FINAL PUBLISHABLE REPORT

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Period covered (dates)	From	1 August 2015	To	31 July 2017
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1 Executive summary

Introduction

This Support for Impact (SIP) project builds on the improved measurement techniques for water vapour transmission rates (WVTR) of barrier materials developed in EMRP joint research project IND07 Metrology for the Manufacture of Thin Films (Thin Films). These measurement techniques for WVTR are important for high-value technologies, from electronic displays to solar cells, where the barrier materials are used to protect electronic devices from exposure to moisture which can damage performance.

Prior to this project, there was a need for the measurement techniques developed in the IND07 Thin Films to be made available to organisations beyond the metrology community.

This project therefore incorporated the work of the IND07 Thin Films project into standardisation, and supported uptake by European industry. This project has also contributed to the development of traceable measurement WVTR facilities that will enable industry to test innovative thin film materials, commercial instrumentation and electronic devices.

The Problem

One of the biggest challenges for emerging technology based on organic electronics and graphene is assuring the lifetime of the product. These thin film materials are highly sensitive to moisture and oxygen, therefore, reliable measurements to determine the performance of the encapsulating barriers is essential for the future success of this technology. According to different market sources for organic electronics, the forecasts are $77 billion for 2023. In order to support research efforts in the development of suitable barrier materials, there is a vital need for documentary standards providing specific advice to industry and end-users on how to conduct and calibrate measurements correctly. In addition, there is a requirement for a traceable measurement infrastructure to address these needs.

The Solution

The project has worked towards guaranteeing the up-take of the traceable measurement facility developed in JRP IND07 in Europe. Work with the primary supporter (The Centre for Process Innovation) has ensured that protocols and facilities have been developed and implemented in industry to ensure the community has access to the traceability to national standards. Best measurement practice and general quality aspects of barrier layer performance measurements have been developed as a documentary standard with an aim to serve the community to ensure measurements are comparable and traceable.

Impact

Methods currently used in industry for determining the performance and acceptance of barrier materials are typically ad-hoc, inaccurate, untraceable and not harmonised. This project has worked towards equipping industry (e.g. manufacturers of products based on flexible electronics, barrier material producers and instrument manufacturers for measuring encapsulation performance and degradation) with the support and guidance to enable accuracy and consistency for measurements of WVTR leading to adequate encapsulation to be demonstrated. This in turn will optimise encapsulation processes, provide a better understanding of the link between encapsulation performance and device lifetime and inform the development of relevant accelerated testing and accurate lifetime models. This work is essential in underpinning and enabling this future technology. The project has ensured that best practice will be incorporated in a standardisation committee to contribute to accuracy and comparability in the measurement of WVTR.

2 Need for the project

One of the biggest challenges for emerging technology based on organic electronics and graphene is assuring the lifetime of the product. These thin film materials are highly sensitive to moisture and oxygen, therefore, reliable measurements to determine the performance of the encapsulating barriers is essential for the future success of this technology. For example: organic thin film LEDs used in phones and televisions need moisture barriers capable of preventing the ingress of even a few micrograms of water per square metre per day – roughly equivalent to one drop across an area the size of a football pitch over a month.

The preceding project IND07 Thin Films developed a traceable measurement system, which reliably assesses the water protection capability of barrier layers manufactured to protect thin film electronic devices, at these very low levels. This measurement system has the capability to allow industries producing devices such as light emitting diodes and solar cells to determine whether the barrier layers provide adequate protection. However, effective dissemination of the measurement protocols and the know-how developed in the IND07 Thin Films project via documentary standards was challenging due to the technology not being sufficiently mature. Now with barrier materials being used more widely in industry, and the technology having matured considerably across Europe, the need for standardisation to provide specific advice to industry and end-users on how to conduct and calibrate measurements correctly is vital.

The Centre for Process Innovation (CPI) identified the need for written advice and standards supporting best practice, as well as a measurement system accessible to industry and the highest measurement accuracy. CPI is a UK-based technology innovation centre and has very strong links to industry throughout Europe. CPI uses applied knowledge in science and engineering combined with state of the art facilities to enable its clients to develop, prove, prototype and scale up the next generation of products and processes. Therefore, this project worked with CPI to develop a capability for the measurement of WVTR in barrier materials. The project also addressed the need to incorporate the measurement protocols and techniques developed in IND07 Thin Films into international standards, thus supporting their uptake across European industry.

3 Objectives

1. To incorporate the measurement protocols and techniques developed in JRP IND07 into standardisation (e.g. under ISO/TC61 Plastics, IEC/TC 119 Printed electronics and via the Organic Electronics Association (OEA)) to support their up-take and dissemination and in order to enable European industry to make accurate, traceable and comparable measurements.
2. To transfer the knowledge developed in JRP IND07 to the primary supporter (The Centre for Process Innovation (CPI)) and contribute to the development of traceable measurement WVTR facilities that can be used by industry to test and validate innovative thin film materials, commercial instrumentation and electronic devices.

4 Results

Objective 1
To incorporate the measurement protocols and techniques developed in JRP IND07 into standardisation (e.g. under ISO/TC61 Plastics, IEC119 Printed electronics and via the Organic Electronics Association (OEA)) to support up-take and dissemination and in order to enable European industry to make accurate, traceable and comparable measurements.

A new work item has been submitted to ISO/TC61 (Plastics) aimed at providing over-arching guidance for the measurement of the water vapour transmission rate. It considers general quality aspects and the sensitivities of various parameters in the measurement. There is a particular focus on measurements below 1×10^{-4} g m^2 day^{-1} for application in organic electronics, where the largest measurement challenges lie and where there is the most pressing requirement from industry to have confidence in measurement comparability. This work item provides best practice guidance on a range of processes in the measurement such as the test conditions employed (relative humidity and temperature), sample preconditioning, lag-time, specification of the gases and reagents used and the measurement traceability. It will improve measurement comparability and provide a basis for the quality assurance of products. Currently there is a lack of comparability in reported measurements of water vapour transmission rate due to the wide variety of techniques and experimental conditions employed and to differences in opinion about the qualitative and quantitative nature of the methods.

This creates inconsistencies in reported data that impact on the development of barrier materials. There is an urgent requirement for standardisation and this work item proposes this.

NPL chaired and organised a one day stakeholder meeting, on standardisation for encapsulation, in cooperation with the Encapsulation Working Group of the Organic Electronics Association. The meeting was attended by over 30 experts and discussed current standardisation activities for encapsulation of plastic electronics and requirements from a variety of industrial stakeholders. Discussions focussed on general quality aspects and sensitivities in the measurement of water vapour transmission rate, new technologies, adhesives, mechanical properties and test architectures. The outputs from this stakeholder meeting were included in the new work item that was submitted to ISO/TC61.

Objective 2
To transfer the knowledge developed in JRP IND07 to the primary supporter (The Centre for Process Innovation (CPI)) and contribute to the development of traceable measurement WVTR facilities that can be used by industry to test and validate innovative thin film materials, commercial instrumentation and electronic devices.

An infrastructure for disseminating traceability for the measurement of the Water Vapour Transmission Rate (WVTR) of barrier materials has been developed. NPL reviewed the measurement methods currently employed at the facilities of the primary supporter (CPI) during a visit in September 2015. The information and knowledge acquired from the assessment and from JRP IND07, has been used by NPL to develop a plan for how CPI will build facilities to enable them to perform high accuracy measurements of WVTR and calibrations to national standards. NPL visited CPI in June 2016 to advise the scientists of these plans and this was followed by a visit from CPI to NPL a month later to outline the sensitivities of the measurement protocols employed at NPL. This led to an assessment of the facilities for WVTR implemented at CPI and protocols for operation. NPL prepared a protocol for best measurement practice for traceable WVTR measurement facilities for adoption by CPI (2017).

Figure 1 NPL facility for disseminating traceability to industry for measurements of WVTR

5 Impact

Benefits to the immediate user communities

Exploitation of the outputs from IND07 Thin Films has directly benefitted the primary supporter CPI as it has instilled a greater understanding of the sensitivities of various WVTR measurement parameters, such as test conditions used (relative humidity and temperature), sample preconditioning, specification of gases and reagents used and measurement traceability, therefore improving measurement comparability in the measurement of WVTR within CPI.

The project has also resulted in the development of a capability for high accuracy WVTR measurements that is traceable to reference standards. The outputs of IND07 Thin Films were transferred, as part of this project to CPI in the form of guidance on the design and assembly of the facility and subsequent high accuracy WVTR calibrations. This facility benefits customers, who are provided with quality assurance of products and information to assist in the development of barrier materials.

Standardisation

As a result of this project NPL is now leading a group devoted to developing standards for encapsulation of organic electronics which has enabled the outputs from IND07 Thin Films to be exploited and to maximise the up-take by industry. This has been achieved by working with the ISO/TC 61 sub-committee SC11, working group WG3 “Plastics”, to provide input to a new draft documentary standard for WVTR measurements. The outputs of IND07 Thin Films identified the critical parameters in the measurement of WVTR, and their sensitivities with respect to measurement accuracy and uncertainty. The new work item delivered to the committee as part of this project focussed on guidance to improve the accuracy of WVTR measurements and their estimated uncertainties. It used the outputs from IND07 Thin Films to set out the most critical parameters in the measurement equation so that these are considered and adopted in measurement facilities for WVTR worldwide. This widespread adoption has already started with CPI and its customers, and will provide the basis for future improvements in international comparability of WVTR measurements.

International industrial bodies such as the OEA recognise encapsulation as one of the major considerations in the quest to make applications based on flexible and printed electronics viable. The working group dedicated to encapsulation highlighted a critical need for standardisation, accuracy and more reliability in measurements of the WVTR of barrier layers. Involvement in this OEA working group has resulted in the dissemination of outputs to the relevant communities of manufacturers, suppliers and end-users. Direct beneficiaries of this include manufacturers of products based on organic electronics and graphene, barrier producers, instrument manufacturers for measuring degradation and encapsulation, standardisation committees, testing labs and the metrology community who have benefitted from better quality data for WVTR to aid their decision making.

Potential Impact

By supporting the adoption of new measurement methods through the development of new standards, the work of this project will encourage innovation within the advanced manufacturing industry. By underpinning the development of high efficiency, low cost photovoltaic devices, it will also have a substantial impact on the environment. Specific examples of wider benefits resulting from greater measurement reliability are:

- Greater accuracy in assessing the performance and suitability of water vapour barrier layers.
- Increased support for instrument developers needing to assess encapsulation performance through accurate measurements of WVTR.
- Reduced time to market for new products from organic electronics developers by greater rigor in assessing material stability and barrier performance.
- Increased product reliability through better comparability of material data between different organisations.

6 List of publications

N/A

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