Applied research on dry-printing technology for remote sensing photo images

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1. INTRODUCTION

The research has been practiced to apply and examine quick precise dry-printing technology for image handling purpose in the field of remote sensing data analysis.

A couple of advanced mono-chrome photo-sensitive sheets, printing paper type and transparency type, have been developed and experienced to reproduce high quality photo images, obtained by earth resources satellites, through quick dry-printing method in an ordinary office room.

Experimental results are evaluated at the standpoints of both photo technology and geological photo interpretation, and proved that the dry-printing technology is useful for earth resources data analysis.

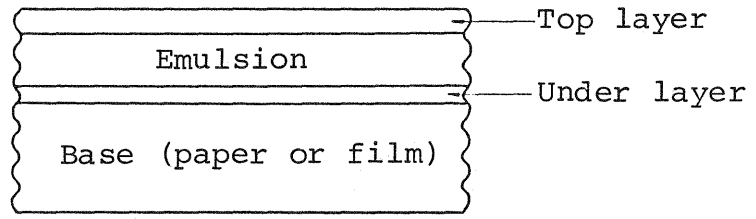
2. DRY-PRINTING METHOD

2.1 Photo Characteristics

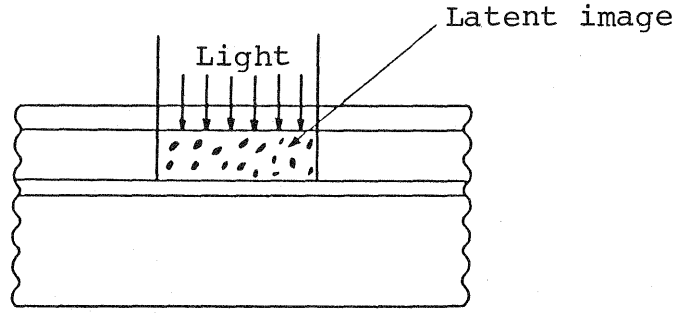
The dry-printing method is devised to overcome the conventional cumbersome developing method using silver halide solution. In this new method, the entire process is completed by applying heat for ten seconds or more after exposure. High-quality images are assured by black metallic silver as is achieved by conventional silver halide photo-sensitive sheets. Figure 1 shows the exposure and developing processes in dry-printing.

To use satellite data more efficiently, the photo data retrieved by the user should be added immediately as high-quality photo print data. The dry-printing process system provides data retrieval service at an analysis center. It can be installed in an ordinary office room to produce hardcopies for quick processing.

Photo characteristics were studied from the technical view-points using printing-paper-based and film-based dry-printing prototypes, in order to confirm their performance. Table 1 shows dry-printing photo-sensitive sheet performance.



Light Exposure



Heat Development

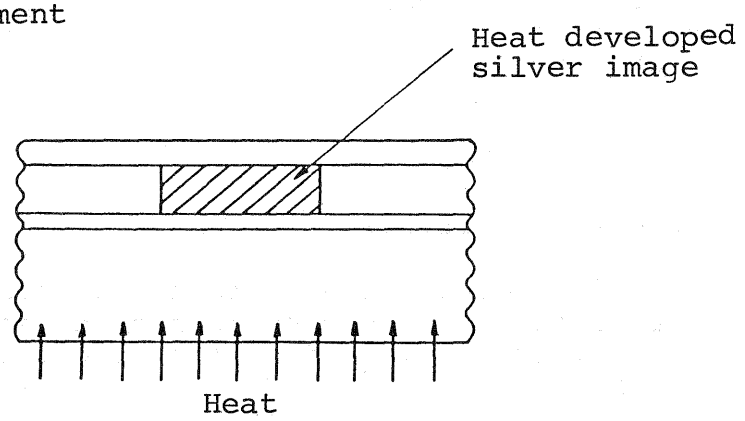


Figure 1 Exposure and development in dry-printing

Table 1 Characteristics of dry-printing photo-sensitive sheets

Item	Printing-paper-based	Film-based
Base	Baryta paper with a thickness of 150§m	Film base for photos
Photographic wave-length band	Orthochromatic	Orthochromatic
Maximum image density	1.6 or more	2.5 or more
Background density	0.1 or less	---
Resolution	50 lines or more per mm	100 lines or more per mm
Developing	120°C for 10 to 15 seconds	120°C for 10 to 15 seconds
Surface of photo-sensitive sheet	Smooth, glaring	---
Tone	Three types (soft, intermediate, and hard)	One type

2.2 Technology Supporting Thermal Development Photo-Sensitive Sheets

There are several recording materials using heat, including those containing silver chloride and those not containing silver chloride. Many heat usage methods are also available. As non-silver chloride materials, heat-sensitive recording sheets, ziazo bubble photo films, and free radical photo materials are available. Heat-sensitive recording sheets produce images directly when heat is applied. For ziazo bubble photo films, ziazonium salt in the thermoplastic resin is decomposed by exposure of ultraviolet rays, then small, high-pressure nitrogen bubbles are generated. When these bubbles are heated, the thermoplastic resin is softened, then compressed nitrogen bubbles expand, providing density enough for photos (development). Free radical photo materials also use ultraviolet ray exposure. When exposed to ultraviolet rays, they produce images directly (printing). The resulting images are heated to disperse carbon halogenide and eliminate photo-sensitivity (fixing).

Thermal development photo-sensitive sheets containing silver chloride are processed in two steps, light exposure and

thermal development. As compared with ordinary wet-type photo-sensitive sheets containing silver chloride which are processed in five steps -- light exposure, development, fixing, rinsing with water, and drying, dry-printing is very excellent in handling photo-sensitive sheets. In addition, wet-printing requires waste fluid processing.

The reason why the silver chloride sheet was selected from among many thermal processing photo-sensitive sheets is explained as follows. In addition to providing the above thermal processing sheet advantages, the silver chloride sheet uses the silver chloride technology, which has always been the major one in the 250-year history of photo technology, for the process from photo-sensing to latent image formation, so the silver chloride sheet assures comparable products to those provided by a wet-type silver chloride photo-sensitive sheet in terms of photo-sensitivity, color-sensitivity, gradation, density range, resolution, and other characteristics required for photo-sensitive sheets. Satisfactory results of the silver chloride sheet were demonstrated in prototype tests.

The three main components of the silver chloride thermal development photo-sensitive sheet are:

(1) Photo-sensitive silver halide that forms latent images through light decomposition.
(2) Heat-sensitive silver chloride that causes a reduction reaction of silver ions by using latent image silver as a catalyst to produce silver to be used as image silver.
(3) Developer that is a phenol compound having very weak reduction power.

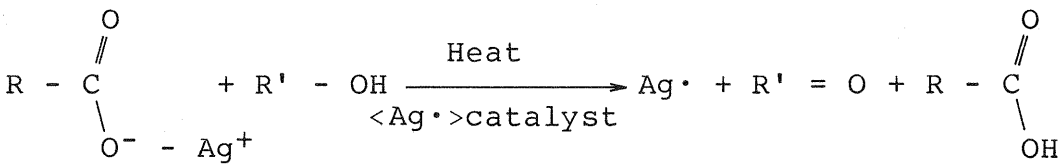
If color-sensitive characteristics such as orthochromatic and panchromatic characteristics are required, color-sensitive coloring matter is added accordingly.

When exposed to light, the photo-sensitive material prepared like this can provide latent image silver through the same mechanism as for ordinary wet-type silver halide photo-sensitive materials.

$$AgX + h\nu \longrightarrow Ag^{+} + X + e^{-}$$

$$\text{Trapped} \quad e^{-} + Ag^{+} \longrightarrow \langle Ag\cdot \rangle$$

Further, when heat is applied to the coated layer of the photo-sensitive sheet after exposure at a temperature of 115°C to 135°C, silver ions isolated from heat-sensitive silver chloride due to heat cause a rapid reduction reaction using latent image silver contained in the coated layer as a catalyst and result in image silver. This forms a photo image.



The reduction reaction occurs on all the surfaces of the heated coated layer. However, reaction speeds at exposed areas differ from those at areas not exposed due to differences in the amount of latent image silver. The difference in reaction speed is reflected on the amount of image silver. This forms a photo image.

In the normal development method, metallic silver on an image after development results from reduction reactions of individual silver halide particles. In the dry-printing method, organic silver compounds to be subjected to reduction reactions that exist together with but independently of silver halide are used as a source of silver ions. In the other words, the former development is a chemical phenomenon, whereas the latter method is a physical phenomenon using heat.

The time required for development varies with temperatures during heating, but it is about 10 to 15 seconds. The following three methods of heating are likely to be used with the shapes of the heat sources taken into consideration:

(1) Rod
(2) Cylinder
(3) Plane

The first method requires extremely high precision to pass an exposed printing sheet or film at a constant speed. The third method cannot ensure continuous processing. For these reasons, the second method, cylinder, is adopted. Note that even if the heater surface is maintained at a constant temperature, uniform development is not possible without uniform adherence of photo-sensitive materials.

3. EXPERIMENTS AND RESULTS

3.1 Preparation of Images to Evaluate Practical Serviceability

The authors printed actual satellite images on printing-paper-based and film-based photo-sensitive sheets to prepare images for evolution of dry-printing. The satellite images used are Landsat satellite images (photoelectric sensor images), Seasat satellite images (radar images), and so on.

Figure 2 plots the characteristics curves of printing-paper-based and film-based dry-printing photo-sensitive sheets.

Figure 3 is a sample of printing.

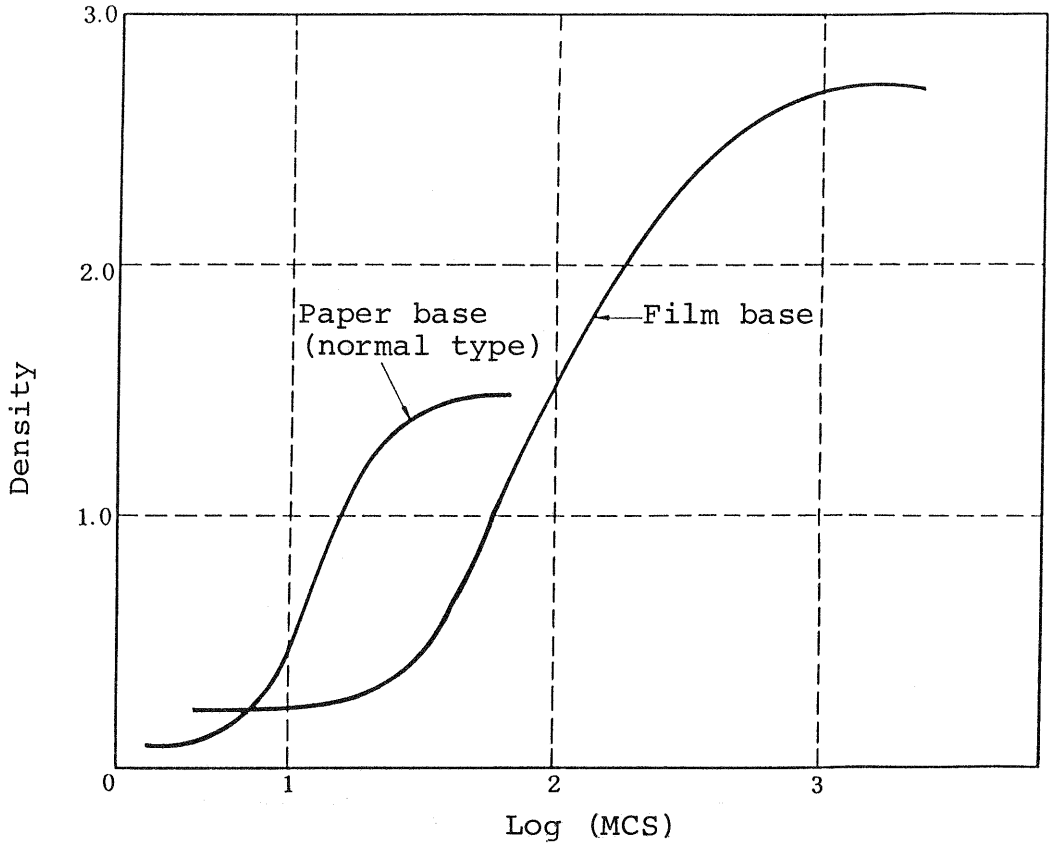


Figure 2 Characteristics curves of photo-sensitive sheets used for dry-printing

3.2 Evaluation of Practical Serviceability

Professionals evaluated the samples using various methods from the standpoints of both photo technology and geological photo interpretation. The evaluation results are as follows:

o Photo technology

(1) Image quality : Almost the same as of conventional wet-photography
(2) Gradation : Allows for a wide range
(3) Processing : Easy and fast

o Geological photo

(1) Interpretation: Almost the same as of conventional wet-photography
(2) Application : A wide variety of applications are possible.

The dry-printing of satellite images and air photos in the remote sensing area can provide comparable evaluation to the conventional wet-photography.

Table 2 compares the dry-printing with the conventional wet-photography.

Figure 3 Example of printing

Table 2 Comparison of dry-printing with wet-photography

	Dry-printing	Wet-photography
Process	One process: Thermal development Processing time: 10 seconds	Five processes: Development, stopping, fixing, rinsing with water, and drying Total processing time: About 10 minutes
Quality	Gradation Printing paper: Three types (soft, normal, hard type) Film: One type Resolution Printing paper: 50 lines or more per mm Film: 100 lines or more per mm Sensitivity About one-third of that for wet-photography	Gradation Printing paper: Five types (from ultrasoft type to ultrahard type) Film: Usually one type Resolution Printing paper: 50 lines or more per mm Film: 100 lines or more per mm
Cost	No developer is required.	A developer, water supply, draining, and waste liquid processing are required.

4. CONCLUSION

The dry-printing is very simple, enabling processing to be performed in an ordinary office.

The dry-printing can be used for recording and interpretation of photo images for the remote sensing purpose. For example, satellite images of Landsat MSS and TM, Seasat, MOS-1, SPOT etc., aerial photo images, and so on. Particularly, it provides a very useful way for photo data retrieval, immediate printing, and distribution in an analysis center.