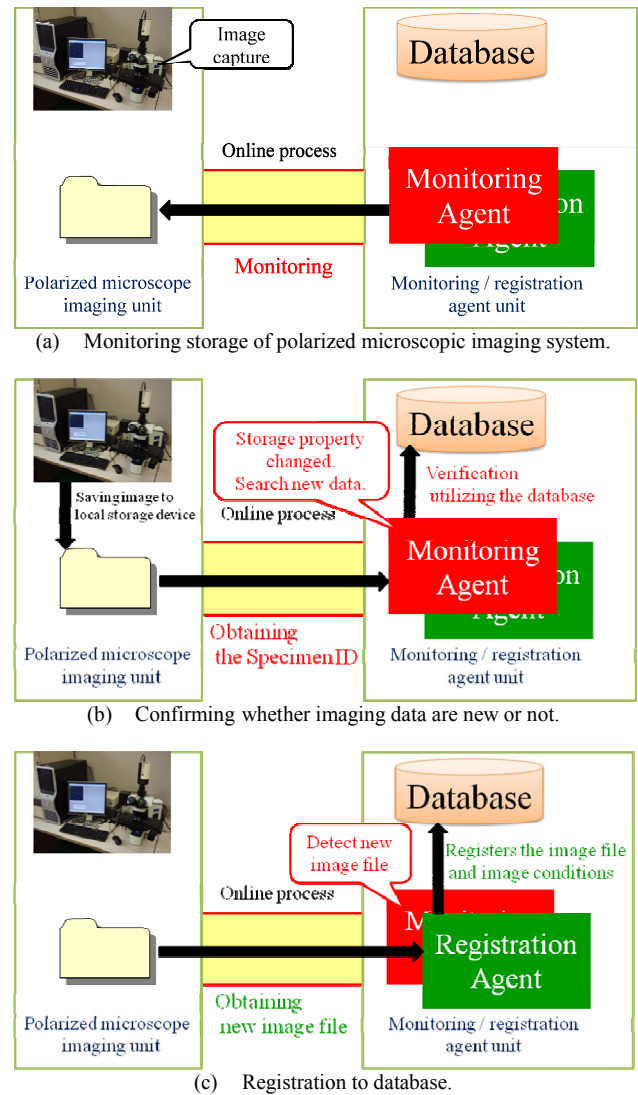

(c)   Registration to database.

Fig. 7. Conceptual diagram of the management agent and registration agent sequence of behaviors.

also observe a unit image by selection of the compartment of the survey image.

By implementing those functions, a microscopic image management system can execute capture, storage, and browsing of microscopic images. It supports interactive asbestos inspection.

We constructed a prototype system using two computers, and one is for microscope control (OS, Windows XP x64 Edition; Microsoft Corp.); another is for database control (OS, Windows VISTA Business; Microsoft Corp.) which are connected via an Ethernet network. MySQL was used as database software; the database computer installs our developed graphical user interface for browsing images.

Functions were verified through experiments using our developed prototype system. Figure 8 portrays a series of experiments. Figure 8(a) shows that the management agent is monitoring the capture image coming in, Fig. 8(b) depicts a management agent checking newly incoming captured images, receiving new images via on-line processing, and registering images and image conditions for the database; it can also check captured images (Fig. 8(c)). Figure 9 presents the browsing portion images of a target area registered database. In this monitor, the lower left window shows the position in the target area; the upper left side window shows the unit image captured by microscope; the right side window shows
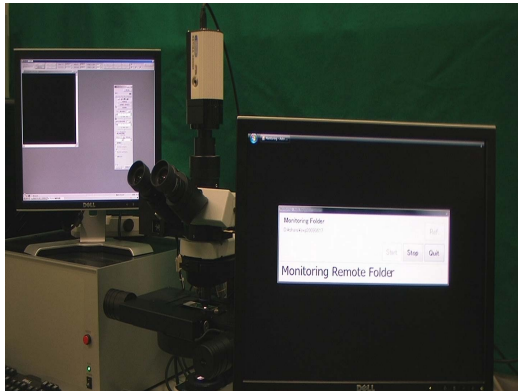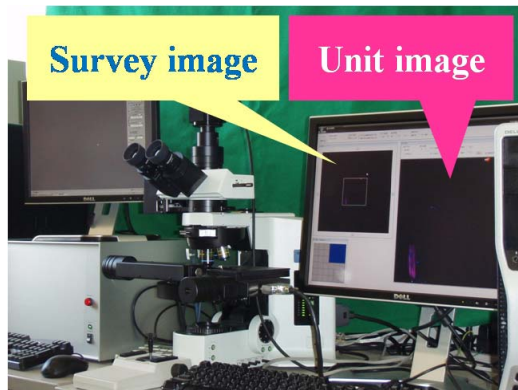
survey image constructed around the nine neighborhood unit images. Figure 10 shows a magnified view of the menu bar in Fig. 9. First, software makes up unit images, survey images and the target area automatically when the inspector selects the specimen ID and pushes the browse sample button. The radio button shows a polarized angle browsing image. Displaying the unit image and survey image switch to other polarized angle according as a mouse wheel running or clicking an arbitrary radio button. The survey image position moves using the arrow button around the survey image or using the arrow keys of a keyboard. In addition, the survey image position can move by selecting the center position on the menu-bar directly. The unit image position is also movable by clicking on the survey image. The position moves according to movement of the survey image position. Other selectable checkboxes and input boxes are not used in this experiment, it is arranged for showing of assistance information by application of image processing, which we consider to be a subject for future work.

Figure 11 shows part of the data list on the database registered in this experiment. Its confirmable registered images with images conditions: specimen IDs, unit view positions, and polarizing plate angles. In this table, "X_coord" and "Y_coord" rows shows image captured positions that expressed matrix by integer number, and "Angle" shows the image captured angle of the polarized image. "Particle" and "Asbestos" rows are items for counting particles or asbestos fibers; they are not used in this experimen. For that reason, those rows input "NULL." Captured images can be searched using items in these data tables, and can be used to present evidence after specimen detection.

Field interviews show that it is better to observe 200–300 unit views on each specimen for reliable inspection. For capturing images consisting of three polarization patterns from the aforementioned 32.32 mm^2 (5.685 mm × 5.685 mm, 225 unit views) area of the cover slip, about half an hour is necessary in the experiments. Development of browsing data and detection functions and discussion effects caused by this system for asbestos qualitative analysis utilizing dispersion staining are anticipated in the future.
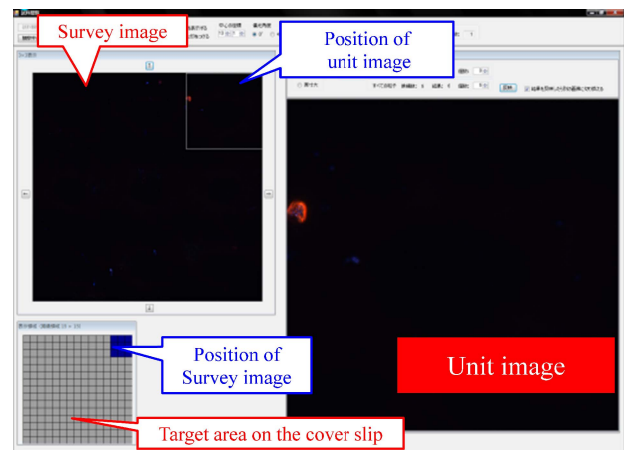

(a) Monitoring the storage using the automated polarized microscopic imaging system.

(b) Confirming incoming captured images and registration of its images.

(c) Browsing portion images of a target area (Survey image and Unit image").

Fig. 9. Experiment of GUI for supporting asbestos analysis.

Fig. 10. Menu bar of GUI

Fig. 11. Example of stored data.

VI. CONCLUSION

This paper describes development of an automated polarized microscopic image management system for supporting asbestos qualitative analysis using dispersion staining, which is an important technique used to perform qualitative analysis of asbestos particles contained in building materials. Referring to the official inspection procedure, we developed a prototype system that automatically captures images for dispersion staining, along with management images functions that register an image and its conditions to the database automatically. The system contributes to management of analysis evidence which conforms with captured images. Moreover, it obviates the use of polarized microscopic images for qualitative analyses by dispersion staining method using computers.

Our future objective is the construction of an automatic counting system that will combine the asbestos fiber and particle detection techniques with image processing methods that are currently under development [14][15].

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