Politechnika Śląska

Wydział Chemiczny
Katedra Fizykochemii i Technologii Polimerów

dr hab. inż.
Przemysław Data
Prof. Pol. Śl.

Gliwice, 14.08.2019

Review

of the doctoral dissertation of Amruth C titled "Adaptation of inkjet printing technique and slot-die coating technique for organic light emitting diode fabrication"

The above mentioned doctoral dissertation was conducted and submitted at the Department of Molecular Physics, Faculty of Chemistry of Lodz University of Technology. Supervisors of the thesis are prof. dr hab. inż. Jacek Ulanski and dr hab. inż. Beata Luszczynska. The main topic of the work is an adaptation of mass production solution processing like inkjet printing and slot-die coating techniques.

In recent years, we have witnessed the rapid development of research on new materials for their applications in optoelectronics. This resulted from the fact that organic materials not only exhibit optical and electronic properties but they are able also easy to tailor which is different in comparison to inorganic materials, moreover in the case of conductive polymers whose electrical conductivity sometimes matches that of metals which gives even bigger perspective for practical implementation. At the same time, organic materials

Politechnika Śląska
Wydział Chemiczny
Katedra Fizykochemii i Technologii Polimerów
ul. Strzody 9, 44-100 Gliwice
+48 32 237 15 09 / +48 32 237 19 25 (fax)
rch4@polsl.pl

NIP 631 020 07 36
ING Bank Śląski S.A. o/Gliwice 60 1050 1230 1000 0002 0211 3056

have interesting mechanical properties that inorganic materials do not have, they can be obtained in the form of panels with a large surface area, are lightweight and their production costs are much lower than the costs of producing devices based on inorganic semiconductors. The advantage of low molecular weight organic, polymer and macromolecular materials is their ease of preparation and relatively simple control of the preparation processes for obtaining materials with specific optical and electrical properties. The particular impulse for research on organic photovoltaics, organic light-emitting diodes, organic transistors after 2000, when H. Shirakawa, A. MacDiarmid and A. Heeger received the Nobel Prize in chemistry for achievements in the field of conductive polymers. Currently, many laboratories around the world are conducting research on the development of modern polymeric and low molecular weight organic materials for the production of organic sensors, light-emitting diodes, solar cells, large-area screens but the scientific work on processing of those materials is usually left for the industry. Solution processing is very tricky technique for organic electronics and there are many problems which needs to be solved and as for, the topic of the PhD student research is very current and important for the development in this particular field.

Mr C doctoral dissertation is a set of published work presenting the practical aspects of organic electronic solution processing technology which confirms the quality of overall work. By going step-by-step through all publication and manuscripts we are learning his approach into controlling the emitter in solution process techniques to obtain as highest possible efficiency and stability. The dissertation was split into two main chapters “Introduction to organic and printed electronics” and “Results and discussions”.

The publications present very good work and the information there were well described but as the publication is usually work of many co-authors, I would like to focus on PhD student work described in the main part of the thesis. The information in "Chapter 1" presents the basics of organic electronics and materials parameters which need to be investigated. Mr C divided organic materials into three main class according to their molecular mass and structure which is reasonable approach. In the next part PhD student present the information about organic light-emitting diodes, recombination process and structures and overall information described there are correct but there is some misleading information presented in this chapter which should be answered by the PhD student. In my opinion the sentence on page 3 "The luminance materials can be categorized into three types: (1) fluorescent emitters (2) phosphorescent emitters and (3) TADF emitters." is simply wrong. First of all, the general process can be split into two categories depending on the state from which emission occurs, if the emission occurs from singlet state it's a fluorescence if from triplet state it's phosphorescence. The fluorescence emission could be split into normal fluorescence and delayed fluorescence and then delayed fluorescence could be split into TTA (triplet-triplet annihilation) and TADF (thermally activated delayed fluorescence).

Another misleading sentence on the same page "This dendrimer with carbazole as electron donor and triazine as electron acceptor has ΔES-T of 0.1 eV, which is low enough to convert triplet exciton back to singlet state through RISC", it's not possible to convert triplet exciton into singlet state. It would be really important to explain what was the PhD student meaning to say.

The part of the work explains the role of the particular layer is very informative, although it would be interesting if PhD student could explain how the "holes"

are injected into the layer. The last part of the "Chapter 1" which should be explained is connected with information provided on page 3 "Anode does two purposes; first, the injection of holes into the adjacent organic layer; second, it allows the light to escape from the device; therefore it has to be transparent." Anode does not need to be transparent (inverted structure), moreover all materials used as anode are not like clear materials but they are very thin layers of colour material allowing light to escape. Information provided about solution processing, comparison between techniques, pros and cons are well described presenting the PhD student good understanding of this field of research and his own understanding of the work.

The second part of the thesis "Chapter 2 Results and discussions" present the main work of the PhD student. The information about the processing of the active layers by slot-die coating and printing are well described. The step-by-step analysis of the processing gained information and conclusion are correct and present the analytical and practical skills of the PhD student. What I couldn't find in the description and in my opinion it's important for the research is the processing after printing, spin-coating, slot-die coating. With all the information about processing of the layer by printing and slot-die coating, influence of the parameters etc. I couldn't find information about spin-coating process and what was going on between processing of the layers if the layers were annealed, dried or directly processed in the next step.

In my opinion PhD student did a very good job and I rate the work very highly. The work is written in an understandable language. Tables and drawings have been prepared clearly and readably. The cited literature has been included in the selection of the subject matter of the dissertation and covers 93 items, of which about 57% covers works from the last four years. The doctoral dissertation was

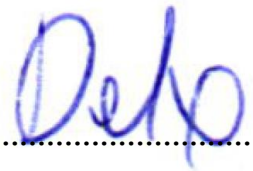
written, nevertheless, there are several mistakes, misspelling in the text and in the literature like ref 78 and 79, this is the same publication, which was written in 2010, not 2009, moreover names and title are written in different way, even it's the same publication. There are several mistakes space and lack of it between numbers and units, additional dots, comas etc. which shows that dissertation could be checked more carefully, nevertheless this is not changing the overall quality of the research work presented in the dissertation.

In the summary of the review, I conclude that the dissertation is a very important contribution to the study of solution process techniques as a way to obtain high efficient organic electronic devices. The presented work is not limited to organic light-emitting diodes but it goes way beyond that and it could be implemented in all the fields or organic electronics. What's more, the PhD student describes how you can significantly increase the performance of such devices and what are the key parameters for their optimization. During the implementation of the planned research, the PhD student achieved his goals. Mr Amruth C demonstrated his ability to conduct experimental work, select appropriate research techniques, the ability to discuss the results obtained against the background of the subject literature and draw conclusions based on the obtained results. The manner of conducting the discussion proves the PhD student's research maturity.

To sum up, I conclude that the doctoral dissertation entitled " Adaptation of inkjet printing technique and slot-die coating technique for organic light-emitting diode fabrication " meets the statutory requirements set out in Article 13 para. l of the Act of March 14, 2003 on academic degrees and academic title

as well as academic degrees and title in the field of art (Journal of Laws 2003 No. 65, item 595, as amended) and I am applying to the Council of the Faculty of Chemistry, Lodz University of Technology for the admission of Mr. Amruth C to the next stages of the doctoral dissertation.

Sincerely,



.....

Dr hab. inż. Przemyslaw Data, Prof. Pol. Śl.