Chapter 10
Visualization of Latent Fingerprint Using Conjugated Polymer Nanoparticles

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Introduction

According to Edmond Locard's exchange paradigm for forensic science, every touch leaves a trace. A multiplex combination such as (lipids, sebum, perspiration, and pollutants) is produced from the skin of a human which is transferred to the substrate when a human figure touches it, resulting in the development of a fingerprint. Ever since the late nineteenth century, fingerprints have already been utilized often as persuasive and effective evidence for human identification due to the individuality and durability of the ridge in the pattern of skin [1, 2]. Latent images of fingerprints (LFPs) found at the place where a crime has been committed are regarded as most important tangible solid evidence in forensic examination and the criminal justice system (CJS) due to the uniqueness and individuality of the pattern of ridges fingerprints [3, 4]. They are thus special and essential in solving any criminal case and correctly determining a suspect's involvement [5–8]. For the production of cyanoacrylate fuming, low-pressure metal installation, fluorescent dyeing, magnetic powder application, tiny particulate solution, and LFP powder sprinkling or dusting method, etc., are the most known methods [9–11]. Because of this, it is difficult to recover fingerprints that are good enough for unequivocal identification, especially when working with metallic surfaces [12, 13]. This chapter explains how to create fingerprints on various

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surfaces using polymer nanoparticles. Nanoparticle made of polymers is one of the types of nanomaterials that are employed in the development of fingerprints, but there is no direct use of nanoparticle made of polymers; the use of polymer nanocrystal is the second phase; the initial stage implies the utilization of conjugated nanoparticle made polymer for various chemicals. In many ways, fluorescent conjugated polymer materials outperform conventional fluorescent materials, such as tiny molecular fluorescent dyes and semi conductive quantum dots. As a result, conjugated polymers are frequently employed in bio imaging, sensing, and photoelectric devices [14–16]. In comparison to other small molecule fluorophores, conjugated polymers have a variety of advantages, such as low toxicity, high emission, great photo bleaching resistance, ease of synthesis at a low cost, superior mechanical stability, and processability [17–22]. These nanocrystals were widely used for identification of fingerprint because to the high-quality images, improved transparency, with perfect features of ridges, improved contrast of background surfaces, stronger selectivity, and result into the increased particle sensitivity with stronger selectivity.

History of Fingerprint Identification

The history of fingerprint identification as we know it now began in the late nineteenth century, and the establishment of identification agencies entrusted with preserving correct information on persons classified not by identity but by some physical characteristic. Modern nations were only bureaucratic enough in the nineteenth century to assume to keep structured criminal records that reached beyond a particular parish or municipality [23]. Fingerprints are formed up of ridges and furrows on the finger's surface, with a central core around which swirls, loops, and arches are curled to guarantee that each print is distinct [24]. An arch is formed when grooves enter a finger through one side, rise in the center to create an arc, and then escape from another. Ridges enter from one side of a finger, bend, and then escape from the same side in the loop pattern. Pattern of ridges develops in a circular pattern around a central spot on the finger in the whorl pattern. The imperfections known as minutiae, which are the distinguishing feature of finger scanning technology, are found in the ridges and furrows. Local ridge features that occur at either a ridge bifurcation or a ridge terminating are known as minutiae points. The point at which a ridge ends is known as the ridge terminating. A bifurcation is a point where a single ridge divides into two. Since no two fingers have been demonstrated to be identical, minutiae and patterns are extremely significant in fingerprint analysis [25]. As previously stated, fingerprint identification is extremely crucial in many sorts of criminal cases since it allows us to identify the primary suspect. As previously stated, fingerprints are unique to each individual. In the beginning, different old methods were used to develop such fingerprints, the most common is the powder method, in which several different powders are applied in the establishment of fingerprints at the site of crime [26]. However, powder methods have a number of flaws, and in order to overcome these flaws, new techniques have been developed so that fingerprints as evidence are not contaminated [27]. Different sorts of chemicals are used in this innovative process to create fingerprints. One of them is the utilization of polymer nanoparticles to make the visualization of latent fingerprints impression; this polymer has a fluorescence property that causes fingerprints to become visible when exposed to various substances.

Nanotechnology Used in Forensics

Scientific proof that is evidence detection on weapons, samples related to biology, and residues or particles using nanotechnology is a rapidly developing field of forensic science that helps law enforcement identify offenders [28–31]. Innovations used in forensic are mostly focused on physiology and anatomy in order to collect solid evidence toward convicts [32–34]. Therefore, forensic research is growing with nanotechnology to collect evidence rapidly at the scene of crime (SOC) and their environment and in a criminal court, submit this after laboratory examination [35, 36]. As a result, nanotechnology is used to increase nanosensors for acquiring evidence at the scene of crime identifying whether or if chemicals, such as natural and explosive gases, were marked as evidence from the activity of terrorist which is involved in this [37, 38]. Forensic scientists have traditionally used bulk chemicals and microsubstances to detect evidence, for example explosives, traces, DNA, fingerprint impression, and gunshot residues (GSR) [39–41]. Therefore, the utilization of nanomaterials in many applications is gradually replacing conventional methods. This chapter discusses the use of nanoparticles in the production of latent fingerprints impression for person recognition in forensic investigations, there are many suspects, and the best strategy for identifying them is to employ fingerprints [35].

Techniques of Preparation and Production

Polymeric Nanoparticles

The study of polymer nanoparticles (PNP) has developed quickly over the past few decades. It has grown in significance in a number of fields, such as electronics, optoelectronic, conducting materials, sensors, biotechnology, pollution prevention, and environment management [42–47]. Preformed polymers can be used to create PNPs, or you can directly polymerize monomers using classical polymerization or poly-reactions [48]. PNP can be manufactured from pre-manufactured polymers using techniques such as solvent evaporation, salting-out, dialysis, and supercritical fluid technology, which includes rapidly expanding a supercritical mixture or rapidly expanding a supercritical mixture into a liquid solvent [49, 50]. In contrast the production of PNP by direct polymerization of various single units, i.e., monomer by using a number of polymerization techniques, like interfacial polymerization, surfactant-free emulsion, mini-emulsion, and micro-emulsion [51].

Pdots

The nanoprecipitation technique previously described was used to prepare the Pdots. A conjugated polymer weighing 500 mg and PSMA weighing 50 mg were fully soluble in 10 mLtr of THF for the manufacture of Pdots. Under intense sonication, The polymer/THF combination was quickly diluted into 10 mL of ultrapure water with 3 ml of concentrated. From the nitrogen bubbling THF was removed on the hot plate. Filtration with a 0.22 m membrane filter allowed for the removal of a minor portion of aggregates [52, 53].

Preparation of CPDs

To create CPDs(carbonized polymer dots), a first-step solvothermal process was employed. 20 mL of toluene and 0.20 g of p-phenylenediamine (PPD) were placed in a Teflon-lined autoclave and cooked for 10 h at 160 °C with a constant temperature in drying oven. After the red precipitate was extracted and cooled at room temperature, the precipitate at the bottom of the autoclave was carefully collected and repeatedly washed with toluene. In order to make it easier to refer to them, CPDs-160, CPDs-180, and CPDs210 were given the respective designations [54] (Fig. 10.1).

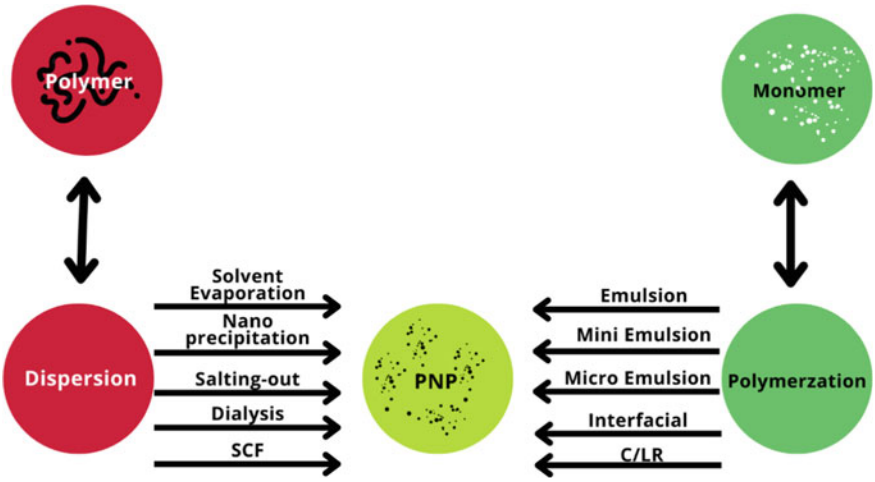

Fig. 10.1 Diagrammatic representation for the preparation of polymer nanoparticles by using various techniques

Use of Polymer Particles for Fingerprint Development

Conjugated Polymer Nanoparticles

Conjugated polymers (CPs), which are bright materials with exceptional light-harvesting capabilities and a range of appealing for use in biological and chemical detection, cell imaging, and photodynamic treatment, ocular characteristics have gained increasing attention [55–59] (Fig. 10.2).

Nanoparticles of Conjugated Polymer in an Aqua-Colloidal Suspension

An approach for creating fingerprints using conjugated polymer nanoparticles is suggested. Fluorescent poly (p-phenylene vinylene) (PPV) nanocrystals create a sustainable colloidal suspension after heat elimination of the polymer precursor (pre-PPV) in an aqueous system with the aid of a surfactant. The diluted colloidal solution may be used for fingerprint impression development by submerging the fingerprint sample for a brief moment in time, extracting it, and then rinsing the sample with deionized water to remove any extra PPV nanoparticles [60]. In terms of toxicity and/or cost, in aqueous solution, PPV nanoparticles have an edge them. Recently, multiple publications have appeared describing the use of conjugated polymers (or dots) as fingerprint-forming agents with excellent or good results [61–63]. Due to the lack of significant components (such as reactant, catalyst, or additive) or advanced processes used, the manufacture of colloidal solutions of PPV nanoparticles will be less expensive. While prior previous systems needed spraying or brushing techniques and the compounds were not reused, the current emerging approach is simpler and more affordable because it simply requires an immersive experience procedure; in some cases, further post-treatment or transmission steps involving fingerprints were required to achieve LFP visualization [60].

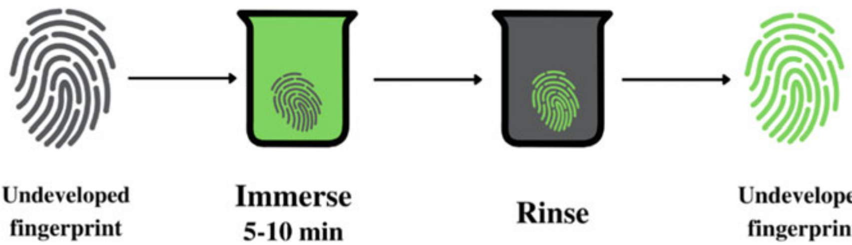

Fig. 10.2 Fingerprint development using polymer nanoparticles in aqueous colloidal solution

Cyanoacrylate Fuming with Conjugated Polymer Nanoparticles

A fingerprint development strategy involving the use of PPV nanoparticles (NPs) and the cyanoacrylate fuming method. To begin, a series of fluorescent PPV NPs with various emission colors are synthesized in aqueous colloidal solution using a modified Wessling approach in combination with in-situ self-assembly. A sequence of modified PPV precursors (pre-PPV-N) can be obtained in parallel by varying the reaction conditions. The simultaneous heat removal and self-assembly of PPV NPs with various emission colors occurs in the presence of surfactant, then using colloidal PPV NPs solutions, superglue-fumed fingerprints are created on various substrates [60]. To begin with, the color-tuning process for nanoparticles is straightforward, requiring only a change in the reaction duration of the substituent step and no further changes. Second, because the finished products are in aqueous solution, they may be used right away, which is good for the environment. Our strategy is, on the whole, cost-effective [64, 65].

Conjugated Oligomer with Silica Nanoparticles

Conjugated oligomers, which have a well-defined molecular weight and are less complex versions of CPs with the same conjugated backbone, have grown in popularity recently [66–69]. Comparatively speaking, conjugated oligomers are simpler to make, purify, and work with than conjugated polymers. Additionally, several special fluorescent properties related to the distinctive structure of oligomers show promise applications in detecting, imaging, antibacterial agents, drug/gene delivery, and controlled release [70–74]. A silane-modified conjugated oligomer was integrated into a silica matrix using a reverse micelle method, producing particles with ultra-bright blue fluorescence and quantum yields of up to 97 percent. The NPs were dispersed in a variety of solvents and showed little variation over a broad pH and temperature range. Silica NPs are widely employed in the materials and biological industries due to their controllable size, optical clarity, ease of modification, straightforward manufacture, and low toxicity. Conjugated polymers and oligomers experience aggregation-induced quenching when they are transformed from solution to nanoparticle form or a solid film (ACQ) [75]. This effect is assumed to be brought on by the aggregation-induced depopulation of excitons. The ACQ problem reduces the efficacy of such materials' emissions and restricts their applications in solid states. As evidence that the effects of ACQ were contained within the particles, photoluminescence quantum yields of fluorescent NPs with conjugated oligomer concentrations as low as 0.025–0.05 mol percent were as high as 97 percent. The resulting hybrid NPs could be used as a dusting agent to find latent fingerprints [75].

Polymer Dots for Latent Fingerprint Detection

In latent fingerprint imaging, the Pdots give exceptional sensitivity and reliability. For fingerprint identification, there are two basic groups of fingerprint matching procedures [76]. The minutiae-based method, which is the most extensively used recognition methodology, detects minutiae points first and then maps their relative arrangement on the finger to match ridge characteristics. Pattern matching, on the other hand, examines two photos to determine how similar they are. The spray approach may be used to detect LFP using radical fluorescence polymer dots. The fluorescence matrix has been altered in this way by mixing two types of polymers with ninhydrin [1]. The fluorescent matrix is used for latent fingerprint detection and colorimetric measurements on any porous or non-porous substrate [1]. These polymer dots are used to enhance the fingerprint ridge's detail and offer advantages including improved selectivity and low inherent interferences. These types of polymer dots have shown great potential as fingerprint detecting agents due to the robust interaction in LFP detection that produces clear fingerprint images. These polymer dots paved the way for a new forensic science study field focused on the detection of LFP [35].

Latent Fingerprint Imaging Using Carbonized Polymer Dots

Carbon-based nanomaterials (CNMs) which are fluorescent, such as graphene quantum dots, carbon nanoparticles, and carbon dots (CDs) have gained popularity due to the consequence of their exceptional optical characteristics, better stability, minimal toxicity, excellent photo-induced e-transfer characteristics, and straightforward synthetic processes [77–79]. CNMs are useful for many different applications, including photocatalysis, light-emitting devices, and bioimaging, among others [80, 81]. The majority of modern CNMs emit intense blue to green light when stimulated by UV(ultraviolet) radiation or light. However, red fluorescent CNMs are extremely difficult to make, and the scarcity of red-emitting CNMs greatly limits their use and advancement [82]. Researchers have made various attempts to create novel fluorescent agents and more efficient techniques for manufacturing LFPs [83]. Recently, bright nanoparticles have been effectively used to detect LFPS, in particular rare earth fluorescent nanomaterials. It is anticipated that CNMs will be employed to visualize LFPS as a sort of economical, extremely luminescent-stable, and environmentally beneficial nanomaterial [54].

Fingerprint Collecting and Development Process

The same methods were used to prepare regular fingerprint specimens for the development of latent fingerprint impression. The contributor should carefully wipe their hands before rubbing their hand away from greasy regions of the body such as the retro auricular region to avoid leaving fingerprints on the material (the adhesive side of the tapes, the aluminum foil, or the cover glass) [60]. With a soft brush, the powdered nanoparticles were applied to the imprinted surfaces to collect the LFPs produced by various nanoparticles, and the extra powder was removed with a moderate air flow [84]. Two different kinds of approaches were needed for the identification of LFP with nanoparticles. Interactions that are taking place are electrostatic and hydrophobic interactions. Because of electrostatic attractions with LFPs, distinct functional groups of amine and carboxylic acid are present in sweat pores, patterns of end ridges, and residues of fingerprint impression. Additionally, the hydrophobic, i.e., repulsion of water mechanism includes the fatty acids of LFPs and the negative charge of nanomaterial. These kinds of procedures showed high sensitivity and higher resolution without the foremost part of interferences in the ridges of LFPs with number of nanoparticles [84, 85]. The ability to quickly discern fingerprints under UV irradiation enables the identification of the culprit due to the characteristics of powdered materials' emissions. To enhance the detection of latent fingerprints and help identify offenders, aluminum foil and carbon-based compounds are frequently used [60].

Conclusion

A number of conjugated polymer nanoparticles with different fluorescence colors were studied and characterized in an aqueous colloidal solution. It was discovered that they were round, nanometer in size, and had the ideal wavelengths for scattering and absorption that can be used as reagents in the creation of fingerprints. The fingerprints were produced by "in-situ" fuming of superglue and then stained with fluorescent dye. This chapter discusses the many characteristics of fingerprints and their production procedures, with a focus on a novel and cost-effective technology that employs polymer nanoparticles and Pdots, which may be employed on a variety of surfaces at various crime scenes. Polymer nanoparticles have varying fluorescence qualities, which can aid in the better viewing of fingerprints and their patterns. Polymer nanoparticles are also employed in a variety of chemicals and shapes. It is inexpensive and easy to create latent fingerprints by using polymer nanoparticles.

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