# Nanoengineered barrier invented to protect plastic electronics from water degradation

**A breakthrough barrier technology from Singapore A*STAR's Institute of Materials Research and Engineering (IMRE) protects sensitive devices like organic light emitting diodes (OLEDs) and solar cells from moisture 1000 times more effectively than any other technology available in the market, opening up new opportunities for the up-and-coming plastic electronics sector.**

A team of scientists from Singapore's Institute of Materials Research and Engineering (IMRE) has developed a new patented film that has the highest reported water vapour barrier performance to date, as tested by the UK Centre for Process Innovation.

The tests have shown that the new film is 1,000 times more impervious to moisture than existing technologies. This means a longer lifetime for plastic electronic devices such as solar cells and flexible displays that use these high-end films but whose sensitive organic materials are easily degraded by water vapour and oxygen.

The new technology is a boon to the burgeoning plastic electronics industry that aims to deliver flexible, lightweight and cheap electronics products to consumers in ways that silicon electronics may never reach such as disposable or wraparound displays, cheap identification tags, low cost solar cells and chemical and pressure sensitive sensors.

A research institute of the Singapore's Agency of Science, Technology and Research (A*STAR), IMRE's breakthrough technology comes as Singapore seeks to jumpstart a plastic electronics industry locally as part of the country's long-term plan to anchor new knowledge-intensive industries in the economy.

The global plastic electronics industry is projected to grow to a market size of more than US$23 billion in the next 5 years .

The performance of devices like organic light emitting diodes (OLEDs) and solar cells is sensitive to moisture because water and oxygen molecules seep past the protective plastic layer over time and degrades the organic materials which form the core of these products.

Current commercially available films used to protect these materials have a barrier property or water vapour transmission rate  of about 10-3g/m2 per day, or one thousandth of a gram per square meter per day at 25°C and 90% relative humidity (RH).

However, the ideal film for organic devices would require a barrier property of better than 10-6g/m2/day at 39°C and 90% RH, or one millionth of a gram per square meter per day.

Defects such as pinholes, cracks and grain boundaries are common in thin oxide barrier films when fabricated onto plastic substrates. These defects cause a 'pore effect', where oxygen and water molecules are able to seep through and penetrate the plastic barrier.

Current barrier technologies focus on reducing these defects by using alternate organic and inorganic multi-layers coated on plastic. These multiple layers "stagger" corresponding pores in adjacent layers and create a 'tortuous', lengthy pathway for water and oxygen molecules, making it more difficult to travel through the plastic.

In contrast, IMRE has taken an innovative approach to resolve the 'pore effect' by literally plugging the defects in the barrier oxide films using nanoparticles. This reduces the number of barrier layers needed in the construction of the barrier film down to two layers in this unique nanoengineered barrier stack. IMRE's barrier stack consists of barrier oxide layers and nanoparticulate sealing layers.

The nanoparticles used in the barrier film have a dual function - not only sealing the defects but also actively reacting with and retaining moisture and oxygen.

The result is a breakthrough moisture barrier performance of better than 10-6g/m2/day, or one millionth of a gram per square meter per day, which surpasses the requirements for flexible organic device substrates.

The barrier film also has a lag time of more than 2300 hours at 60°C and 90% RH (i.e. the time required for moisture to pass through the barrier film under those conditions).

These plastic barrier properties were tested and validated by the Centre for Process Innovation, UK.

“With a level of protection that surpasses the ideal requirements for such films to date, manufacturers now have the opportunity to extend the lifetime of plastic electronic devices by leaps and bounds!," says Senthil Ramadas, principal investigator of the project.

A stumbling block in developing ultra-high barrier substrates has been the availability of an appropriate testing methodology.

Overcoming this hurdle, the IMRE project team has developed a highly sensitive moisture and oxygen permeation measurement system in tandem with the development of the film which is able to effectively measure permeation of less than 10-8g/m2/day. This system has been successfully implemented in a number of service based industry projects.

Adds Senthil, “Together with our expertise in encapsulation processes and permeation measurement technologies we are also able to provide a total solution package for industries such as flexible solar cells and OLED displays producers”.

Recognising the potential of the high performance substrate technology, Exploit Technologies Pte Ltd (ETPL), the commercialisation arm of A*STAR, has funded the team through a ‘flagship project’ that seeks out research with excellent commercialisation potential.

Boon Swan Foo, the Executive Chairman of ETPL said, “Exploit Technologies sees commercial potential in A*STAR IMRE's breakthrough barrier film technology. It has excellent promise for enabling the fast growing plastic electronics industry. We want to take this technology from the lab to the market.”

“The research team is already in talks with solar cells and flexible displays and lighting industry manufacturers who are currently evaluating the barrier films for product qualification”, says Dr. Mark Auch, a member of the IMRE team who is actively involved in the commercialization of the technology.

IMRE has already signed agreements with a number of companies to advance the technology into the commercial domain. This includes a collaboration agreement with G24Innovations, a thin film solar cell manufacturer to look into developing the films for use in solar cells.

Clemens Betzel, the president of G24Innovations, who was in Singapore for the signing of the cooperation agreement, said, "The cutting edge work of IMRE's Barrier Substrates is likely to mean significant progress for Dye Sensitized Solar Cells, as exclusively manufactured today by G24I. We are looking forward to broadening our relationship with IMRE in the coming months."

IMRE has also signed a commercialisation agreement with KISCO (Asia), a subsidiary of the Japanese parent company KISCO Ltd., to commercialise and market the barrier films in the Asia Pacific region.

“We have a long-standing research relationship with IMRE and are very familiar with their work. We have high confidence in the quality of IMRE’s barrier films and we believe, that this partnership will be beneficial to both parties,” says  Albin Tan, General Manager of KISCO (Asia), Singapore.

Current barriers have a series of alternating polymer and metal oxide layers that make up the plastic. This staggers adjacent ‘pinholes’, natural defects in the layers, thus slowing the passage of moisture and air through the ‘pinholes’.

The secret behind the effectiveness of IMRE’s technology lies in the unique barrier stack design, where nanoparticles are used when layering the barrier films. The design has a special layer of nanoparticles between the “pinhole” oxide layers. The innovativeness becomes clear as the nanoparticles “plug” the gaps and cracks in the oxide layer thus making for a more impermeable layer. In addition to sealing of oxide barrier film’s defects, the nanoparticles absorb and retain the water and oxygen molecules. This concept helps reduce the number of barrier stacks to two or three only.

IMRE has successfully resolved the ‘pore effect issue’ in multi-layered barrier stacks and developed ultra high barrier plastic substrates (barrier properties
Source: Agency for Science, Technology and Research (A*STAR), Singapore