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A Summary of Taggant Materials in Forensic Science

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Abstract

The use of taggant technology to mark things so they can be identified is becoming an important part of national strategies to reduce crime. By associating an object with a specific piece of information, taggants may be able to prevent or monitor crimes. A specific "coding" element will typically be included to infer marker uniqueness, despite the fact that the material properties of a taggant will largely vary depending on the application. Continuing advancements in portable in-field analysis, nanotechnology, and material science ought to have made it possible to develop new and improved forensic marking agents because the speed, simplicity, and accuracy of coding component analysis largely determine the overall efficacy of taggants. Nevertheless, the scant amount of recent research in this field suggests otherwise. Before attempting to provide insight into the direction that forensic marking technology will take in the future, this critical review therefore examines the state of the taggants that are currently available.

Keywords: Taggant • Forensic • Identification • Security • Fluorescence • DNA • Peptide • Mass spectrometry

Introduction

The social and economic effects of organized crime in the UK are significant, amounting to about £24 billion annually. The biggest criminal offenses, according to reports, are those that involve drug trafficking (£10.7 billion), organized fraud (£8.9 billion), and acquisitive crime (£1.8 billion). The forensic science community places a high priority on the development of strategies that are capable of either preventing these crimes or assisting in their investigation, as these estimates are only based on data from crimes that have already been committed. As a result, it is likely that actual costs will be even higher [1].

Forensic taggants may be regarded as one of the products that have been commercially available to reduce criminal activity the most effectively. Since 2008, the UK court system has widely accepted the use of taggant materials as evidence, and certain marking agents have contributed to the conviction of over 1,000 criminals since then. In areas where forensic taggants (such as SmartWater®) were utilized, household burglaries in London decreased by nearly 30%, according to statistics that were made public by the Metropolitan Police Service. Taggants are a category of materials that can be applied to or incorporated into an object to make it easier to identify it. This is accomplished by making each "batch" of taggant in a way that is completely unique to it. This makes it possible to register the particular molecular composition against a particular piece of information. This composition can be examined to discover the identity of the taggant and, consequently, the object it is marking once it is recovered at a later date [2].

Literature Review

A forensic taggant with all the right characteristics should be inexpensive to produce, have a high coding capacity, not be harmful to people or the environment, be easy to detect and analyze using non-destructive methods, and be complex enough to prevent duplicates. The majority of taggant manufacturers assert that their products can be utilized in a wide variety of settings [3].

Property marking: Taggants can be applied to valuable items like electronics and automobiles to identify their owners. It may be returned to the original purchaser if that property is stolen but later recovered. Property taggants are usually hard to see with the naked eye because they don't want to ruin the item's appearance or get caught by thieves.

Counterfeiting – Industries at risk of counterfeiting (such as clothing, currency, and pharmaceuticals) may decide to include taggants in their products to differentiate them from counterfeits. This application's marking agents are typically invisible and have replaced more easily replicated traditional anti-counterfeit technologies like barcoding and holograms.

Tracking – Law enforcement agencies may tag materials used in the production of dangerous or potentially illegal goods to aid in detection or trace their initial origin. These marking agents are mostly used in the production of industrial explosives that can be used illegally. It is possible to find robust taggants that can withstand detonation and reveal information about the type of explosive, the supplier, or the batch ID. Taggants can also be secretly added to large quantities of illegal narcotics, making it possible to monitor their distribution.

Monitoring: Taggants can be applied to valuable objects, commercial buildings, or their exterior surfaces. These taggants may be transferred to an individual as a result of criminal activity (such as trespassing or out-of-hours burglary). This provides strong physical evidence to associate the taggants with that crime. If the taggant goes through a secondary object-to-person-to-object transfer, additional information about the suspect's subsequent actions can also be gleaned [4].

A taggant's physical characteristics will largely depend on which of these four functions it serves. For instance, markers that are used to mark money taken in a CViT (Cashand-valuables-in-transit) robbery should be hard to remove after they are applied. In contrast, a forensic coating applied to firearms and cartridge casings to verify handling ought to be transferable to the fullest extent possible. As a result, the variety of taggant formulations is extensive. During manufacturing processes, markers can be dispersed within a medium like grease, paint, or ink, sprayed with an aerosol, applied directly as a powder, or embedded into materials [5].

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Taggants that are made to be applied covertly (to keep them from being destroyed or found by criminals) may also have a second component that lets them be found later. These taggants, which are not visible to the naked eye, must be located in order to be successfully recovered for analysis. Adding fluorescent compounds to the taggant is the most common method for achieving this, and these compounds will then produce light when excited at particular wavelengths of the visible or ultraviolet spectrum. Radioactive isotopes or volatile chemicals for vapour identification are two additional methods of detection. Even though these components of detection might not always be necessary for a taggant, every forensic marker will have a primary "coding" component in order to infer the necessary statistical uniqueness. A taggant can effectively "store" information about the object it is marking by developing a formulation that cannot be duplicated [6].

Discussion

Current technology

Known for being one of the first forensic marking materials ever created; coding systems for physical taggants are based on the straightforward morphological characteristics of their components. Typically, solid particles of a particular size, appearance, or structural arrangement are used to make these taggants unique. Since basic visual techniques like low-power microscopy are typically used to conduct analysis, these encoding mechanisms may also be referred to as "graphical".

The microdot, a tiny polymer disc containing minute photographic information between 2 and 1000 micrometers in size, is one common coding element utilized in physical taggants. Text or images etched onto microdots are typically too small to see with the naked eye, but with optical magnification, they can be seen. Companies like DataDot and Microtrace have incorporated microdot technology into a variety of ink and varnish-based suspensions despite the fact that it was initially developed as a covert method of transferring data during World War II. After that, the dots that make up these suspensions are able to function as straightforward tagging mechanisms because they are imprinted with a specific numerical code. This code is then registered against a specific owner in an electronic database. The order in which these components are layered together is unique to each taggant formulation produced. The marker's identity and the batch it came from are then revealed by a visual inspection of the layers. These particles have become the most common tagging agent for the identification of post-detonation explosive materials because of their robust nature in layer construction [7].

Future perspectives

In terms of coding capacity, covert usage, overall stability, or method of analysis, each of the commercially available taggant mechanisms in this review exhibits a distinct set of strengths and weaknesses. A single taggant type cannot currently be used as a universal product identification system due to these drawbacks, necessitating the use of distinct marking techniques for various purposes. However, it is important to note that major practical advancements in nanotechnology, material science, and analytical instrument portability have taken place since the establishment of the scientific technologies that underpin these coding mechanisms. Numerous research groups are currently utilizing these advancements to develop forensic tagging reagents capable of identifying any object, regardless of circumstance [8].

Nanomaterial-based encoding strategies have been the focus of a lot of research on the design of globally applicable marking systems. Due to their small size (which prevents detection and the physical alteration of marker properties), variety of potential analysis methods, and ease of formulation within traditional marking reagent media, nanoscale particles, wires, and tubes all show great potential as next-generation tagging mechanisms. Currently, spectroscopic taggants with optical properties superior to those of organic dyes or lanthanide ion complexes are being made using semi-conductive quantum dot nanoparticles. Quantum dots may present an excellent opportunity to enhance the multicomponent spectral encoding mechanisms currently utilized by spectroscopic taggants because of their narrow emission wavelengths, color-tuneable signals, and environmental-independent fluorescence properties. The relative cytotoxicity of metal ions used in the synthesis of quantum dot particles may have hindered the commercialization of this technology. Through the creation of heavy metal-free quantum dots, efforts are currently being made to lessen these potential harms to human health and the environment [9].

However, due to the fact that many counterfeiters are now familiar with optical anti-counterfeit methods and are able to identify markers with obvious visible emissions, there has been debate regarding whether fluorescent molecules should be included in tagging materials at all. A number of taggants that can only be analyzed with Raman spectroscopy have recently been produced in an effort to address this issue. These reagents, like other types of spectroscopic coding mechanisms, are made up of compounds that are mixed in a particular way to make a unique spectral fingerprint (which is made in this case by the inelastic scattering of monochromatic laser light). The fact that Raman spectroscopy can also be used for identification and the initial detection of tagging materials is the method's primary advantage. This eliminates the need for additional tracing components that could lead to an unwanted discovery. Through the phenomenon of surface enhanced Raman scattering (SERS), the direct conjugation of Raman-active compounds to a number of metallic nanoparticles may also significantly increase the sensitivity of such detection [10].

Conclusion

Forensic taggants continue to play a crucial role in reducing criminal activity by authenticating objects, preventing theft, and monitoring illegal activity. This review has attempted to document the most prominent commercially available coding mechanisms used to infer identity in a wide range of products and highlight the significant capabilities of tagging materials. Even though it is abundantly clear that none of the commercial marking methods that are currently available have all of the characteristics required of a universally applicable forensic taggant, the most recent research that is the subject of this article demonstrates that coordinated efforts are being made to improve taggants.

The technical development and validation of forensic marking materials is fairly challenging due to the numerous surfaces, environments, and time periods to which they can be applied. Steps toward the creation of a single, adaptable platform for object identification can only be made through ongoing advancements in instrumentation, nanotechnology, and material science. In order to make universal marking systems a reality, it is hoped that this review will inspire analytical chemistry researchers to become interested in taggant technology and participate in its development.

Acknowledgement

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Conflict of Interest

None.

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