Thin Film Materials and Devices

Sandesh R. Jadkar,¹ Deepak Dubal,² Dattatray Dhawale,³ Shoyebmohamad F. Shaikh,⁴ Ravindra Bulakhe,⁵ Ying Li,⁶ Qinglong Jiang⁷ and Habib M. Pathan^{1,*}

Received date: 20 November 2020; Accepted date: 26 November 2020

Article type: Editorial article.

As the sizes of materials decrease from a macroscopic scale to smaller ones, many unique physical and chemical properties of the materials become prominent. Thin film materials, in the size from a few nanometers to micrometers, have chemical, optical, electrical, magnetic, thermal, mechanical, acoustic, and other properties different from bulk materials due to the large surface to volume ratio, quantum confinement effects, and many other interesting effects. For example, when transforming to a thin film, inert materials may turn into active catalysts, stable materials may become unstable, and opaque materials turn into transparent (e.g. ITO, Cu, and FTO). Thus, the unique surface phenomena for thin film materials have created many interdisciplinary science and engineering areas, ranging from chemistry, physics, electronics, and biology to engineering.^[1] Thin film materials and technologies (in nano and microscale) have served as enabling technology in diverse fields, such as catalysts for environmental applications and CO₂ capture and conversion;^[2-4] antibacterial applications;^[5] enhanced mechanical strength; semiconductor;^[6] improved energy efficiency for solar cells^[7, 8] and energy storage devices,^[8,10] sensors,^[11] light-emitting devices,^[12-14] electrochromism,^[15,16] and so on.

The suitability of the thin film for a particular application is dependent upon their morphology and stability. The morphology and the stability on the thin film hinge to the deposition techniques. In the present era of technology, there are constant and continuous demands of

new materials for multitudinous applications, in which thin films play an important role. This issue of *ES Materials and Manufacturing* presents the latest developments and advances in the field of thin film nanomaterials with special attention to the synthesis, and applications of thin films. It broadly covers thin film-based nanomaterials, their synthesis, and applications in sensing, photocatalysis and photovoltaics.

Fig. 1 Thin film materials in halide perovskite solar cell (a and b),^[17] dye sensitized solar cell (c),^[18] light emitting (d)^[12] and electrochromis (e).^[19]

In the present issue, Jadkar *et al.* reported the synthesis of TiO₂ thin films by using a simple, inexpensive, low-temperature chemical bath deposition (CBD) method followed by annealing at 300, 400, and 500 °C, and the obtained TiO₂ thin films were sensitized with melanin. The influence of annealing temperature on the structural, optical, morphology, and photoelectrochemical cell properties were investigated using a variety of techniques. Sannakki *et al.* prepared Gold (Au) nanoparticles by electrochemical deposition of an aqueous solution of auric chloride (AuCl₄) on a titanium dioxide (TiO₂) film. Before and after the electrochemical deposition, the TiO₂ film was soaked into the dye solution of Rose Bengal. It was found that the photoelectrochemical properties enhanced after the deposition of Au nanoparticles

¹ Department of Physics, Savitribai Phule Pune University, Pune, India.

² Queensland University of Technology, Brisbane, Australia.

³ Hamad Bin Khalifa University, Qatar.

⁴ Department of Chemistry, King Saud University, Saudi Arabia.

⁵ Korea National University of Transportation, Chungju, South Korea.

⁶ J. Mike Walker '66 Department of Mechanical Engineering, Texas A&M University, College Station, TX, USA

⁷ University of Arkansas, Pine Bluff, AR, USA

* E-mail: pathan@physics.unipune.ac.in (H.M. Pathan)

on the TiO₂ film. Lokhande *et al.* reported successive ionic layer adsorption and reaction (SILAR) deposited Cu₃SnS₄ (CTS) thin films. This study gives promising results in developing photovoltaic devices using SILAR CTS as the absorber.

Bangi *et al.* reported the influence of a glycerol additive on the chemical structure, hydrophobicity, morphology, and optical properties of a sol-gel based zirconia coating. Experimental results reveal that the porous morphology of the zirconia coatings leads to an optical transmission larger than 90%.

Guo and Zhang *et al.* fabricated an alternating multilayer polydimethylsiloxane resin nanocomposite coating for anti-corrosion purposes, which exhibits the best corrosion resistance at a 4.82 V corrosion potential (E_{corr}). Palve *et al.* reported the synthesis of copper selenide nanocrystals on a glass substrate by a chemical bath deposition technique, and investigated the reaction between Cu-ions and selenosulfate in an aqueous solution that forms Cu₃Se₂ at room temperature. Pathan *et al.* presented the synthesis of Eosin-Y sensitized bi-layered ZnO nanoflower-CeO₂ photoanode for DSSCs. The results show that a nanoflower morphology and a porous, rough and spongy morphology of CeO₂ are effective for dye adsorption.

Jadkar *et al.* reported the synthesis of an n-type hydrogenated nanocrystalline silicon (nc-Si:H) thin film using silane (SiH₄) and phosphine (PH₃) acting as dopant gases by a catalytic chemical vapor deposition technique (Cat-CVD). The optoelectronic and structural properties of nc-Si:H has been studied, which shows that the deposited film can be useful as n-layer Si:H based c-Si hetero-junction solar cells. Zhang *et al.* prepared hollow spheres/epoxy resin encapsulated steel pipe structures by using Al₂O₃ hollow spheres with macromolecule materials for encapsulation and studied their damping properties.

In summary, thin film-based nanomaterials have great potentials for various applications with new capabilities. This important field of research will continue to grow undoubtedly and *ES Materials and Manufacturing* welcomes manuscripts that describe thin film synthesis and exciting new nanomaterials-based on thin films along with the innovative applications that they enable.

References

- [1] C. Liu, Q. Jiang, Z. Guo, N. Lu and M. Mortazavi, *Nano Science: Nanomaterial, Nanotechnology and Applications*, Engineered Science Publisher, 2019, Knoxville, USA, ISBN 978-1-970059-00-72019.
- [2] T.-W. Liao, S. W. Verbruggen, N. Claes, A. Yadav, D. Grandjean, S. Bals and P. Lievens, *Nanomaterials*, 2018, **8**, 30, doi: 10.3390/nano8010030.
- [3] D. Yu, Z. Tian, M. Waqas, Z. Jin, A. El Kasmi, D. Tian and P. M. Kouotou, *ES Energy & Environm.*, 2019, **5**, 75–84, doi: 10.30919/esee8c301.
- [4] F. Liu, G. Li, S. Luo, W. Li, Z. Huang, W. Li, F. Su, C. Li, Z. Ding and Q. Jiang, *ACS Appl. Mater. Interfaces*, 2019, **11**, 1691–1698, doi: 10.1021/acsami.8b16463.
- [5] G. Benetti, E. Cavaliere, A. Canteri, G. Landini, G. M. Rossolini, L. Pallecchi, M. Chiodi, M. J. Van Bael, N. Winckelmans, S. Bals and L. Gavioli, *APL Mater.*, 2017, **5**, 036105, doi:10.1063/1.4978772.
- [6] J. Kim, J. Bang, N. Nakamura and H. Hosono, *APL Mater.*, 2019, **7**, 022501, doi: 10.1063/1.5053762.
- [7] Q. Jiang and T. Xu, *Comment. Inorg. Chem.*, 2016, **36**, 4, 200–214, doi: 10.1080/02603594.2015.1116985.
- [8] J. Jiang, J. Xu, H. Walter, A. Kazi, D. Wang, G. Wangila, M. Mortazavi, C. Yan and Q. Jiang, *ES Mater. Manuf.*, 2020, **7**, 25–33, doi: 10.30919/esmm5f705.
- [9] Y. Wang, Y. Liu, C. Wang, H. Liu, J. Zhang, J. Lin, J. Fan, T. Ding, J. E. Ryu and Z. Guo, *Engi. Sci.*, 2020, **9**, 50–59, doi: 10.30919/es8d903.
- [10] Y. Liu, J. Jiang, Y. Yuan, Q. Jiang and Chao Yan, *Nanomaterials*, 2019, **9**, 1336, doi: 10.3390/nano9091336.
- [11] M. J. Haslinger, D. Sivun, H. Pöhl, B. Munkhbat, M. Mühlberger, T. A. Klar, M. C. Scharber and C. Hrelescu, *Nanomaterials*, 2020, **10**, 1866, doi: 10.3390/nano10091866.
- [12] Q. Jiang, M. Chen, J. Li, Q. Xiao, X. Zeng, T. Besara, J. Lu, Y. Xin, B. Pan, C. Wang, T. Siegrist and Z. Yu, *ACS Nano*, 2017, **11**, 1073–1079, doi: 10.1021/acs.nano.6b08004.
- [13] J. Li, X. Shan, S. G. R. Bade, T. Geske, Q. Jiang, X. Yang, and Z. Yu, *J. Phys. Chem. Lett.*, 2016, **7**, 20, 4059–4066, doi: 10.1021/acs.jpcclett.6b01942.
- [14] J. Jiang, D. Wang, X. Ma, Z. Xiao, M. Wu, P. Peng, F. Li, F. Liu, R. Jing, C. Yan, Z. Guo, Q. Jiang, *APL Mater.*, 2020, **8**, 071115, doi: 10.1063/1.50001680.
- [15] Y. Gong, X. K. Fu, S. P. Zhang, Q. Jiang, *Chin. J. Chem.*, 2007, **25**, 1743–1747, doi: 10.1002/cjoc.200790322.
- [16] Q. Jiang, Xi. Zeng, N. Wang, Z. Xiao, Z. Guo and Jun Lu, *ACS Energy Lett.*, 2018, **3**, 264–269, doi: 10.1021/acsenergylett.7b01230.
- [17] Q. Jiang, L. Wang, C. Yan, C. Liu, Z. Guo and N. Wang, *Engi. Sci.*, 2018, **1**, 64–68, doi: 10.30919/es.180329.
- [18] Q. Jiang, Y. Yeh, N. Lu, H. Kuo, M. Lesslie and T. Xu, *J. Renew. Sustain. Energy*, 2016, **8**, 013701, doi: 10.1063/1.4941790.
- [19] Q. Jiang, F. Liu, T. Li and T. Xu, *J. Mater. Chem. C*, 2014, **2**, 618–621, doi: 10.1039/C3TC31692K.

Author information

postdoctoral training at Laboratory of Physics of Interfaces and

Dr. Sandesh R. Jadkar is Senior Professor in Physics at Department of Physics and Director, School of Energy Studies, Savitribai Phule Pune University, Pune 411 007 (India). He completed M. Sc. and Ph. D. degrees in Physics from Savitribai Phule Pune University in 1990 and 2001 respectively, followed by

Thin Films (LPICM), Ecole Polytechnique, Palaiseau, France (2002-2003), and Department of Physics, Camerino University, Italy (2008-2009). He is Fellow of Maharashtra Academy of Sciences. His research focuses mainly on materials for low cost thin film solar cells, water splitting, photodetectors and sensors, and 2D materials. Till so far 22 students have completed Ph. D. and 11 students are working for Ph. D. under his supervision. He has published more than 250 research articles in peer reviewed international journals and also published 03 book chapters.

Dr. Deepak P. Dubal is Associate Professor (Australian Future Fellow) at Queensland University of Technology (QUT), Australia. After receiving his PhD in 2011, he worked at several esteemed institutions with prestigious fellowships such as “BK-21 Post-doctoral Fellow” (Gwangju Institute of Science and Technology,

South Korea), “Alexander von Humboldt” fellow (Chemnitz University of Technology, Germany) and “Marie-Curie” fellow (Catalan Institute of Nanoscience and Nanotechnology ICN2, Spain). Prior joining QUT, he received Vice Chancellor fellowship from University of Adelaide, Australia in 2017. His research is focused on the development of multifunctional hybrid materials for clean energy conversion and storage technologies with special focus on Supercapacitors, Metal-ion batteries and Flow cells. In addition, his is also active in the areas of valorisation of wastes and recycling of Li-ion batteries. He is Editorial board member of Scientific Reports (Nature Publishing Group), member of Royal Australian Chemical Institute (MRACI) and Foreign Fellow of Maharashtra Academy of Sciences (FMASc).

Dr. Dattatray S. Dhawale is Scientist at the Qatar Environment and Energy Research Institute (QEERI), Qatar Foundation, Qatar since June 2016. Before moving to QEERI, he served at KAUST, Saudi Arabia during 2013-2016. Prior to

joining KAUST, he worked as a Postdoctoral Research Fellow at the University of Queensland, Australia from 2011 to 2013 and Research Associate at the National Institute for Materials Science, Japan during 2010-2011. He obtained his PhD from the Shivaji University Kolhapur India in 2010. His research interest encompasses the development of efficient nanomaterials for electrocatalysis, solar energy conversion, energy storage, photocatalysis, carbon capture and conversion, and sensors. He is co-authored of more than 65 peer-reviewed publications in high-quality journals with the citation of ca. 3880 with h index 36 and 4 patents in the field of energy technology.

Dr. Shoyebmohamad F. Shaikh is an Assistant professor in King Saud University, Riyadh, Saudi Arabia. He completed is Ph.D. degree in Clean Energy and Chemical Engineering from UST (University of Science and Technology), South Korea for which I worked in Korea Institute of Science and Technology, Seoul, South Korea

during 2010-2015. During Ph. D. course his major concern was to enhance the power conversion efficiency of metal oxide-based nanostructures in Dye Sensitized Solar cells. For that various surface modifications were attempted by considering band gap engineering kinetics. He has one-year Postdoctoral experience in perovskite solar cell, Yonsei University, South Korea during academic year 2015-2016. His research interest on electrochemical supercapacitors, gas sensor and water spitting by using conducting polymers, metal oxide and carbon-based materials.

Dr. Ravindra N. Bulakhe is a Research Professor in the Department of Polymer Science and Engineering, Korea National University of Transportation, Chungju, South Korea. He received his postdoctoral research fellowship from Yeungnam University, and Hanyang University South Korea. He

received his M.S. and Ph.D. in 2009, and 2014 from the Department of Physics, Savitribai Phule Pune University Pune, and Shivaji University, Kolhapur, India. His present research interests include chemical synthesis of nanohybrid materials using metal oxides/sulfides and their composites with graphene, and application in energy storage devices as well as gas sensors.

Dr. Ying Li is a Professor and Pioneer Natural Resources Faculty Fellow in the J. Mike Walker '66 Department of Mechanical Engineering at Texas A&M University. Prior to joining in Texas A&M, Dr. Li was a faculty member in the Mechanical Engineering Department at the University of

Wisconsin-Milwaukee (UWM) from 2009 to 2014. Dr. Li's current research focuses on nanomaterials and catalysis for energy and environmental applications, including solar energy harvesting and conversion, carbon capture and utilization, rechargeable batteries, water treatment and desalination, and air pollution control. He has published about 90 refereed journal articles. He received the National Science Foundation (NSF) CAREER Award in 2013.

Dr. Qinglong Jiang is an Assistant Professor (Tenure Track) in the Department of Chemistry and Physics in University of Arkansas, Pine Bluff. Prior to joining in UAPB, Dr. Jiang worked in Argonne National Lab after his postdoc researcher career in Florida State University. His research focuses on nanomaterials and technologies for electric-optical devices, such as halide perovskite for solar cell and light emitting, dye sensitive solar cell, electrochromism, sensors, fluorescence, etc. He has publications on *Adv. Energy Mater.*, *Angew. Chem. Int. Ed.*, *ACS Nano*, *Nano Energy*, *ACS Energy Lett.*, et al.

Dr. Habib M. Pathan currently working as assistant professor at the Department of Physics, Savtribai Phule Pune University Pune since 2008. Before joining there, he worked as a visiting scientist (2004-2007) at Korea Institute of Science and Technology (KIST), South Korea. Recently he was appointed

as a visiting professor at Chonbuk National University Iksan, South Korea. He obtained his Ph.D. in 2003 from Shivaji University, Kohlapur. He founded “Advanced Physics Laboratory” and actively engaged in teaching and research. His research is focused on thin-film deposition, nanostructured material for Dye sensitised solar cells and supercapacitor applications, PEC hydrogen Generation. His accomplishments till now include 205 scientific publications, 04 patents, and 2640 citations. Besides he is also Life Member of Material Research Society of India. Dr. Habib M. Pathan is an Executive editorial board member of *ES Energy and Environment*. He is also an Editorial board member of the *Journal of Material Science: Materials in Electronics*.

Publisher’s Note Engineered Science Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.