

TAMPER TAPE SEALS

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TAMPER TAPE SEALS

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ABSTRACT

Tamper tapes are appealing for many applications due to their ease of use and relative robustness. Applications include seals for temporary area denial, protection of sensitive equipment, chain-of-custody audit trails, and inventory control practices. A next generation of adhesive tamper tapes is being developed that combines the best features of commercially available devices with additional state-of-the-art features in tamper indication, tamper-resistance, and counterfeit-resistance. The additional features are based on U.S. Department of Energy (DOE) research and development (R&D) activities that were originally associated with preparations for the Strategic Arms Reduction Treaty (START). New features include rapid-set, chemical-cure adhesive systems that allow user-friendly application and layered levels of counterfeit-resistance based on unique "fingerprint" characteristics that can be accessed as desired.

INTRODUCTION

A tamper tape is an adhesive-backed label that possesses various tamper-indicating, transfer-resistant, or counterfeit-resistant properties. The greatest appeal of a tamper tape is its ease of use. Readily and reliably applied to substrate surfaces like an adhesive bandage, the tamper tape is practical and desirable for many scenarios. Although tamper tapes are very user-friendly, they do not offer the same level of rigid security as classic START tags and seals, but can still provide significant confidence when used within an appropriate security perspective.

For the past few years, the DOE Office of Research and Development, NN-20 (formerly the

Office of Arms Control and Non-Proliferation), has tasked the Pacific Northwest Laboratory (PNL) to investigate the development of tamper tapes for a number of applications. The objective of this ongoing work is to combine the best features of commercially available tamper tapes with state-of-the-art design, unique identification, and counterfeit-resistant features. Several interim designs have been produced as more advanced features are being developed.

DESIGN DESCRIPTION

The PNL tamper tape is commercially produced by 3M (Safety and Security Systems Division, 3M Center, St. Paul, MN) and uses their patented Confirm[®] tamper-indicating technology. Schematic diagrams (See Figure 1) illustrate the design of the tamper-indicating material and the basic layout of the tamper tape. The complete tamper tape consists of a top layer of Confirm[®] that is bonded to a polyester underlay material.

The Confirm[®] top layer of the tamper tape is made of glass beads that are embedded in a brittle bonding material. If transfer is attempted, the logo pattern reflected from beneath the glass beads is distorted as the beads are disrupted from the bonding layer. The integrity of the logo pattern is easily verified by visual observation when it is illuminated with a light source (e.g., a flashlight) held perpendicular to the tamper tape surface. Alterations to the tamper-indicating material can be detected by examining the integrity of the logo printing. Tamper tapes have been prepared using the generic Confirm[®] logo, a logo that 3M uses for illustration purposes. Confirm[®] tamper tapes with a unique PNL logo that provides enhanced security is currently being manufactured.

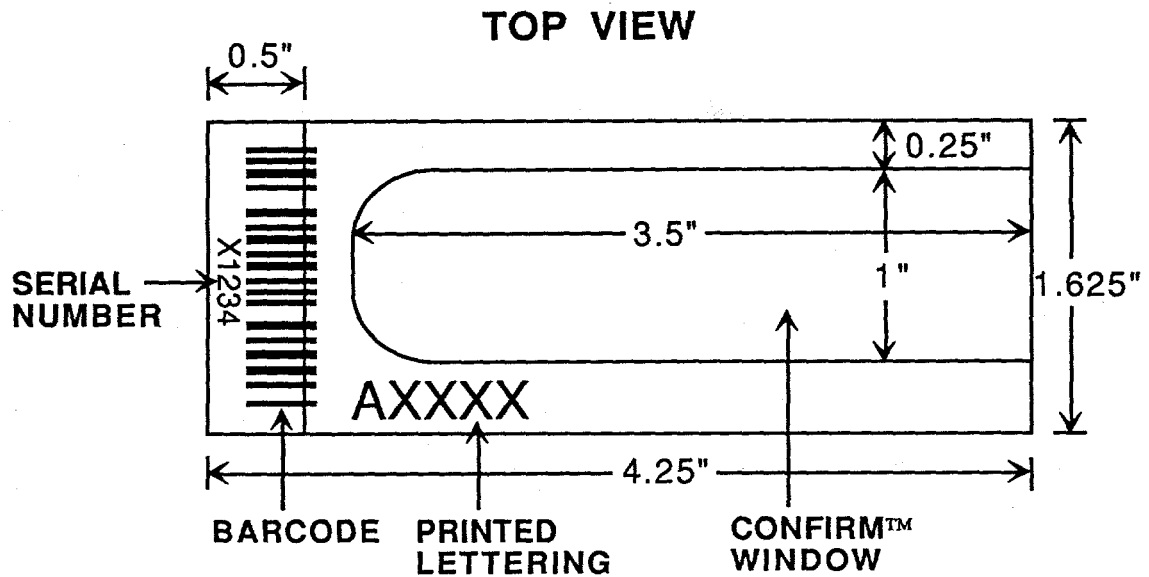


FIGURE 1. Schematic Diagrams of the Current PNL Tamper Tape Design

The polyester underlay material provides support around three sides of the tamper tape to allow the fragile Confirm® to be efficiently applied to a surface. The area where the polyester underlay is not present is known as the Confirm® window. Larger window regions render the tamper tape more transfer-resistant, but also more difficult to apply. The current configuration (1" wide-window with a narrow support frame) was chosen after several iterations of size and shape were evaluated for ease-of-use and acceptable transfer-resistance.

Score lines that will tear during label transfer attempts have been added to the polyester support frame.

ADHESIVE OPTIONS

A pressure-sensitive adhesive (PSA) attaches the tamper tape to a substrate. The PSA provides user-friendly application (removal of a slip sheet) and generally bonds well to a wide variety of

substrates. The current PSA is based on an acrylic formulation that was optimized for adhesion to acrylic paints, base metals, and plastics for time periods of up to ten years. The adhesive that bonds the Confirm® to the polyester is weaker than the adhesive used to bond the tamper tape to its substrate, which further enhances the tamper-indicating performance.

Although tamper tapes fabricated using PSAs are very user-friendly, they do not achieve maximum surface bonding strength to the substrate for several days. The exact bonding time is a function of the physical characteristics of the substrate and the environmental conditions. Thus, PSA tamper tapes may not be suitable for scenarios where immediate security is required.

Another adhesive option that is being investigated is a curable-PSA. This adhesive contains a secondary component that reacts with moisture (always present) on a substrate surface. Maximum bonding strengths are projected to be obtained in hours rather than days. The curable-PSA would also be fabricated on a slip-sheet and have the same user-friendly features as the regular PSA tamper tapes. Because of the chemical reactivity of the adhesive, curable-PSA tamper tapes would have a more limited shelf-life than tamper tapes fabricated with regular PSAs.

A third adhesive option and a major focus of R&D activities is a rapid-set, chemical-cured adhesive system that reaches maximum bonding strength within minutes after application. A four-part epoxy formulation has been developed that is compatible with the tamper tape components and several representative substrates; e.g., steel, aluminum, wood, concrete, polyurethane paint, and epoxy fiberglass. The adhesive system is also resistant to mechanical, thermal, and solvent attack that could be used by an adversary for undetected removal. A major challenge of this adhesive system is to be as user-friendly as the PSA tamper tapes. A tamper tape dispenser system is under development using concepts similar to those used in instant cameras. Commercial fabrication concepts for the tamper tape without using the PSA have also been developed. It is expected that the pocket-sized tamper tape dispenser system will be nearly as user-friendly as PSA tamper tapes. Tamper tapes that provide maximum bonding strength in less than 30 minutes will be suitable for

a wide range of applications. A user will have the option of selecting the adhesive system that matches the application requirements.

COUNTERFEIT RESISTANCE OPTIONS

The current PNL tamper tape design includes three counterfeit-resistant features that provide increasingly greater levels of confidence. The first level is the printed serial number and its accompanying barcode, which renders the tamper tape unique, although it provides little protection against duplication. The barcode is printed on both the polyester underlay and the Confirm® to ensure that it can be confidently read. The retro-reflective Confirm® makes it very difficult to read barcodes that are printed on its surface or underneath its surface. Lightweight, hand-held, stand-off barcode readers can be used conveniently in the field.

The second level of counterfeit-resistance is provided by the microvideographic analysis of the printed barcodes. Variations in printing on the textured upper surface of the glass bead layer and its intersection with the polyester underlay material, examined at six-times magnification, provide unique surface features that can be recorded and compared for later authentication. Using microvideographic images, an example of the differences in edge structure for two individual printings of the same barcode is shown in Figure 2. A repackaged field-portable microvideography system that weighs approximately 12 lb is currently being completed.

The third counterfeit-resistance feature requires custom Confirm® glass bead material to be fabricated. Experiments using "hand-made" Confirm® demonstrate that an intrinsic reflective signature can be generated by replacing 5 to 20% of the regular glass beads with opaque glass beads. The opaque beads do not interfere with the normal manufacturing process, but introduce optical imperfections in the glass bead network. These imperfections can be examined using microvideography and/or with any of the numerical correlation reader systems that were designed for use on reflective particle tags (RPT) or RPT variations; e.g., the Universal Reader. Microphotography examples of the intrinsic reflective signatures generated with opaque glass beads are shown in Figure 3.

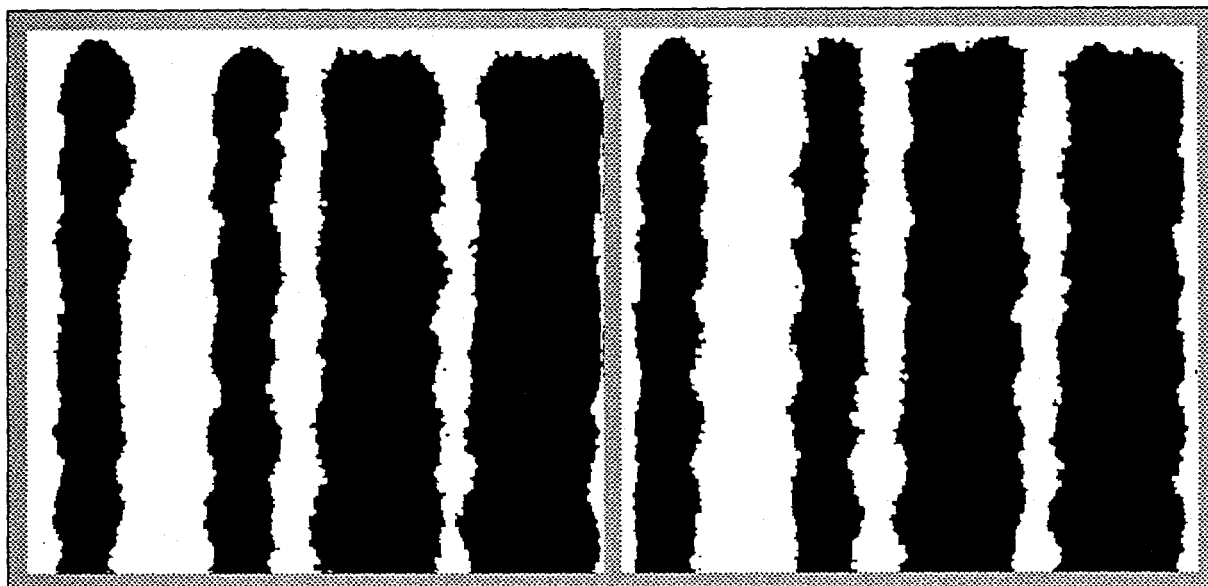


FIGURE 2. Microvideograph of Two Printings of the Same Barcode on Confirm® Tamper Resistant Labels

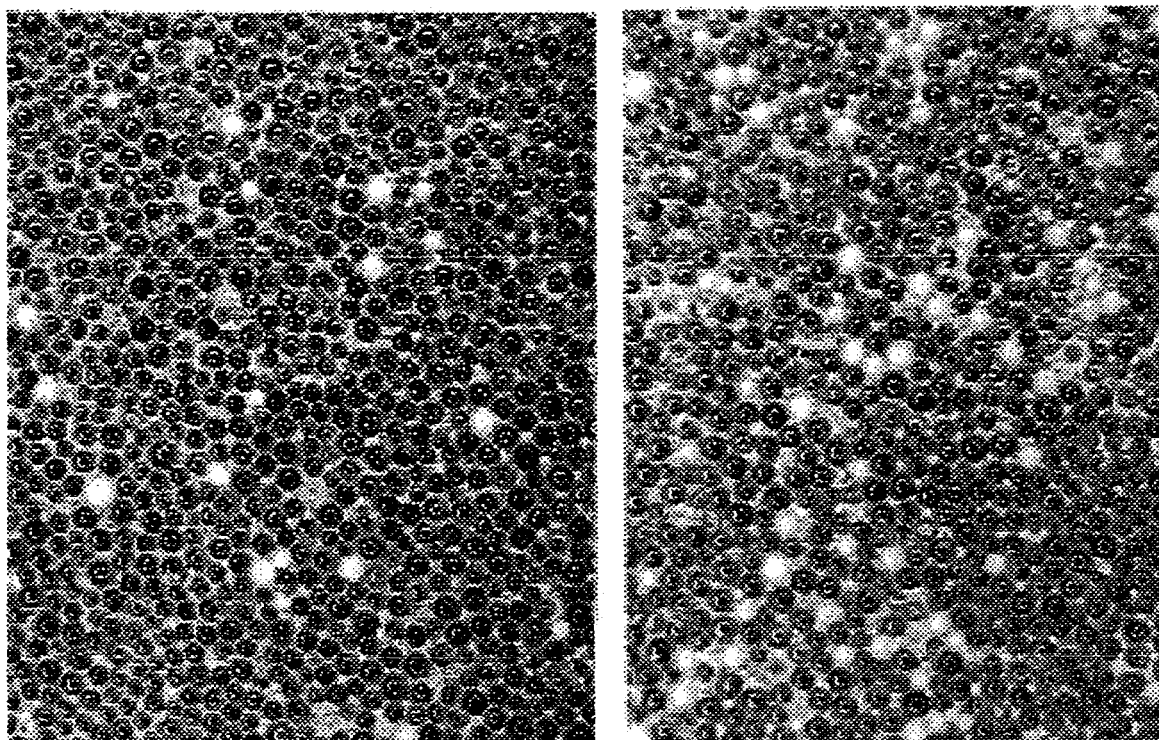


FIGURE 3. Microphotographs of Opaque-Bead-Altered Structure Producing an Unique Intrinsic Reflective Signature. Left: 5% opaque beads. Right: 20% opaque beads.

Many of the unique counterfeit-resistance features for each tamper tape can be recorded prior to use allowing future authentication options to remain open. Typical numerical correlation data showing "like" and "unlike" comparisons for the 5 and 20% opaque bead Confirm® are presented in the histograms of Figure 4. Based on RPT experience, acceptable "like" comparisons correlate with a median value of approximately 0.63 or greater. Acceptable "unlike" comparisons correlate with factors less than approximately 0.2. The correlation data of Figure 4 show that the opaque beads give the tamper tapes unique and identifiable patterns. Authentication could be made in the field or the appropriate parts of the tamper tape could be removed and sent home for authentication. Insufficient data presently exist to confidently predict if the intrinsic reflective signature will remain stable during application and possible removal of the tamper tape.

ENVIRONMENTAL STABILITY

The PNL tamper tapes with the commercial PSA option have been subjected to limited aging

and accelerated aging/weatherability tests. Tamper tapes were applied to a number of substrates including aluminum, Kevlar®, steel, stainless steel, brass, copper, fiberglass/resin/gel coat, fiberglass/resin, ABS plastic, and painted aluminum. Accelerated aging included exposure of the tamper tape panels to four-hour cycles of simulated sunlight at 60°C followed by condensing humidity/moisture at 40°C. The test panels were also exposed to temperatures ranging between -65°F and 115°F.

The accelerated weathering studies indicated that seven weeks of hot and cold cycling did not have any visual effects on the tamper tapes. However, after such treatment, attempts to transfer the tamper tapes were less successful. After seven weeks of intense exposure to UV light and condensing humidity, slight yellowing of the tape surfaces occurred and small cracks began to develop in the window area on a few tamper tapes. Attempts to transfer these exposed tamper tapes were much easier to discern than freshly applied tamper tapes. On very rough surfaces some failure of the adhesive was observed.

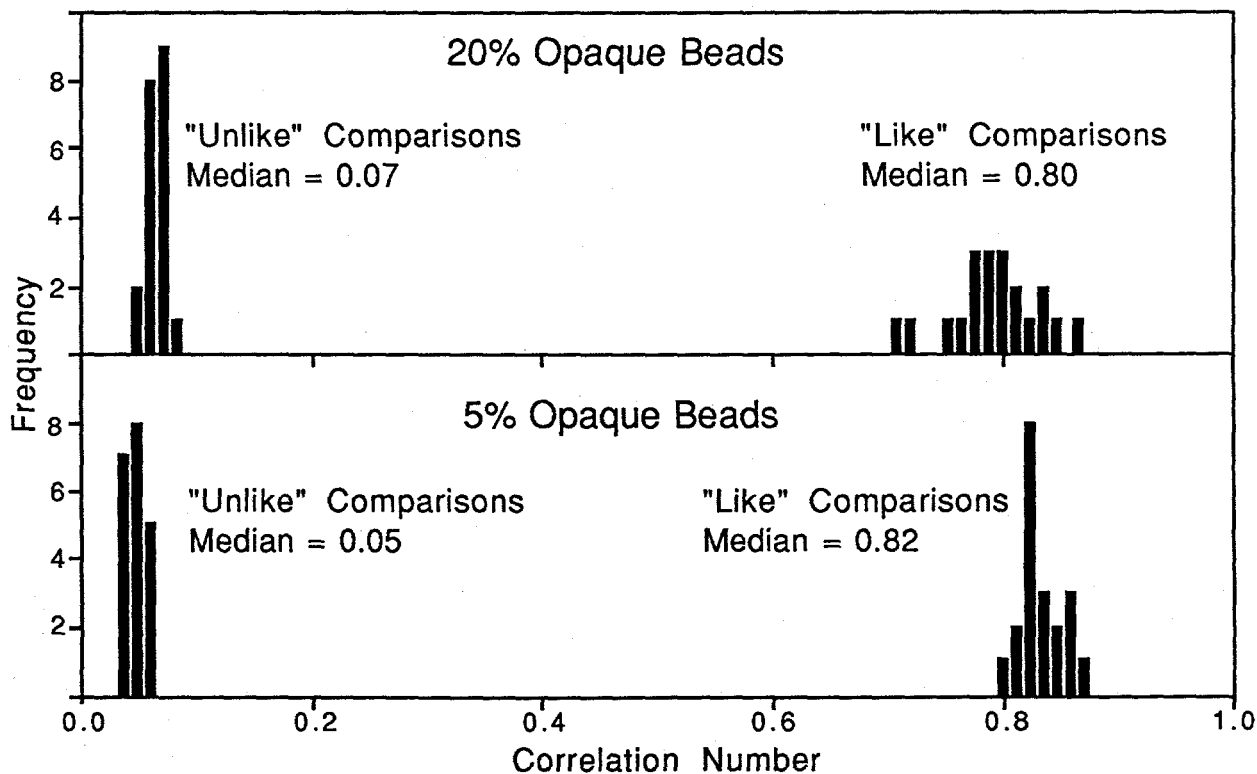


FIGURE 4. Histograms of "Like" and "Unlike" Correlations of Opaque-Bead-Altered Tamper Tapes.

A few tamper tapes were exposed to sunlight and ocean air/moisture at Daytona, FL. After seven weeks of a vertical south exposure, one tamper tape developed cracks in one corner. Tamper tapes were still intact after 20 weeks of exposure. Tamper tapes have also been applied to the bumpers and hubcaps of PNL staff members' automobiles. Although no rigorous documentation procedures were followed, these tamper tapes were still in place for at least 12 months following their application.

Mild exposure to organic solvents had minimal impact on the tamper tapes and their adhesives. Exposure to strong acids and bases destroyed the tamper tapes, as expected. The surface could withstand mild abrasion, but the printing was

adversely affected if the surface layers were removed.

Additional environmental stability studies are on-going to further characterize the behavior of both PSA and rapid-set adhesive tamper tapes. PSA tamper tapes are also scheduled for performance and operational evaluation in DOE Safeguard applications.

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