A New Erasable Ink for Paper Recycling and Reuse

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Abstract

A new erasable(decolorable) ink has been developed for paper recycling and reuse. The erasable ink can be easily decolored in two ways; a heat treatment and a solvent treatment. It is composed of three components; leuco dye, developer and erasing reagent. The leuco dye is originally colorless, but it acquires color with developer. The developer is a phenolic compound. The erasing reagent absorbs the developer, and thus, the dye is not developed. It is easily understood as reverse of thermal sensitive recording paper(thermal paper) process. The erasable ink is originally colored by a bond between the dye and the developer, heat treatment or solvent treatment breaks the bond, and the developer bonds with the erasing reagent. Thus the printed image is stably decolored. One of the principal advantages of this erasable ink is that a huge volume of paper can be decolored using the two methods. The various possible applications of the erasable ink include erasable toner, erasable ink ribbon, erasable crayon and erasable liquid ink. Therefore, this ink has the potential to realize an efficient, cost-effective paper recycling and reuse system.

Background

Paper disposal is a serious environmental issue. In Japan, 40%[1] of office trash is paper. Obviously paper reuse can decrease the amount of paper trash. Several paper reuse systems have been proposed, such as light decolorable toner,[2] toner strip machine[3] and rewritable marking media[4] in order to reduce the amount of paper trash. However, no practical in-house paper reuse system has been widely adopted yet. The proportion of the paper trash which is recycled, currently, 54%,[5,6] is insufficient, since it is difficult to remake paper cheaply from printed paper. For a paper remaking system, a large scale factories and complicated processes are requires. Printed paper is pulped and the ink is removed chemically or physically. However, conventional ink is not easily decolored. In order to remove the ink completely, pulp must be treated with a bleaching process which requires many agents and much energy. Therefore, if complete bleaching is required, it is more costly to remake paper from used paper than it is from virgin pulp. Given that landfill sites are scarce, in Japan, a more efficient paper recycling and reuse system is required. We have found a solution to the problem of paper trash, namely a new erasable ink. The images printed by the erasable ink on conventional paper can be efficiently decolored by two methods; a heat treatment or a solvent treatment, and thus recycling and reuse of paper is possible without high cost.

Decoloring Principle

The new erasable ink is composed of three elements, leuco dye, developer, eraser. The leuco dye, which is conventionally used in the thermal paper, is normally a colorless dye, but it acquires color with the developer. The developer is a phenolic compound. The eraser is a material which can trap the developer. It can be understood as the reverse of the thermal paper coloring process. In Fig. 1 the decoloring principle of the erasable ink and the coloring principle of the thermal paper are compared. In the case of the thermal paper, the colorless leuco dye and capsules containing the developer are dispersed on paper surface independently. Heat treatment breaks the capsule, and then the leuco dye acquires color by an interaction with the developer. As for the erasable ink, the leuco dye is colored originally. Heat treatment or solvent treatment cuts the interaction between the leuco dye and the developer, and the developer is trapped stably by the eraser. Therefore the ink is decolored and can not acquire color again.

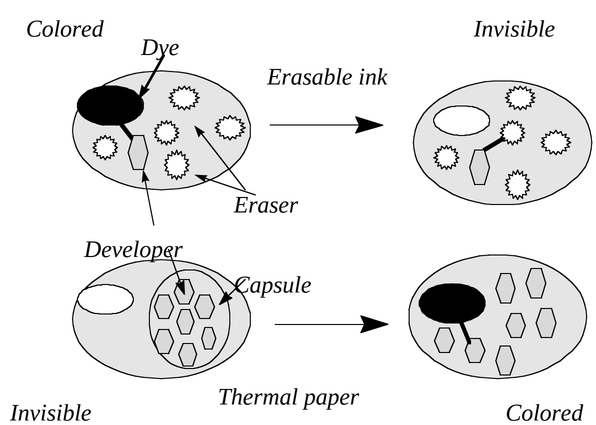

Figure 1. Principle of decoloring process

Fig. 2 shows an example of the erasable ink decoloring process. In this figure, three components are shown: Crystal Violet Lactone, Propyl Gallate, Cholic Acid. Crystal violet lactone is a conventional blue leuco dye and propyl gallate is a conventional developer; both are used in thermal paper and propyl gallate, a compound, is also used as a food additive. Cholic acid is a kind of cholesterol and a component of bile. In colored ink, lactone ring is opened by the interaction of the hydroxyl of the propyl gallate, the central double bond is conjugated with two benzene rings. After the heat or solvent treatment, dissociation of developer renders the carbonic acid part too unstable to make the lactone ring. In this process, the central double bond loses one bond to the lactone ring. As a result, it becomes colorless. At the same time, the dissociated propyl gallate is trapped by the cholic acid, and so the dye loses the active developer.

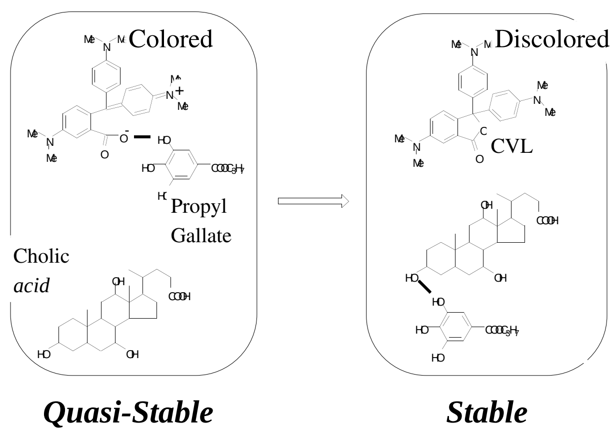

Figure 2. Concrete example of erasable ink

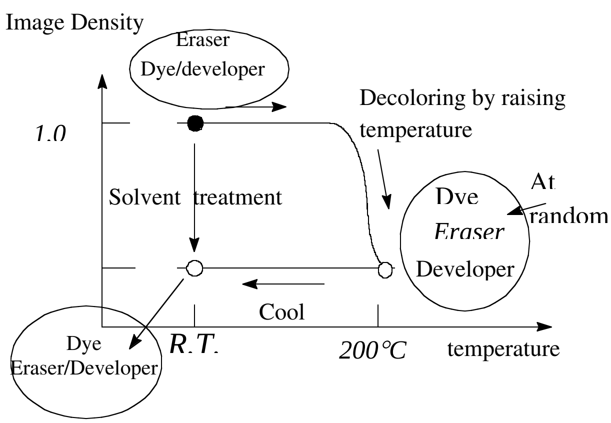

Figure 3. Concept of erasable ink decoloring method

Decoloring Method

The concept of the erasable ink decoloring methods is shown in Fig.3. In this figure, the horizontal axis indicates temperature and the vertical axis indicates optical density of an image. One of the decoloring method is a heat treatment. The decoloring occurs in the range of 120°C to 240°C. The optical density of an image decreases with increased temperature because of the developer dissociation, and the image becomes colorless.

The dissociated developer moves easily in the softened matrix and is trapped completely by the eraser at a temperature above the melting point of the eraser. After cooling down, the image remains colorless.

The other decoloring method is solvent treatment. The solvent permeates the matrix material of the erasable ink.

Then the developer dissociates from the dye due to solvation and becomes colorless. The dissociated developer moves easily in the relaxed matrix material and is trapped completely by the eraser at room temperature. After the solvent evaporates, the picture remains colorless. Isopropyl alcohol is one of the various solvents could be used.

Fig. 4 shows a reuse cycle of electrophotographic printing, heat decoloring and overwriting on decolored paper. In the case of this heat decoloring method, only the printed image on the paper loses color and the binding polymer of the toner remains on the paper surface. The decolored printed image remains visible, because the surface reflectance of the image is different from that of the paper. Hence, the decolored image can be recognized. However, provided that the security is not issue, the paper can be reused several times.

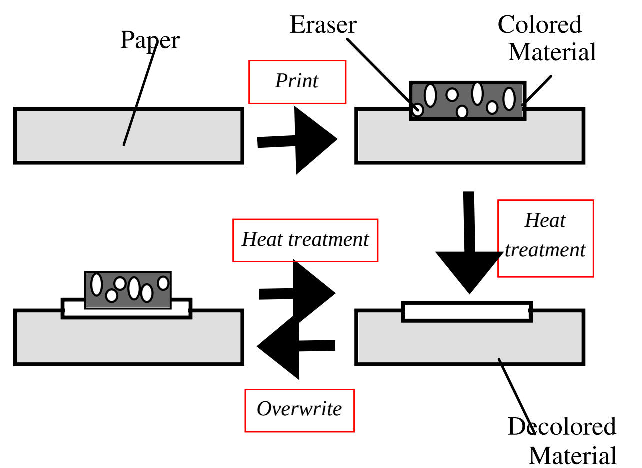

Figure 4. Concept of paper reuse cycle using heat decoloring treatment

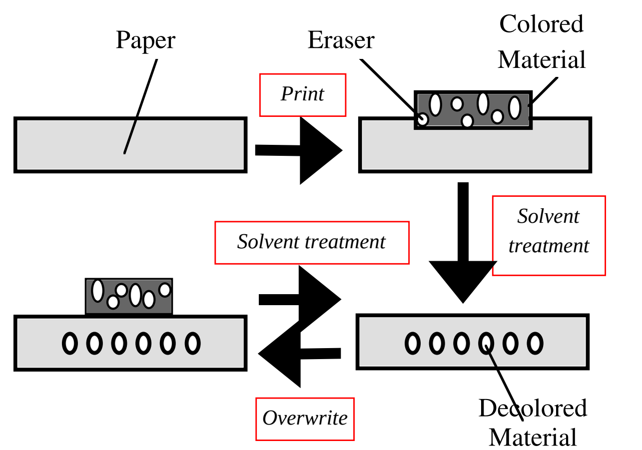

Figure 5. Concept of paper reuse cycle using solvent decoloring treatment

Fig. 5 shows a reuse cycle of electrophotographic printing, solvent decoloring and overwriting on decolored paper. In the case of this solvent decoloring method, the printed image on the paper loses color and the decolored toner permeates the paper fiber. Because almost no binding polymer remains on the paper surface, the image is perfectly invisible. This is one of the most important advantage of the solvent decoloring method.

The paper can be used several times. In the reuse experiments we conducted, the solvent decolored paper was used ten times in a copy machine and its performance was the same as that of a new paper. This process could be applicable to the conventional office shredder and could realize cost-effective protection of confidential information. In addition, the solvent treatment method could be applied to stationery, for example an erasing pen using the pure erasing solvent. These applications constitute important advantages.

The most important advantage of the erasable ink is that it is possible to easily decolor a huge volume of paper in one lot by applying whichever of the two decoloring methods is most suitable for a given task.

Applications

The erasable ink can be used for various image forming materials. Depicted in Fig. 6 are four applications made possible by changing of the matrix material of the erasable ink. In the case that the matrix material is the binding polymer, the erasable ink can be applied to toner of electrophotographic printers used in offices. In the case that the matrix material is wax, the image forming material can be applied to crayons or the cores of color pencils. When the solid state ink is formed as a thin film on a sheet, it can be used as thermal transfer sheet or a pressure transfer sheet. In the case that the matrix material consists of wax, oil, or vehicle resin, the image forming material can be applied to a liquid ink for the conventional printing, such as gravure printing. It can also be applied to ink for a stationery, such as ball-point pen, line marker and fountain pen. Therefore, the erasable ink can be used for both printing ink and writing ink. In terms of paper reuse, this constitutes an important advantage of the erasable ink.

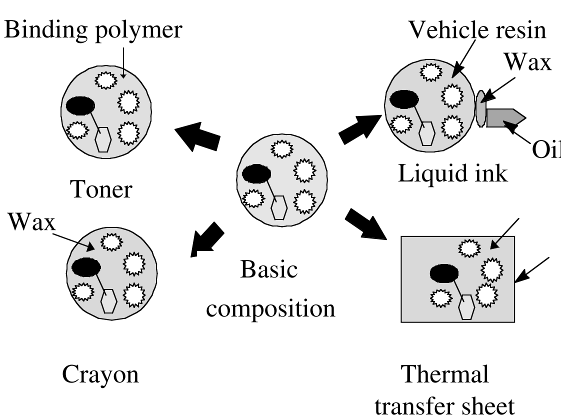

Figure 6. Possible applications of erasable ink.

Given that the erasable ink is applicable to diverse printing and stationery tools, it could improve paper recycling and reuse with little change to conventional printing systems. Figure 7 shows a new paper reusing infrastructure of an office based on the erasable ink. The system includes pens and makers, various printers, copy machines, and erasing pens, document erasers, and a large heating room. The erasing pens are used for modifying documents. The document erasers, a heat treatment machine or a solvent erasing machine, are used for paper reuse in the office. The heating room is used for paper recycling. Paper which is damaged through handling is collected and decolored in one lot in the heating room which is kept at erasing temperature. A huge volume of decolored paper is sent to the paper-making company.

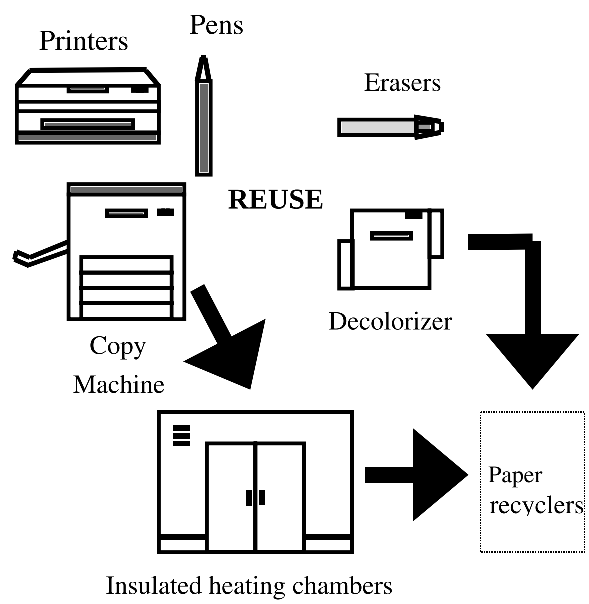

Figure 7. A new paper recycling infrastructure of a office

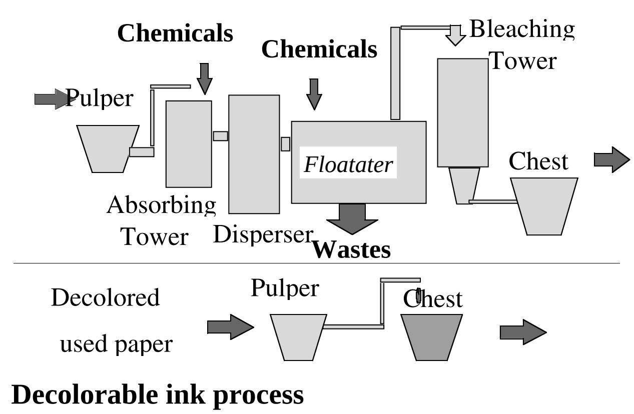

Figure 8. Two decoloring processes for paper remaking

Next, the decoloring process of the paper remaking from the printed paper using this erasable ink is compared with the conventional process. Figure 8 shows the two decoloring processes for paper remaking. In the case of conventional ink, very complicated process is required, involving pulpers, absorbing towers, dispersers, floataters, and bleaching towers, etc. to make pulp white. On the other hand, only pulpers are indispensable, if the erasable ink is decolored previously. Of course, in remaking paper, it is preferable for impurity particles to be removed, and for that purpose, in the process a floatater is required after the pulpers. Clearly, most of the cost of paper remaking would be drastically reduced. We think that erasable ink will play an important roll in paper recycling systems.

Conclusion

A new erasable ink has been developed for paper recycling and reuse. The possible applications of the erasable ink include toner, ink sheet, crayon and liquid ink. The erasable ink can be easily decolored in two ways; heat treatment and solvent treatment. The heat treatment is useful for the paper recycling, because it can decolor a huge volume of paper at little cost. The solvent treatment is useful for paper reuse, because it can erase images perfectly. We think that the erasable ink we have developed has the potential to solve the environmental problem posed by paper trash.

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Biography

Satoshi Takayama received the M.E. degree in 1982 from Waseda University, Japan. In 1982, he joined the Research and Development Center, Toshiba Corporation, Kawasaki, Japan, where he has been engaged in research and development of image sensors, printing devices, and printing materials. He is now a Research Scientist of the Research and Development Center.

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