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Advances in the Applications of Organic Materials for Fingerprint Detection

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ABSTRACT

One of the most significant parts of physical evidence at a crime scene is a fingerprint, which can be used to directly identify a person. The fingerprint has long been regarded as the "head of physical evidence" and is crucial to forensic science and criminal investigations. Usually, three types of fingerprints are identified at crime scenes: plastic fingerprints, visible fingerprints/patent, and invisible fingerprints/latent. Invisible or latent fingerprints necessitate special examination because they cannot be observed with the naked eye. Latent fingerprints can be discovered on a variety of surfaces, whether they are porous (like wood, clothing, or paper) or not (plastic, metal, or glass). Some persons were unaware of latent fingerprints until forensic investigators enhanced them using physical or chemical techniques. Additionally, the latent fingerprint contained water, amino acids, oils, and other materials found in the human body. Chemical aspects of Ninhydrin, cyanoacrylate, Fluorescent Organic materials (curcumin, benzazole dyes, rhodamine B, rhodamine 6 G, fluorescein and brilliant Blue G-250) exhibit a high affinity or strong attraction to amino acids, fatty acids, and proteins in a fingerprint, with the vapors of the super glue adhering to these components. Therefore, it can capture fingerprints clearly, making it possible to verify

Introduction

Fingerprints stand out as among the most noteworthy biometric features for individual identification in the realm of forensic studies, showcasing exclusivity and stability throughout a person's lifetime. Representing an image of raised ridges and recessed furrows created by the touch of a finger, fingerprints have been a distinctive forensic tool for over a century. These patterns, whether found on porous surfaces like paper or clothing or non-porous materials such as metal or glass, contribute to their significance in forensic investigations [2, Figure 1].

It wasn't until Ode'n and von Hofsten recommended using ninhydrin in criminal investigations in 1954 that the utility of the compound for the development of latent fingerprints was understood.

a) Latent print b) Patent print c) Plastic print
Figure 1: Types of fingerprints

It is the reagent that used to discover hidden fingerprints on porous surfaces similar cardboard and paper. In Figure 2,The interaction between ninhydrin and aminoacid which is one of eccrine components produces Ruhemann's purple, a dark purple complex to improve fingerprint. Several ninhydrin derivativess have been created and applied as possible substitutes for the traditional ninhydrin reagent for the improvement of latent fingermarks on surfaces, including Diazafluorenone (DFO) and Indanedione [3]. Fuming cyanoacrylate Colorless, monomeric liquids known as

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cyanoacrylate esters are sold commercially as strong, quick-drying glues like Superglue. When combined with moisture, specific eccrine and sebaceous components, and cyanoacrylate liquid, a vapor is created that interacts to create a latent fingerprint. Metal, glass, and plastic are just a few of the nonporous surfaces that the process works well on. The technology was first are great sensitivity, contrast, selectivity, and independency on equipment. Taking into account the security of users and the environment. After cyanoacrylate fuming method are applied, fluorescent reagents (such as curcumin, safranin O, Ponceau 4R red, diphenylpyrimidinone-salicylideneamine DPPS-1, imidazole derivative (IMD FTs) are employed to enhance the developing effect by staining the fumed fingerprints. The majority of fluorescent powders are small fragments, and they are frequently employed on a variety of surfaces when exposed to light because they provide a stark contrast to the background of the surface. Fluorescent organic minuscule components necessitate amalgamation with alternative matrices to heighten their biocompatibility, diminish toxicity, and augment hydrophilicity. This methodology enhances fluorescent imaging for latent fingerprints (LFPs), rendering the procedure more convenient and efficacious [5].

1. Ninhydrin and Ninhydrin derivatives

Ninhydrin, a chemical reagent, is commonly used to detect latent fingerprints in porous materials like paper and cardboard. The reaction of this compound with the amino (eccrine) component of the fingerprint deposit produces Ruhemann's purple, a deep purple substance, as shown in Figure 2. To achieve optimal results, it is crucial to manage development parameters, including temperature, acidity (pH), and humidity, due to the highly intricate chemical processes involved. For a brief period, paper products are submerged in a solution of ninhydrin dissolved in a small amount of polar solvent and acetic acid. Afterward, they are dissolved in a nonpolar carrier solvent like hydrofluoroether HFE-7100 or HFC-4310. Applying the solution involves using a brush or spray. After application, the drying process takes place, and the developed marks, appearing as dark purple hues, are typically captured in photographs taken under white light. This occurs over 24 to 48 hours at room temperature, with 50 to 80 percent relative humidity being essential for optimal results. Ninhydrin has been used to detect fingerprints more than 40 years old, despite the technique's generally high sensitivity [4]. Nevertheless, faint prints or prints on dark or colorful surfaces should have low difference. Mixing with a metal salt can change the fingermarks' dark purple coloring after ninhydrin development. For instance, when treated by a zinc(II) salt, the result is orange, and when treated with a cadmium(II) salt, the result is red. The color alternations result from the metal ion and Ruhemann's purple, a byproduct of the ninhydrin process, forming a complex (Figure 2). The luminescence properties of the zinc and cadmium complexes are excellent and could be used to improve fingermarks created by ninhydrin. For instance, by treating a weak ninhydrin-developed mark by a zinc salt mixture to create a colored fluorescent complex, then visualizing the result under favorable fluorescence emission conditions in this circumstance, excitation at two different wavelength which are 490 nm and 550 nm, through cooling of sample to 77 K utilizing liquid nitrogen to rise the emission intensity), a weak ninhydrin-developed mark may be improved [7]. As replacements to the traditional ninhydrin reagent for the production of latent fingermarks on porous surfaces, several of ninhydrin derivatives have been created and assessed.

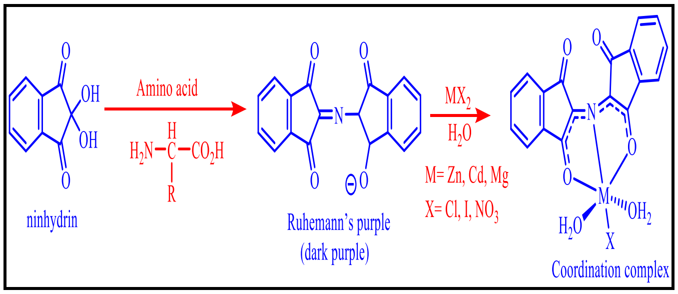

Figure 2: the interaction of ninhydrin with an amino acid, which results in the creation of Ruhemann's purple, a deep purple chemical.

Figure 3 displays a variety of ninhydrin derivatives exhibit improved sensitivity for fingerprint detection. Compared to ninhydrin alone, more potent fingerprint luminescence achieved. Regrettably, their usage for ordinary tasks constrained by their high price and scarcity [8].

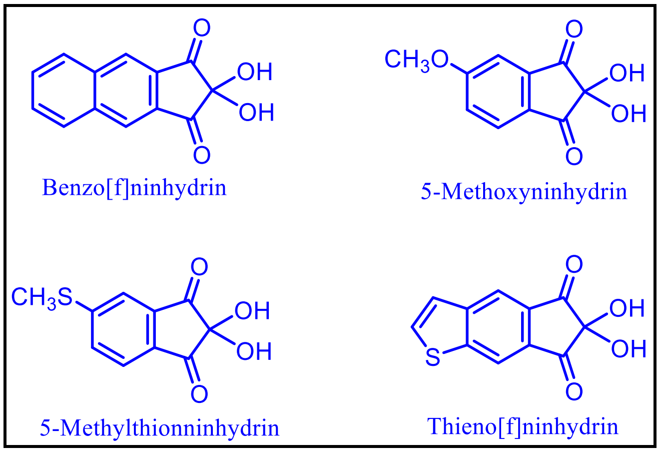

Figure 3: Many ninhydrin compounds have been effectively used to find hidden fingerprints on paper surfaces.

2. Diazafluorenone

Treatment of DFO 1,8-diazafluoren-9-one with amino acid (Figure 4) may result in the detection of latent fingerprint, (In contrast to ninhydrin, heat is required to speed up the reaction. Which was accomplished by rising the temperature up to 100 °C for 20 minutes or (180 °C for 10 s). The colour of developed marks is a light pinkish-purple, and they glow brightly at room temperature (excitation: 470–550 nm, emission: 570–620 nm). Similar chemical processes have been suggested for ninhydrin its derivatives. DFO irecognized as the chemical agent that is most sensitive commercially available for detecting latent fingermarks on the top of the paper [9].

3. Indanedione

This substance resembles ninhydrin chemically and is thought to interact with amino acids in a similar way. Yet, generated marks are luminous at ambient conditions without any additional process, unlike ninhydrin. According to the findings of research done in several nations, indanedione has a sensitivity that is comparable to DFO on a variety of paper substrates. A variety of reagent compositions have been suggested, and indanedione is being marketed [10].

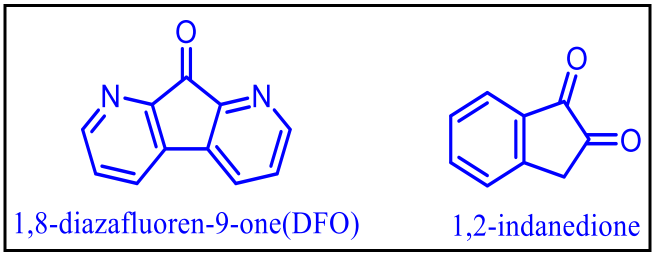

Figure 4: A luminous produced by the reaction of the chemicals DFO and indanedione with amino acids.

4. Cyanoacrylate Fuming

Cyanoacrylate esters, also recognized as monomeric liquids with no color, are commonly available in the market as potent and fast-curing adhesives, such as Superglues, often in methyl or ethyl ester forms. These esters rapidly undergo polymerization at room temperature, employing an anionic process facilitated by mild bases like alcohol and water (as illustrated in Figure 5). The end result, polycyanoacrylate, manifests as a rigid and white solid. Through a selective polymerization process on the ridges of latent fingerprints, cyanoacrylate vapor forms by evaporating the adhesive under ambient conditions or through heating (ranging from 80 to 120 °C), ultimately generating a solid and white representation of the fingermark.

Alcohols and moisture present in the latent deposit act as catalysts, accelerating the polymerization process. Excellent fingerprint detail can be generated on generally treated objects, even with relatively ancient latent impressions (up to several years of age). Typically, the objects are placed in an enclosed chamber with a small amount of cyanoacrylate ester that is then heated to promote evaporation (as depicted in Figure 6). After sufficient fingerprint detail is seen, the objects are taken away. vacuum cyanoacrylate systems have recently been created, and they promise to provide higher fingerprint detail in less time.

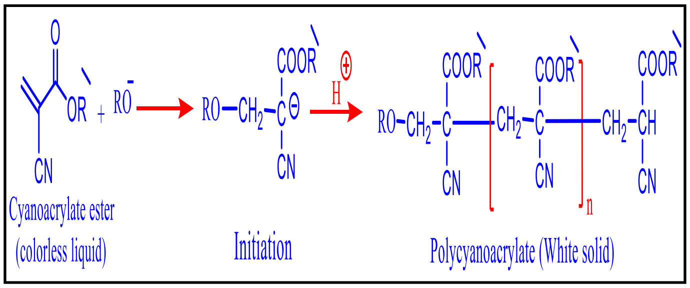

Figure 5: Synthesis of hard white solid of polycyanoacrylate.

Figure 6: The fuming chamber for cyanoacrylates that is sold commercially.

Using diffuse reflection (episcopic coaxial illumination, it is possible to effectively record cyanoacrylate produced marks on smooth, flat surfaces like credit cards. In general, the use of a colorful or luminous stain can greatly enhance the difference in cyanoacrylate-developed marks.

The surface under examination's color and luminescence characteristics will determine which staining method is best. Staining techniques that are frequently used include those using gentian violet, rhodamine 6G, Ardroxs, Basic Yellow 40, and safranine. Nacuum metal deposition (NMD) may also be used after cyanoacrylate fuming if background printing or background luminescence conflict with standard improvement techniques as polymer banknotes , credit cards, etc.) [11], [12].

5. Fluorescent Organic Materials

Organic fluorescent materials typically consist of aromatic organic molecules with π conjugated systems that exhibit desirable optical properties. Organic fluorescent materials offer a wide range of applications, including light-emitting diodes, disease diagnosis and treatment and biological detection, according to their diverse structural composition. The excellent benefits of organic fluorescent materials in the aforementioned sectors have marked the beginning of a new direction of latent fingerprint display research.To obtain effective and sensitive latent fingerprint visualization, many researchers are devoted to creating new organic fluorescent materials and combining them with established techniques (such as powder brush display, solution immersion method, glue post-fumigation staining method, etc.). Based on the chemical composition of fluorescent organic materials, including both fluorescent organic molecules and fluorescent polymers, the subsequent sections have been categorized into two groups, as outlined in references [13] and [14].

5.1. Materials Dependent on Fluorescent Organic Molecules for LFP Imaging

As a result of their low affinity for fingerprint residues and other chemical and physical properties , fluorescent organic molecules like rhodamine 6G, fluorescein, dazzling Blue G-250, and rhodamine B could only be employed in a few specific circumstances. As LFP imaging reagents, modified organic small molecules with diverse matrices, low-toxic nanomaterials, and different functional groups have been designed to increase the reaction between organic molecules and LFPs. As a carrier, bio affinity enhancer, and fluorescence developer, the matrix utilized for fluorescent organic small molecules in LFP imaging was employed. A precedent for the use of fluorescent dyes in the display of latent fingerprints was established with the proposal of fluorescent dye coumarin-6 as shown in Figure 7(A) argon ion laser for latent fingerprint visibility. Consequently, it has been reported that conventional fluorescent dyes like rhodamine B (B) and rhodamine 6G (C) are used in the study of latent fingerprint appearance. When used for latent fingerprint visualization, these fluorescent dyes typically have better resolution and a higher signal-to-noise ratio. These conventional fluorescent dyes, however, still have flaws when it comes to revealing latent fingerprints, such as weak or nonexistent fluorescence in the aggregated or solid form, or what is known as aggregation-caused quenching (ACQ). As a result, numerous new organic light-emitting materials, including polymeric semiconductor nano (Pdots) materials and aggregation-induced emission (AIE) materials reated by researchers that exhibit good performance for the development of latent fingerprints[15].

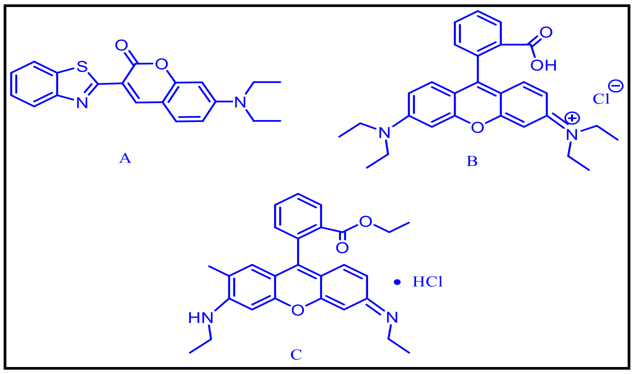

Figure 7: fluorescent dyes (A) Coumarin derivative, (B) Rhodamine B, (C) Rhodamine 6G.

5.2. Fluorescent Molecules With AIE properties for LFP Imaging

Tang Benzhong's study team's findings are based on the unique property of 1-methyl-1, 2, 3, 4, 5-pentaphenylthirole as shown in Figure 8, which glow faintly in benign solvents and strongly when aggregated. The idea of AIE was put up in 2001, which caught the interest of many academics. In recent years, researchers have consistently investigated the uses of AIE molecules in a variety of domains, including forensic science, chemical sensing, and illness therapy [16], [17].

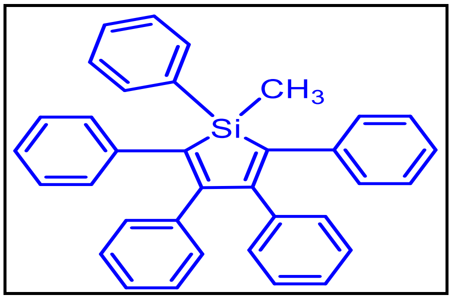

Figure 8: Fluorescent Molecule 1-methyl-1, 2, 3, 4, 5-pentaphenylthirole.

Using the condensation reaction between triphenylamine and pyridine salt to build a "push-pull" electronic structure, a noel AIE molecule for latent fingerprint viewing was created. The probe triphenylamine derivative’s hydrophobic end is the triphenylamine group, which is a great electron-donor group. The hydrophilic portion of a synthetic derivative, the pyridylcationic group, has strong electron-absorbing characteristics. Triphenylamine derivative dye has good water solubility (can be dissolved in water without any organic co-solvent) because of the presence of pyridyl cationic groups. As a result, it has no fluorescence in pure water, but when undesirable solvents are added to its aqueous solution, it aggregates and produces strong red fluorescence. The latent fingerprint on a range of items (including rough surfaces, such as walls, bricks, and paper) can be immersed or sprayed after the pure aqueous solution of the dye acts on the object under 405 nm laser stimulation as shown in figure 9 [18].

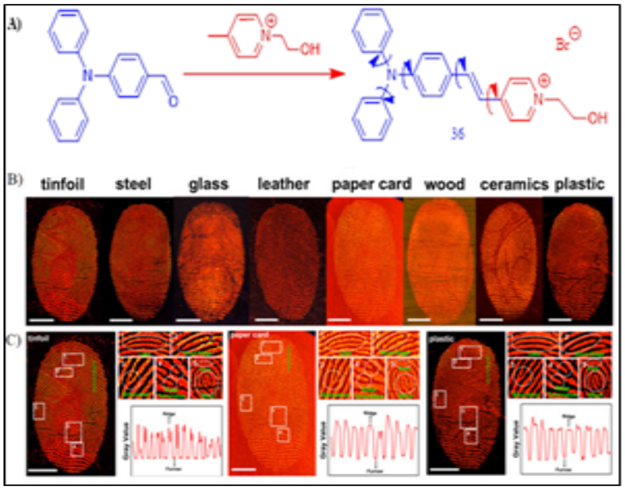

Figure 9: (A) Diagram showing synthesis of a derivative of the color triphenylamine, (B) Fluorescence imaging of latent fingerprints from various items in a pure aqueous solution of the dye triphenylamine derivative , and (C) Details of local LFPs at levels 1, 2, and 3 created by an aqueous synthetic dye solution on foil, paper, cards, and plastic (the variations of the fluorescence intensity between the fingerprint ridges and furrows across the green line).

5.3. Materials Dependent

As a transporter, bio affinity enhancer, and fluorescence developer, the matrix utilized by fluorescent organic small molecules for LFP imaging is divided into two groups [13], [14]. Employing diverse methods, such as organic polymers, including conjugated oligomers, polymer dots, and various polymeric matrices, represents a novel category of materials for fluorescence imaging. Recently, it has been established that conducting polymer dots are an innovative type of ultraviolet fluorescent probes, offering wide applicability in analytical detection. The capacity to detect LFPs on both porous and non-porous surfaces using colorimetry and fluorescent dual-readout, demonstrated by ninhydrin embedded in the near-infrared fluorescent polymer dot matrix, has successfully generated fingerprints revealing level 1-3 details with significant contrast, excellent selectivity, and minimal background interference [19]. Wu Changfeng et al. (2015) Three semiconductor polymers (Figure 10: 1, 2, 3) with oxetane created, and all three exhibited high Uv absorption before emitting blue, green, and red light, respectively. Nano-reprecipitation has effectively produced photo-crosslinked semiconductor polymer dots (ox-Pdots) with high fluorescence intensity, a substantial Stokes shift, and favorable surface characteristics. A three-dimensional spatial network structure created by the cross-linking reaction between ox-PDTS and amino acids and other substances in the residue on the fingerprint line under brief ultraviolet irradiation, which fixes the fingerprint on the surface of the object in situ and exhibits greater stability and better resistance to outside interference [20].

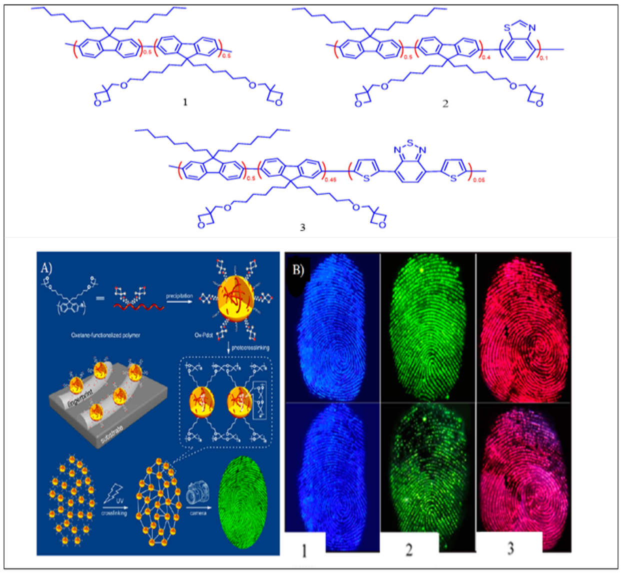

Figure 10: (A) Latent fingerprint visualization using photocrosslinked ox-Pdots, schematic diagram. (B) Latent fingerprint fluorescence picture seen through photocrosslinked ox-Pdots (bottom row is the latent fingerprint fluorescence image after tetrahydrofuran treatment).

3. Conclusion

In order to adequately address the demands of practical work, this study first covers the conventional organic materials that are frequently utilized in latent fingerprint display in actual argument. Cyanoacrylate Fuming is a straightforward procedure, although the white color of the resulting polymer frequently displays insufficient contrast with light-colored or transparent surfaces. However, their individual flaws cannot be ignored, which motivates research and development staff to devote their time to creating new latent fingerprint display materials or new technologies. Researchers have created a variety of novel organic fluorescent materials, such as conjugated polymer materials, aggregation-induced luminescent materials, and other organic fluorescent materials, etc., for the study of latent fingerprints in order to overcome these flaws. These materials frequently have excellent optical properties, good stability, low toxicity, and other traits. The use of newly developed organic fluorescent materials in latent fingerprinting over the last ten years is thoroughly reviewed in this research. The polymerization of the cyanoacrylate during the fuming process may be affected by the colorant/fluorescent dye present. Therefore, it is crucial to be aware that these novel organic fluorescent materials demonstrate the benefits of high contrast, high selectivity, high sensitivity, and somewhat non-destructive display of latent fingerprints, according to the reviewed literature.

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التقدم في تطبيقات المواد العضوية للكشف عن بصمات الاصابع

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الملخص:

أحد أهم أجزاء الأدلة المادية في مسرح الجريمة هو بصمة الإصبع، والتي يمكن استخدامها لتحديد هوية الشخص مباشرة. لطالما اعتبرت بصمة الإصبع «اهم الأدلة المادية» وهي ضرورية لعلوم الطب الشرعي والتحقيقات الجنائية. اكتشفت ثلاثة أنواع من بصمات الأصابع في مسرح الجريمة: بصمات بلاستيكية، وبصمات مرئية، وبصمات غير مرئية/كامنة. تتطلب البصمات غير المرئية أو الكامنة فحصًا خاصًا لأنه لا يمكن رؤيتها بالعين المجردة. يمكن اكتشاف بصمات الأصابع الكامنة على مجموعة متنوعة من الأسطح، سواء كانت مسامية مثل الورق والملابس والخشب او غير مسامية مثل المعدن والزجاج والبلاستك. لا يتم اكتشاف بصمات الأصابع الكامنة مالم يتم تعزيزها بالطرق الفيزيائية أو الكيميائية. بالإضافة إلى ذلك، احتوت البصمة الكامنة على الماء والأحماض الأمينية والزيوت وغيرها من المواد الموجودة في جسم الإنسان. تمتاز المركبات الكيميائية مثل نينهيدرين، سيانوكريلات، مواد عضوية فلورية (فلوريسين، رودامين 6 جي، رودامين بي، كركمين، اصباغ بنزازول) بوجود الفة عالية للتفاعل مع الأحماض الأمينية والأحماض الدهنية والبروتينات في بصمة الأصابع وتلتصق أبخرة غراء اكريلات السيانيد بهذه المكونات ولذلك يمكنه التقاط بصمات الأصابع بوضوح، مما يجعل من الممكن التحقق من بصمات الأصابع بسرعة ودقة.

الكلمات المفتاحية: بصمات الأصابع، ننهايدرين، اكريلات السيانيد، المواد العضوية الفلورية، بوليمرات أشباه الموصلات.