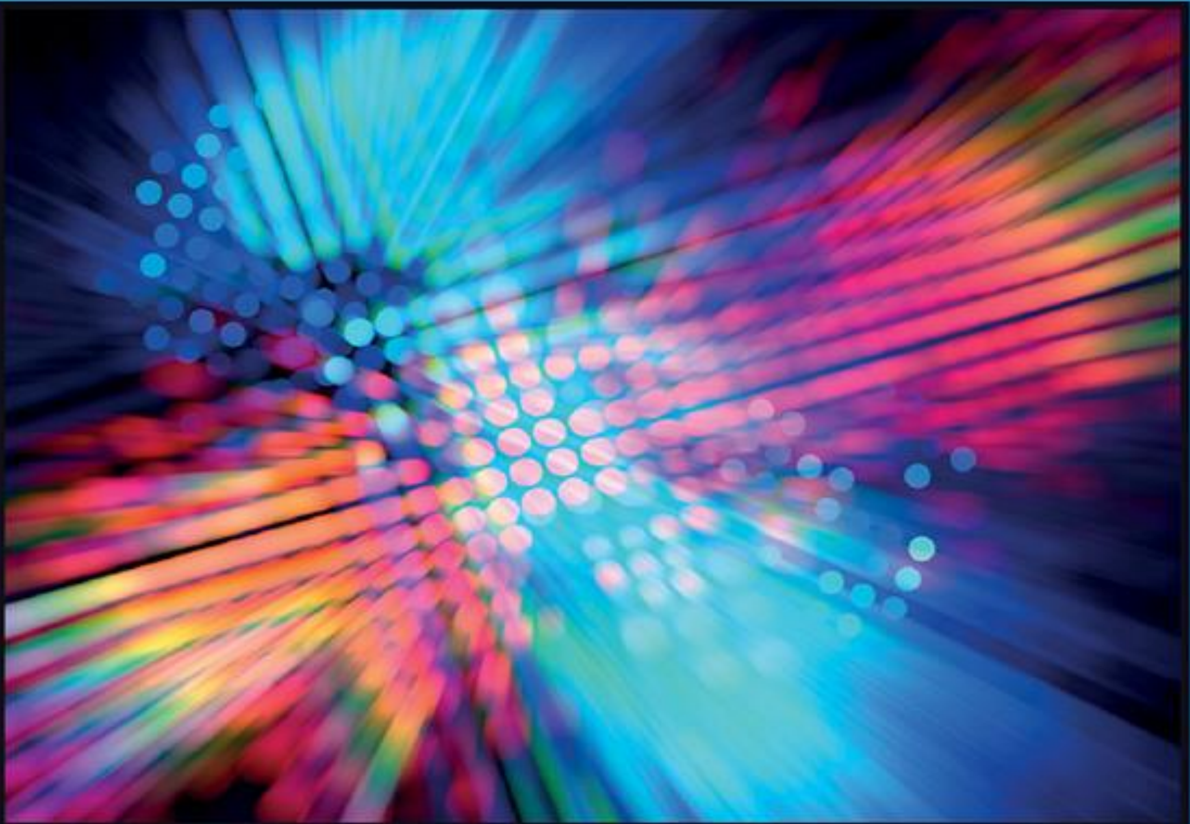
WOODHEAD PUBLISHING SERIES IN ELECTRONIC AND OPTICAL MATERIALS



QUANTUM DOTS: EMERGING MATERIALS FOR VERSATILE APPLICATIONS

Edited by
N. THEJO KALYANI
SANJAY J. DHOBLE
MARTA MICHALSKA-DOMAŃSKA
B. VENGADAESVARAN
H. NAGABHUSHANA
ABDUL KARIEM AROF

ELSEVIER

Woodhead Publishing Series in Electronic and Optical Materials

Quantum Dots

Emerging Materials for Versatile Applications

Edited by

N. Thejo Kalyani

Sanjay J. Dhoble

Marta Michalska-Domańska

B. Vengadaesvaran

H. Nagabhushana

Abdul Kariem Arof

ELSEVIER

WP
WOODHEAD PUBLISHING
An imprint of Elsevier

Woodhead Publishing is an imprint of Elsevier
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, OX5 1GB, United Kingdom

ISBN: 978-0-323-85278-4 (print)

ISBN: 978-0-323-85279-1 (online)

For information on all Woodhead Publishing publications
visit our website at https://www.elsevier.com/books-and-journals

Publisher: Matthew Deans
Acquisitions Editor: Kayla Dos Santos
Editorial Project Manager: Sara Greco
Production Project Manager: Surya Narayanan Jayachandran
Cover Designer: Christian J. Bilbow

Typeset by MPS Limited, Chennai, India

5.5.1 Flexible display device 150
5.5.2 Flexible transparent device 150
5.6 Current available technologies in the market 150
5.7 Future demands and scope 151
5.8 Conclusions 151
References 151

Section II Quantum dots: Applications and prospectives

6. Quantum dots-based solar cells: Futuristic green technology to accomplish the energy crisis **157**
G.P. Darshan, D.R. Lavanya, B. Daruka Prasad, S.C. Sharma and H. Nagabhushana
6.1 Introduction 157
6.2 Various generations of SCs 160
6.2.1 First-generation SCs 160
6.2.2 Second-generation SCs 163
6.2.3 Third-generation SCs 164
6.2.4 Fourth-generation SCs 166
6.3 Architectural design of QDS SCs 167
6.3.1 Excitonic absorber 168
6.3.2 Electron transport material 169
6.3.3 Hole transport material 173
6.3.4 Counter electrode 176
6.4 Experimental background in quantum dot SCs 176
6.4.1 Current-voltage characteristics 176
6.4.2 Electrochemical impedance spectroscopy 177
6.5 Summary and future prospects 179
References 180

Quantum dots-based solar cells: Futuristic green technology to accomplish the energy crisis

6

G.P. Darshan[1], D.R. Lavanya[2], B. Daruka Prasad[3], S.C. Sharma[4] and H. Nagabhushana[2]

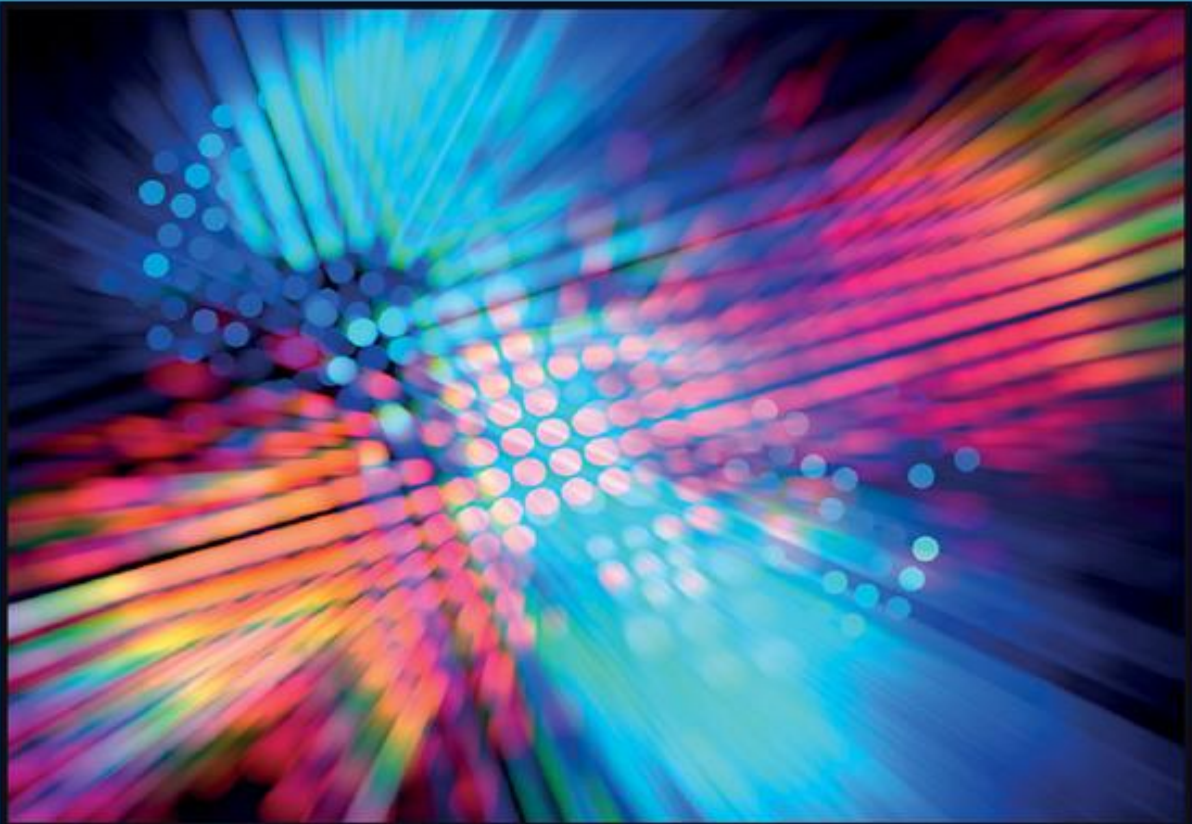
[1]Department of Physics, Faculty of Mathematical and Physical Sciences, M.S. Ramaiah University of Applied Sciences, Bengaluru, Karnataka, India, [2]Prof. C.N.R. Rao Centre for Advanced Materials, Tumkur University, Tumkur, Karnataka, India, [3]Department of Physics, BMS Institute of Technology and Management, Bengaluru, Karnataka, India, [4]National Assessment and Accreditation Council, Bengaluru, Karnataka, India

6.1 Introduction

For the past few decades, quantum dots (QDs) have received much attention among the research community due to its interesting physical and chemical properties. QDs are basically fluorescent semiconductor nanoparticles with an average diameter of 2–10 nm. The size of QDs may influence many properties, such as optical, electrical, structural, etc. [1–4]. QDs are also known as artificial atoms because of the presence of same number of electrons and atoms, demonstrating their movement in three dimensions with narrow electronic energy level [5]. QDs offers various interesting features, such as (1) QDs resist to degradation as compared to other materials; this property allows to use in bio-imaging applications [6], (2) QDs are 10–20 times brighter and have longer photo stability in comparison to organic dyes [7], (3) QDs have stable fluorophore because they are made up of inorganic semiconductor materials [8], (4) QDs possess large surface area [9], (5) QDs are feasible for surface modification, which makes them suitable for various applications [10], (6) they can be easily fabricated into variety of shapes, size and coatings with other materials [11], (7) QDs are chemically inert and can encapsulate both hydrophilic and lipophilic surfaces [12], (8) Because of the modification in shell of QDs various changes occur such as charge, size and solubility [13] and (9) QDs have low cost, good stability, good flow ability and narrow size distribution [14]. They exhibit narrow and sharp peak with broad excitation spectra. These advantages make QDs more interesting and widely used in great potential applications, like bio-imaging, sensing, solar cells (SC), forensic, magnetic resonance imaging, etc. [15–19]. Generally, the quantum confinement effect is caused due to the splitting of energy levels in QDs; causing increase in semiconductor band gap with decrease in size of the nanocrystal. Basically, QDs can be categorized into three main types [20]—(1)

Quantum Dots. DOI: https://doi.org/10.1016/B978-0-323-85278-4.00004-0

WOODHEAD PUBLISHING SERIES IN ELECTRONIC AND OPTICAL MATERIALS



QUANTUM DOTS: EMERGING MATERIALS FOR VERSATILE APPLICATIONS

Edited by
N. THEJO KALYANI
SANJAY J. DHOBLE
MARTA MICHALSKA-DOMAŃSKA
B. VENGADAESVARAN
H. NAGABHUSHANA
ABDUL KARIEM AROF

ELSEVIER

Woodhead Publishing Series in Electronic and Optical Materials

Quantum Dots

Emerging Materials for Versatile Applications

Edited by

N. Thejo Kalyani

Sanjay J. Dhoble

Marta Michalska-Domańska

B. Vengadaesvaran

H. Nagabhushana

Abdul Kariem Arof

ELSEVIER

WP
WOODHEAD PUBLISHING
An imprint of Elsevier

Woodhead Publishing is an imprint of Elsevier
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, OX5 1GB, United Kingdom

ISBN: 978-0-323-85278-4 (print)

ISBN: 978-0-323-85279-1 (online)

For information on all Woodhead Publishing publications
visit our website at https://www.elsevier.com/books-and-journals

Publisher: Matthew Deans
Acquisitions Editor: Kayla Dos Santos
Editorial Project Manager: Sara Greco
Production Project Manager: Surya Narayanan Jayachandran
Cover Designer: Christian J. Bilbow

Typeset by MPS Limited, Chennai, India

19. Quantum dot-based security ink and fluorescent flexible films: Preparation, characterization, and applications to multiple anti-counterfeiting and cell imaging **501**
G.P. Darshan, G.R. Suman, H.B. Premkumar, B. Daruka Prasad, S.C. Sharma, H. Adarsha and H. Nagabhushana
19.1 Introduction 501
19.2 Systematic study of various QDs used for anti-counterfeiting applications 503
19.3 Bio-imaging applications of various QDs: a case study 521
19.4 Conclusions and future outlook 534
References 535

20. Fluorescent quantum dots as labeling agents for the effective detection of latent fingerprints on various surfaces **539**
G.P. Darshan, B. Daruka Prasad, H.B. Premkumar, S.C. Sharma, K.S. Kiran and H. Nagabhushana
20.1 Introduction 539
20.2 Latent fingerprints 540
20.2.1 Chemical views to look latent fingerprints 540
20.2.2 Types of latent fingerprints and their ridge details 542
20.2.3 Environmental factors affecting on latent fingerprints (light sources, temperature and humidity, vaccum, etc.) 544
20.2.4 Types of development techniques 546
20.3 Properties of various quantum dots useful for latent fingerprints visualization 548
20.4 Reported QDs used to visualize the latent fingerprints 556
20.5 Concluding remarks and outlook 568
References 569

21. Sustainability, recycling, and lifetime issues of quantum dots **575**
N. Thejo Kalyani, H. Nagabhushana, Marta Michalska-Domańska, B. Vengadaesvaran, Abdul Kariem Arof and Sanjay J. Dhoble
21.1 Introduction 575
21.2 Practical issues of quantum dots 575
21.2.1 Sustainability 577
21.2.2 Recycling 577
21.2.3 Lifetime issues 578
21.3 Toxicity approach 578
21.4 Future prospective 579
21.5 Conclusions 579
References 579

Quantum dot-based security ink and fluorescent flexible films: Preparation, characterization, and applications to multiple anti-counterfeiting and cell imaging

19

G.P. Darshan[1], G.R. Suman[2], H.B. Premkumar[1], B. Daruka Prasad[3], S.C. Sharma[4,5,6], H. Adarsha[7] and H. Nagabhushana[8]

[1]Department of Physics, Faculty of Mathematical and Physical Sciences, M.S. Ramaiah University of Applied Sciences, Bengaluru, Karnataka, India, [2]Department of Physics, School of Applied Sciences, Reva University, Bengaluru, Karnataka, India, [3]Department of Physics, BMS Institute of Technology and Management, Bengaluru, Karnataka, India, [4]National Assessment and Accreditation Council, Bengaluru, Karnataka, India, [5]Jain University, Bengaluru, Karnataka, India, [6]Centre for Energy, Indian Institute of Technology, Guwahati, Assam, India, [7]Department of Mechanical Engineering, Faculty of Engineering and Technology, Jain Global Campus, Bengaluru, Karnataka, India, [8]Prof. C.N.R. Rao Centre for Advanced Materials, Tumkur University, Tumkur, Karnataka, India

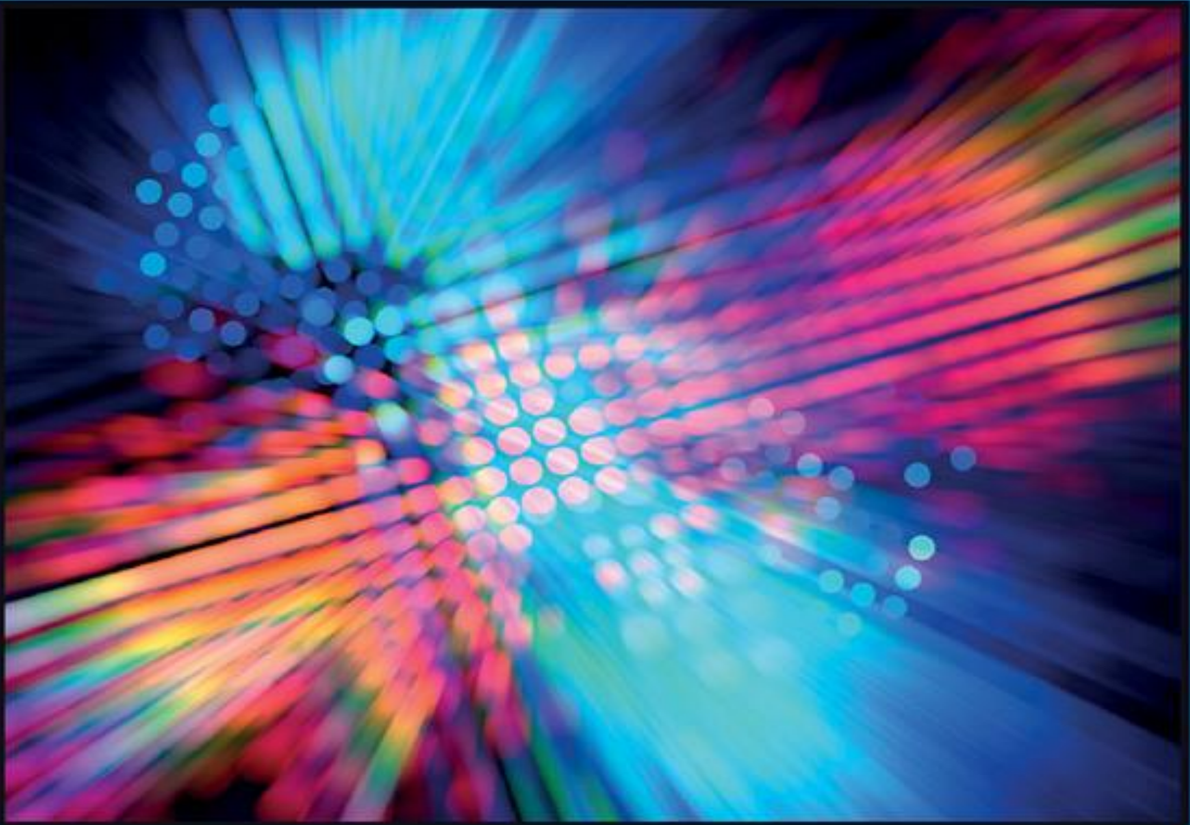
19.1 Introduction

For the past few decades, counterfeiting of banknotes, goods, fuels, coatings, medicine, and labels has become a global issue, which imbalances the economic condition, human health, and scientific development [1−3]. Hence, the progress of anti-counterfeiting (AC) technology, especially the design and development of high-security AC materials with various colors and complex and multiple authentication technologies, is absolutely needed to combat counterfeiting in various fields [4]. A survey on "anti-counterfeiting" by searching keyword in the scholar Web sites in last two decades revealed a substantial surge, particularly in 2018 and 2019 (Fig. 19.1). The obtained output demonstrated the considerable increase in the necessity of AC materials [5]. Therefore, developing versatile AC technique is highly demanded to prevent forging.

Till date, significant research on AC techniques has been performed to distinguish original and counterfeited products, namely bar codes, QR codes, security inks, simple markers, radio frequency identification, laser holograms, optical watermarks, etc. [6,7]. Among them, only few techniques are quite upright in the present scenario because some of them may soon be out-of-date and/ or can be easily replicated by forgers. In particular, luminescent based AC technology has been paid

Quantum Dots. DOI: https://doi.org/10.1016/B978-0-323-85278-4.00014-3

WOODHEAD PUBLISHING SERIES IN ELECTRONIC AND OPTICAL MATERIALS



QUANTUM DOTS: EMERGING MATERIALS FOR VERSATILE APPLICATIONS

Edited by
N. THEJO KALYANI
SANJAY J. DHOBLE
MARTA MICHALSKA-DOMAŃSKA
B. VENGADAESVARAN
H. NAGABHUSHANA
ABDUL KARIEM AROF

ELSEVIER

Woodhead Publishing Series in Electronic and Optical Materials

Quantum Dots

Emerging Materials for Versatile Applications

Edited by

N. Thejo Kalyani

Sanjay J. Dhoble

Marta Michalska-Domańska

B. Vengadaesvaran

H. Nagabhushana

Abdul Kariem Arof

ELSEVIER

WP WOODHEAD PUBLISHING

An imprint of Elsevier

Woodhead Publishing is an imprint of Elsevier
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, OX5 1GB, United Kingdom

ISBN: 978-0-323-85278-4 (print)

ISBN: 978-0-323-85279-1 (online)

For information on all Woodhead Publishing publications
visit our website at https://www.elsevier.com/books-and-journals

Publisher: Matthew Deans
Acquisitions Editor: Kayla Dos Santos
Editorial Project Manager: Sara Greco
Production Project Manager: Surya Narayanan Jayachandran
Cover Designer: Christian J. Bilbow

Typeset by MPS Limited, Chennai, India

). **Quantum dot-based security ink and fluorescent flexible films: Preparation, characterization, and applications to multiple anti-counterfeiting and cell imaging** **501**
G.P. Darshan, G.R. Suman, H.B. Premkumar, B. Daruka Prasad, S.C. Sharma, H. Adarsha and H. Nagabhushana
19.1 Introduction 501
19.2 Systematic study of various QDs used for anti-counterfeiting applications 503
19.3 Bio-imaging applications of various QDs: a case study 521
19.4 Conclusions and future outlook 534
References 535

). **Fluorescent quantum dots as labeling agents for the effective detection of latent fingerprints on various surfaces** **539**
G.P. Darshan, B. Daruka Prasad, H.B. Premkumar, S.C. Sharma, K.S. Kiran and H. Nagabhushana
20.1 Introduction 539
20.2 Latent fingerprints 540
20.2.1 Chemical views to look latent fingerprints 540
20.2.2 Types of latent fingerprints and their ridge details 542
20.2.3 Environmental factors affecting on latent fingerprints (light sources, temperature and humidity, vaccum, etc.) 544
20.2.4 Types of development techniques 546
20.3 Properties of various quantum dots useful for latent fingerprints visualization 548
20.4 Reported QDs used to visualize the latent fingerprints 556
20.5 Concluding remarks and outlook 568
References 569

l. **Sustainability, recycling, and lifetime issues of quantum dots** **575**
N. Thejo Kalyani, H. Nagabhushana, Marta Michalska-Domańska, B. Vengadaesvaran, Abdul Kariem Arof and Sanjay J. Dhoble
21.1 Introduction 575
21.2 Practical issues of quantum dots 575
21.2.1 Sustainability 577
21.2.2 Recycling 577
21.2.3 Lifetime issues 578
21.3 Toxicity approach 578
21.4 Future prospective 579
21.5 Conclusions 579
References 579

ıdex **581**

Fluorescent quantum dots as labeling agents for the effective detection of latent fingerprints on various surfaces

20

G.P. Darshan[1], B. Daruka Prasad[2], H.B. Premkumar[1], S.C. Sharma[3,4,5], K.S. Kiran[6] and H. Nagabhushana[7]

[1]Department of Physics, Faculty of Mathematical and Physical Sciences, M.S. Ramaiah University of Applied Sciences, Bengaluru, Karnataka, India, [2]Department of Physics, BMS Institute of Technology and Management, Bengaluru, Karnataka, India, [3]National Assessment and Accreditation Council, Bengaluru, Karnataka, India, [4]Jain University, Bengaluru, Karnataka, India, [5]Centre for Energy, Indian Institute of Technology, Guwahati, Assam, India, [6]Department of Physics, Faculty of Engineering and Technology, Jain Global Campus, Bengaluru, Karnataka, India, [7]Prof. C.N.R. Rao Centre for Advanced Materials, Tumkur University, Tumkur, Karnataka, India

20.1 Introduction

The human fingertip has characteristic complex patterns consisting of raised papillary ridges and depressed furrows [1,2]. The papillary ridge patterns are completely distinguished and differ from one individual to another as well as one finger to another [3]. When finger touches the surface of the substrates, aqueous ectocrines (sweat) and oily substances (sebum) are transferred onto the surfaces, leading to the formation of a fingerprints (FPs) [4,5]. Hence, FPs are considered as most significant evidences for personalization, due to its uniqueness, stability of the ridge features as well as complexity [6,7]. From late 19th century, FPs have become most-established criminal investigation tool for personal identification during crime investigation [8,9].

For many decades, a significant attempt has been performed by the research community, and investigators have developed a unique technique for personal identification. Till date, several methods have been established, namely DNA matching, Bertillion method, facial recognition and FPs (Czarnecki, 1995) [10–13]. Among them, the Bertillion method of anthropometry was mostly used technique for personal identification for about two decades [14]. Furthermore, this method has its own limitations when two individuals with most analogous anthropometrical details were interrogated during investigation and hence FPs comparison led to the identification of real convict [15]. Henceforth, FPs science gained much attractiveness and recognition over the Bertillion method. Since then, FPs have been considered and

Quantum Dots. DOI: https://doi.org/10.1016/B978-0-323-85278-4.00006-4