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A Comparison of Adhesive Tape-Separation Methods from Surfaces; Dipping in Liquid Nitrogen, Liquid Nitrogen Spray and an Adhesive Neutralizer Method

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Abstract

The separation methods of duct tape, packing tape, aluminum foil tape, clear tape, electrical tape and the semi-transparent tape was studied. Adhesive-side to adhesive-side adhered tapes, adhesive-side to non-adhesive-side adhered tapes and adhesive-side to A4 paper adhered tapes were prepared, and the performance of three separation methods (dipping in liquid nitrogen, liquid nitrogen spraying with a cryogun and application of Un-Du) were compared. The fingermarks on the surface of the adhesive surface were developed with Adhesive Side Developer (duct tape, packing tape and aluminum foil tape) and Rose Bengal dye dissolved in a phase-transfer catalyst (clear tape, semi-transparent tape). No differences were observed between the dipping in liquid nitrogen and liquid nitrogen spray methods with respect to the following features: tape fracture and brittleness; transfer of adhesive material to the adhesive-facing side of the tape; separation of the adhesive material from the plastic backing layer; and fingermark development. Un-Du method was successful in separating adhesive-side to adhesive-side adhered tapes, adhesive-side to non-adhesive-side adhered tapes and adhesive-side to A4 paper adhered tapes. We also confirmed a decrease in fingermark quality when using the Un-Du method.

Keywords: Adhesive tape; Liquid nitrogen; Dipping; Cryogun; Un-Du separation

Introduction

Adhesive tape is commonly used for restraining a victim or for packing objects related to criminal activities [1-5]. During either process, the tape's adhesive surface may retain fingermarks of the individuals related to the incident, and this discovery may become a critical clue in solving the case [4]. Therefore, many forensic scientists have studied latent fingermark development and enhancement methods on the surface of the adhesive side of the tape.

However, the tape associated with the incident is often found adhered to another surface or adhered to another adhesive side of a tape [4]. In this case, in order to develop the latent fingermark, the adhesive side of the tape must be separated from the other surface. Therefore, development of a separation method of the adhesive tapes from an object became an important topic of research. Heating, chemical, and liquid-nitrogen-cooling methods are examples of successful separation tools [2-4,6-12].

The heating method requires exposing the adhesive surface of the tape by using microwave or heating gun [4,12]. However, this method nowadays is not used widely because of the deformation of the tape and fingermark shape during the process of pulling.

One of the known chemical separation methods involves the use of a mixture of 95% of Shandon solvent (a blend of aliphatic and halogenated hydrocarbons) and 5% chloroform [4]. In addition, another successful chemical separation method involved the use of heptane as a solvent to separate adhesive tape from a surface [10]. This formulation is commercially available as the Un-Du® product. [13]. Un-Du has an advantage in separating adhesive side with easy manner from both the non-porous and porous surfaces [8-11,13]. However, the decrement of developed fingermark quality by the action of the solvents contained in the Un-Du was reported as a disadvantage of Un-Du method [2,4,9].

It is known that the cooling method using liquid nitrogen does not damage the latent fingermark deposited on the surface of the adhesive side of a tape [7]. This is a method for separating the tapes by weakening the sticky strength by contacting the tapes with liquid nitrogen (-196.79°C). Dipping the tapes in the liquid nitrogen (dipping method) and a spraying liquid nitrogen using a cryogun (cryogun method) are two known methods of applying liquid nitrogen to the tapes, and the utility of these methods was studied by previous researchers [2,3,7,14].

Bailey compared the effectiveness of the dipping method, cryogun method and Un-Du method in separating the tapes adhered to each other's adhesive sides [2]. Bailey mentioned that the cryogun method was the most effective in separating the adhered tapes and developing the latent fingermark which was deposited on the surface of the adhesive side. Moreover, Bailey pointed out the tape becoming more brittle or fracturing in the course of liquid nitrogen dipping and recommended the use of a cryogun [2]. However, the authors did not verify the occurrence of brittleness and fracture of the tape by experiment. Instead, Bailey cited the Baker's previous report [14]. However, even in the Baker's report, the occurrence of tape fracture and brittleness during the course of dipping the product in liquid nitrogen was not examined [14].

Materials and Methods

Materials

Duct tape (green and grey, 46 mm × 10 m, 3M, Korea), packing

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tape (brown and transparent, 48 mm × 50 m, 3 M, Korea), aluminum foil tape (40 mm × 5 m, Okong, Korea), clear tape (18 mm × 30 m, 3 M, Korea), electrical tape (19 mm × 10 m, Okong, Korea) and semi-transparent tape (18 mm × 15 m, 3 M, Korea) were purchased from a local market.

Un-Du Original Sticker, Tape & Label Remover (Un-Du Inc, USA) was used as an adhesive neutralizer. ACry-Ac-3 (Brymill, USA) cryogun with a nozzle diameter of 0.031 mm was also used.

The latent fingermarks which were deposited on the adhesive side of duct tape, packing tape, aluminum foil tape were developed with the DARK Adhesive-Side Developer (SIRCHIE, Cat. No. ASD7D, USA). Electrical tape was treated with the WHITE Adhesive-Side Developer (SIRCHIE, Cat. No. ASD7L, USA). Clear tape and the semi-transparent tape was treated with the phase transfer catalyst solution which was formulated with 0.01 M tetrabutylammonium iodide (Acros Organics, USA) and 0.01 M Rose Bengal (Junsei, Japan) [15].

Preparation of tapes

Before the experiment, the ends of all the tapes adhesive surfaces were manually folded in order to facilitate the separation. Latent fingermarks were collected from a 27-year-old female donor. The donor pre-touched her forehead and nose three times with the tip of her right thumb and deposited her right thumb fingermark by 3 consecutive natural touches of the adhesive side of the tapes.

Adhesive-side to adhesive-side adhered tape (A-A tape) was prepared by adhering the latent fingermark bearing adhesive-side and untouched adhesive-side of a tape. Adhesive-side to non-adhesive-side adhered tape (A-N tape) was prepared by adhering the latent fingermark-bearing adhesive-side and untouched non-adhesive-side (backing plastic layer) of the tapes. Adhesive-side to paper adhered tape (A-P tape) was prepared by adhering the fingermark-bearing adhesive side and neat A4 paper. After a period of 24 hours, three separation methods were used to separate the tapes.

Separation of tapes and development of fingermarks

In the case of a dipping method, after dipping the samples into the liquid nitrogen for a given time, it was separated by pulling two ends of the sample by hand. In the case of the cryogun method, after spraying liquid nitrogen from the corner of the sample for a given time, it was separated by pulling two ends of the sample by hand. In the case of Un-Du method, the Un-Du was dropped on the corner of the sample, and it was separated by pulling two ends of tapes by hand. Immediately after the separation, the latent fingermarks were developed by an Adhesive Side developer or Rose Bengal dye. All the separation and fingermark development experiments were repeated 10 times.

Results

Change of the tape according to the liquid nitrogen exposing time

The change of tapes as a function of time after the contact with liquid nitrogen (dipping and cryogun methods) was observed. In the case of duct tapes, the ends of the tape started rolling up immediately after contact with liquid nitrogen in both methods. The brittle and fracture features of the backing plastic layer during bending of the samples were observed after 10 sec of contact, and breaking of the adhesive material was observed after 20 sec of contact. In the case of packing tape and clear tape, the ends of the tapes started rolling up immediately after the contact with the liquid nitrogen in both methods. However, in the case of drawing out from liquid nitrogen or discontinuing the cryogun spray, the dried tape returned quickly to its original state. Unlike to the duct tape, with simple exposure to the liquid nitrogen, brittleness and fracture of the adhesive and backing plastic layer were not observed. However, the tapes were torn by applying a pulling force to separate the adhered tapes. More than 30 sec of contact with liquid nitrogen did not cause brittleness or fracturing of the aluminum foil tape. In the case of electrical tape and semi-transparent tape, brittleness and fracture

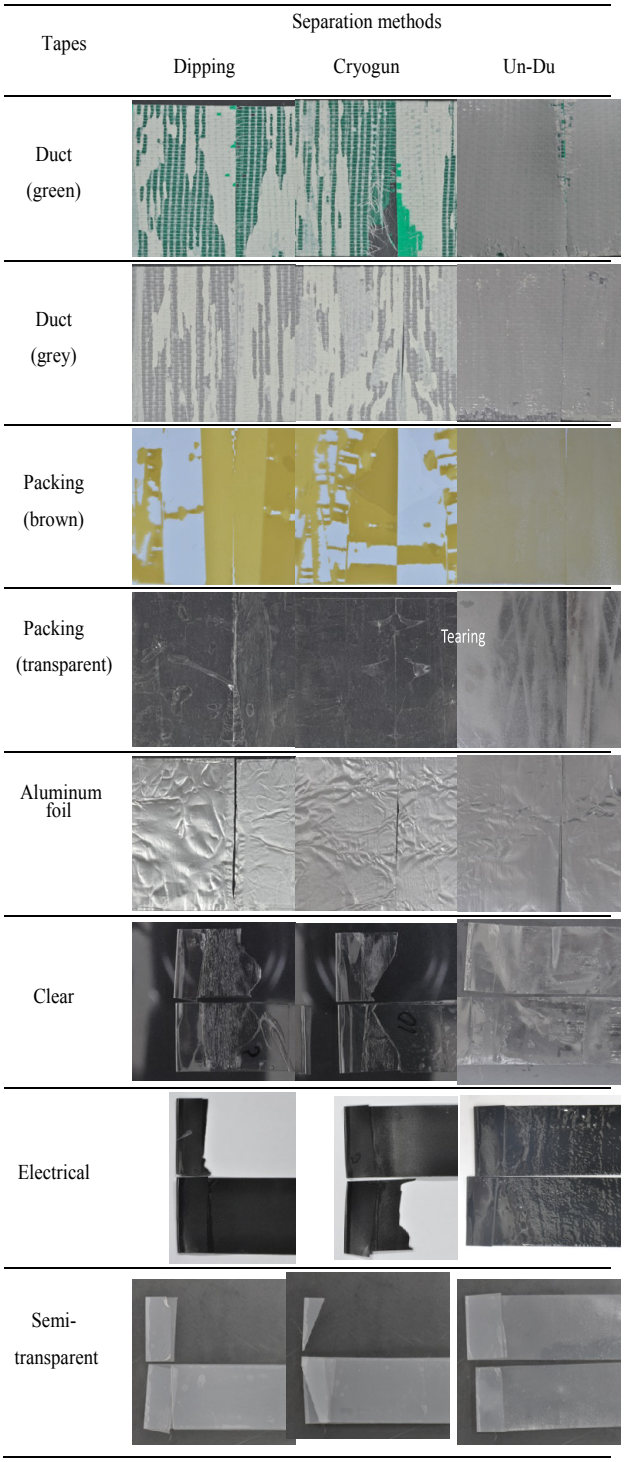

Figure 1: Separation results of A-A tapes.

Separation methods	Observed features					
	Tapes	Brittleness	Tearing	Irregular separation of adhesive material	Transfer of the adhesive material to the facing tape	Development of the whole fingermark
Dipping	Duct (green)	X	X	O	X	impossible
	Duct (grey)	X	X	O	X	
	Packing (brown)	X	X	O	X	
	Packing (transparent)	X	4/10	O	X	
	Aluminum foil	X	X	X	O	
	Clear	X	O	X	X	
	Electrical	O	X	X	X	
	Semi-transparent	O	X	X	X	
Cryogun	Duct (blue)	X	X	O	X	impossible
	Duct (grey)	X	X	O	X	
	Packing (brown)	X	X	O	X	
	Packing (transparent)	X	7/10	O	X	
	Aluminum foil	X	6/10	X	O	
	Clear	X	X	X	O	
	Electrical	O	X	X	X	
	Semi-transparent	O	X	X	X	
Un-Du	Duct (blue)	X	X	X	X	possible
	Duct (grey)	X	X	X	X	but the quality is reduced
	Packing (brown)	X	X	X	X	
	Packing (transparent)	X	X	X	X	
	Aluminum foil	X	X	X	X	
	Clear	X	O	X	X	
	Electrical	X	X	X	X	
	Semi-transparent	X	X	X	X	
*O: Observed, X: Not observed, Numbers in the table: number of observation out of 10 trials						

Table 1: A summary of latent fingermark development results from the adhesive side of A-A tapes.

were observed from 5 sec contact with liquid nitrogen. Therefore, in the following experiments, the time interval of both the liquid nitrogen cooling methods was limited to 5 sec.

Separation of A-A tapes and development of latent fingermark: A-A tapes were separated by three separation methods, and the result was compared. The cooling time with liquid nitrogen was limited to 5 sec. Figure 1 shows the deleteriously-separated tapes, and the phenomenon observed from the tapes were summarized in Table 1. In Figure 1, the separation result of aluminum foil tape using dipping and cryogun methods looks successful but actually it was not. The adhesive material in one tape transferred to the facing adhesive side of the tape, but it is not readily apparent on the photograph. As shown in the Figure 1 and Table 1, both the cooling methods were not successful in separating the A-A tapes. The Un-Du method was successful in separating A-A tapes. However, the quality of developed latent fingermark was reduced (Figure 2).

Separation of A-N tapes and development of latent fingermark

A-N tapes were separated by three methods, and the separation result is summarized in Table 2. The contact time with liquid nitrogen was limited to 5 sec. The adhesion of aluminum foil tape was separated irregularly by using cooling methods while the separation of the other tapes was successful. When using Un-Du method, all tapes were separated successfully, but the quality of developed latent fingermark was reduced. Figure 2 shows the reagent developed latent fingermarks which were deposited on the surface of the adhesive side of the tape. Decreased quality of latent fingermark is seen in the Un-Du treated tapes comparing to the liquid nitrogen treated tapes.

Separation of A-P tapes and development of latent fingermarks

A-P tapes were separated by three methods, and the separation result is summarized in Table 3. The contact time with liquid nitrogen was limited to 5 sec. As shown in Table 3, when using liquid nitrogen cooling methods, successful separation and development of latent fingermark were not accomplished because of the occurrence of the peeling of paper or peeling of adhesive material from the backing plastic layer. Successful separation was achieved by using Un-Du, but the fingermark quality was decreased.

Discussion

Bergeron conducted the 'adhesive-side to adhesive-side attached tape-separation' experiment with liquid nitrogen dipping and concluded that the 10 sec dipping was not sufficient for the separation. Bergeron also mentioned that dipping for more than 30 sec did not have a detrimental effect on the tape [7]. However, in the present study, brittleness and fracture of tapes was observed from 5 sec contact with liquid nitrogen (dipping and cryogun spraying), and it produced a deleterious effect on the latent fingermark development.

Many forensic scientists have reported successful separation of A-A tapes by cooling method using liquid nitrogen [2,3,7,14]. However, while applying liquid nitrogen, the occurrence of an irregular (asymmetric) or total transfer of adhesive material to the facing adhesive material phenomenon shown in the Figure 1 has not been reported. More research is required to find the reason for this phenomenon. The Un-Du method was free from this deleterious phenomenon but decrease in the quality of the developed fingermark was observed by the action of the solvents [2,4,9].

Methods	Observed features					
	Tapes	Brittleness	Tearing	Irregular separation of adhesive material	Transfer of the adhesive material to the facing tape	Development of whole fingermarks
Dipping	Duct (green)	X	X	X	X	Possible
	Duct (grey)	X	X	X	X	
	Packing (brown)	X	X	X	X	
	Packing (transparent)	X	X	X	X	
	Aluminum Foil	X	X	O	X	Impossible
	Clear	X	X	X	X	Possible
	Electrical	O	X	X	X	
	Semi-transparent	O	X	X	X	
Cryogun	Duct (green)	X	X	X	X	Possible
	Duct (grey)	X	X	X	X	
	Packing (brown)	X	X	X	X	
	Packing (transparent)	X	X	X	X	
	Aluminum	X	X	O	X	Impossible
	Foil					Possible
	Clear	X	X	X	X	
	Electrical	O	X	X	X	
	Semi-transparent	O	X	X	X	
Un-Du	Duct (green)	X	X	X	X	Possible but reduced quality
	Duct (grey)	X	X	X	X	
	Packing (brown)	X	X	X	X	
	Packing (transparent)	X	X	X	X	
	Aluminum Foil	X	X	X	X	
	Clear	X	X	X	X	
	Electrical	X	X	X	X	
	Semi-transparent	X	X	X	X	
* O: Observed, X: Not observed						

Table 2: A summary of latent fingermark development results from the adhesive side of A-N tapes.

Methods	Tapes	Brittleness	Tearing	Transfer of paper peel to the adhesive material	Separation of adhesive material from the plastic layer	Fingermark development
Dipping	Duct (green)	X	X	O	X	impossible
	Duct (grey)	X	X	O	X	
	Packing (brown)	X	X	O	O	
	Packing (transparent)	X	X	O	X	
	Aluminum Foil	X	X	O	X	
	Clear	X	X	O	X	
	Electrical	O	X	O	X	
	Semi-transparent	O	X	O	X	
Cryogun	Duct (green)	X	X	O	X	impossible
	Duct (grey)	X	X	O	X	
	Packing (brown)	X	X	O	O	
	Packing (transparent)	X	X	O	X	
	Aluminum Foil	X	X	O	X	
	Clear	X	X	O	X	
	Electrical	O	X	O	X	
	Semi-transparent	O	X	O	X	
Un-Du	Duct (green)	X	X	X	X	Possible but reduced quality
	Duct (grey)	X	X	X	X	
	Packing (brown)	X	X	X	X	
	Packing (transparent)	X	X	X	X	
	Aluminum Foil	X	X	X	X	
	Clear	X	X	X	X	
	Electrical	X	X	X	X	
	Semi-transparent	X	X	X	X	

Table 3: A summary of latent fingermark development results from the A4 paper to sticky side attached adhesive tapes.

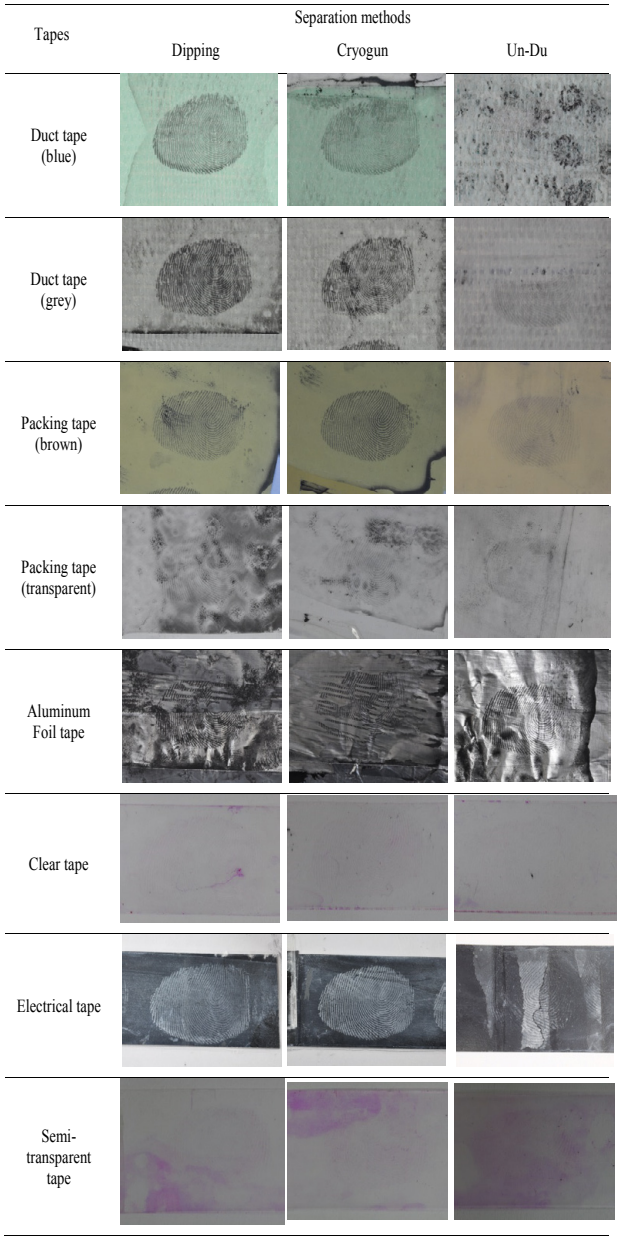

Figure 2: Latent fingermark development results from the adhesive side of tapes.

In A-N tape separation, all tested tapes except aluminum foil tape were successfully separated by cooling methods (liquid nitrogen dipping and cryogun spraying). The quality of the latent fingermark developed from the A-N tape separated by the cooling method was not decreased. Un-Du was also successful in the A-N tapes, but the quality of latent fingermark was decreased because of the solvents [2]. Therefore, it is seen that cooling methods (liquid nitrogen dipping or cryogun spraying) are better than Un-Du method when separating A-N tapes, except the aluminum foil tape.

Bailey pointed out the possibility of brittleness and fracture of the tapes while applying liquid nitrogen dipping method for the A-N tape separation, and Bailey recommended the use of a cryogun spray method instead of a liquid nitrogen dipping method [2]. However, we could not find any difference between the performance of liquid nitrogen dipping and cryogun spraying method. Both the freezing methods had induced the same separation behaviors of A-N tapes.

Both the dipping in liquid nitrogen and cryogun spraying methods are not successful in the separation of A-P tape. However, Un-Du method was successful in the A-P tape separation, but the quality of the developed fingermark was decreased by the action of the solvents [2].

The present study shows that separation features of A-A, A-N and A-P tapes are identical (brittleness and fracture, transferring adhesive material to the facing adhesive side of the tape, separation of tape plastic backing layer from adhesion). We believe that the same separation features are obtained from the two freezing methods because both the methods accompany the physical contact with liquid nitrogen except for the contacting manner.

As mentioned previously, the phenomena observed in this study differ with the phenomena observed in other studies in many aspects [7,14,15]. The liquid nitrogen dipping time necessary for the successful separation of tapes, and the differences in features of the tapes after liquid nitrogen treatment are the examples. The materials used in the making, manufacturing methods, storage conditions, etc., vary for different types of tapes. Hence, the tapes used in the present study do not represent all the tapes. Therefore, it is recommended to perform preliminary experiments with the suggested methods on similar tapes, before processing the real evidence acquired from the crime scene. Therefore, it is recommended to carry out a preliminary examination with the similar tapes to the evidence material before separating evidence tapes using cooling methods such as liquid nitrogen dipping and cryogun spraying.

Conclusion

The separation feature of adhesive-side to adhesive-side adhered tape, adhesive-side to non-adhesive-side adhered tape, adhesive-side to A4 paper adhered tape were studied using duct tape, packing tape, aluminum foil tape, clear tape, electrical tape and semi-transparent tape. No difference between liquid nitrogen dipping and cryogun spraying methods in the tape separation features such as, brittleness and fracture of the tape, transferring adhesive material to the facing adhesive side of the tape, separation of adhesive material from the plastic layer of the tape. On the contrary, Un-Du method was successful in separating adhesive-side to adhesive-side adhered tape, adhesive-side to non-adhesive-side adhered tape, adhesive-side to A4 paper adhered tape. But the decrease of fingermark quality when using Un-Du method was confirmed. The results obtained from the present study does not coincide with the results of previous studies, and it indicates the importance of preliminary examination with the tape similar to the evidence material, before separating the evidence tape using cooling methods such as liquid nitrogen dipping and cryogun spraying.

Acknowledgements

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