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Loughborough's track record in solar

Mention **Loughborough University** and the conversation usually turns to sport and how this University has long been a breeding ground for International sports stars and Olympic athletes. Famous alumni include Sebastian Coe, Steve Backley, Paula Radcliffe…the list goes on. In solar circles, the University is now making a name for itself as a centre for photovoltaic research and development. In particular, CREST, the University's Centre for Renewable Energy Systems and Technology, is establishing a reputation for working on successful PV projects relevant to today's industrial requirements. Here, **Michael Walls one of the Loughborough PV team,** outlines some of the capabilities on offer.

CREST was set up in 1993 following a generous donation to Loughborough University by Tony Marmont a successful local entrepreneur and philanthropist. Since then, the Centre has grown steadily and is now housed in an impressive facility in the University's Holywell Park research complex. CREST now has state of the art facilities for crystalline silicon, thin film and excitonic photovoltaics, world class cell and module testing, together with strong activities in concentrators, BIPV and solar-thermal. Relevance and co-operation are the key words used to describe the ethos of the Centre. CREST welcomes the opportunity to work with solar companies and other research organisations throughout the world. Here we outline some of the activities at CREST.

Crystalline silicon PV

Crystalline silicon (c-Si) is the dominant technology for today's photovoltaic modules representing over 80% of the market in 2009. Leading manufacturers produce cells with efficiencies over 20%. c-Si solar panels have exhibited excellent long term reliability and performance over decades of utilization. The challenge for c-Si, as with the other technologies, is cost reduction.

The c-Si Laboratory at Loughborough has facilities on an industrial pilot plant scale with two diffusion furnaces, Nd-Yag and a Copper Vapour lasers (CVL), wet chemical benches, electroless plating and a two reactive sputtering units. The Lab has capability to produce both screen printed silicon cells and Laser Grooved Buried Contacts (LGBC).

The cost of the processed silicon wafer represents a significant fraction of the cost of the PV module. Research at CREST is focused on reducing this cost either by thinning the wafer while maintaining efficiency or by using lower cost silicon reclaimed from electronics applications. Research is also underway on Concentrator photovoltaic (CPV) systems in which optically concentrated sunlight is focused on smaller area cells thereby cutting the cost of the bulk material. CPV is best achieved using cells with LGBC contacts, a specialist technology at CREST.

Thin Film Photovoltaics

Thin film photovoltaics, and particularly those based on CdTe absorbers are rapidly gaining market share. In 2009, First Solar Inc, a thin film CdTe manufacturer shipped over 1GW of capacity making it the largest PV company world-wide.

The Centre's work on thin film photovoltaics is primarily based on thin film CdTe and CIGS. In both cases, the work is focused on devising new processes for lowering the cost of PV modules either by improving efficiency or by devising processes that are automated, continuous and which make most efficient use of materials.

A large scale magnetron sputtering tool is being used to devise new processes for each of the layers in the thin film CdTe stack. Sputtering produces thin films with uniformity in the +/- 1% range which is far superior to the conventional close space sublimation technique. This allows the absorber thickness to be optimised which also has implications for downstream module production processes. CREST is working with a number of industrial partners on improving cell efficiency, building integrated products and novel interconnect processes. The equipment used is capable of producing 300 x 100mm mini-modules, but the processes developed are scaleable to industrial scale in-line production tools.

The Centre has a number of other deposition tools and another area of focus has been the development of improved or lower cost transmitting conducting oxides (TCO's). One outcome of this work has been the development of processes that lead to the deposition of super-smooth ITO. Smoothness of the TCO is important since the CdS buffer layer is very thin and roughness in the TCO can cause shunting.

Cell and Module performance

CREST is particularly strong in measuring cell and module performance and has a long history of working with and providing services to the solar industry. The Centre has a large group working on understanding the risks associated with installing modules and systems. Their work has shown that the main risk involved in any PV installation is in the energy yield of systems. This tends to be dominated by system up-time and the initial rating of the modules, which are both key areas of research. Failure mode analysis of fully encapsulated modules using innovative techniques such as luminescence measurements or laser-beam induced current measurements are helping to develop a better understanding of these risks.

Work ranges from physical modelling of device structures to evaluate if certain structures have a benefit in the energy yield over competing approaches through to quality assurance of large scale systems. An emphasis is placed on understanding and modelling module performance. This involves power rating using a large area solar simulator, durability investigations as well as energy yield estimations. These measurements underpin the development of models for the long-term energy yield of modules using all technologies. CREST is active in investigating the idiosyncrasies of new and emerging device technologies and investigating the homogeneity of large area modules.

Researcher measures the response of a BIPV module in Loughborough's Solar Simulator.

The characterisation of modules and systems often reveals the limitations of commercially available equipment and another focus is the development of the equipment required for high performance characterisation. As an example, CREST has developed a high performance Class A LED based solar simulator.

Concentrators and Solar thermal

In parallel with the work on c-Si devices specifically designed for CPV, another team is looking at the optical design, thermal management and performance of concentrator PV systems with concentrations ranging from 2.4x to 300x. Building integrated PV façade systems have been designed

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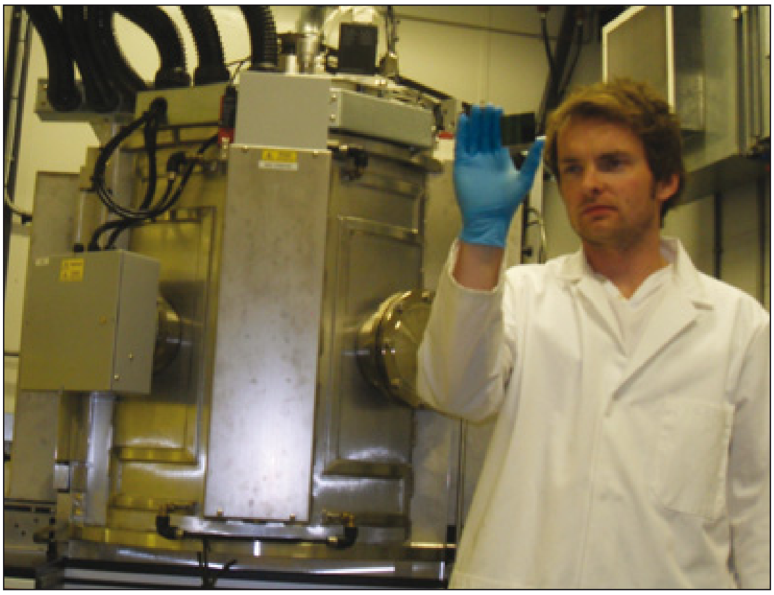

Jake Bowers inspects a thin film CdTe PV device deposited using magnetron sputtering

that utilise asymmetric compound parabolic concentrators which are non-tracking and provide concentrations of 2.45x with efficiency and performance similar to a standard silicon module. Optical performance and heat sinking requirements for concentrations in the range from 50x to 300x have also been examined with ray trace and finite element heat transfer models developed. Collimated solar simulators have been developed to enable indoor characterisation of line-axis and point focus PV concentrator units. Infra-red thermography is utilised to non-intrusively measure temperatures for the analysis of heat flow.

Work in the area of solar thermal systems includes the design, development and characterisation of efficient Compound Parabolic Concentrators for regions with high diffuse radiation fractions, applications including water heating and driving building cooling systems. Research is ongoing to develop high energy density thermal storage for a range of temperature applications from 55 to 200ºC. The modelling techniques used include a suite of in-house developed ray trace and finite element/finite volume heat transfer models that can be adapted to suit particular applications.

Building-Integrated PV

As the cost of PV reduces towards 'grid parity', the rate of expansion of the PV industry will continue to increase rapidly. Building integrated products, which comprise an integral part of a building's façade, windows, walls or roof will form a significant proportion of this expanding market, and so are an important focus for research and development at CREST.

CREST has been active in BIPV since 1995 when it was involved in the development of one of the world's first ventilated PV facades at the Mataro library in Barcelona. Since then, capabilities have been developed in both pre-construction performance assessment and post-construction metrology. Today, this involves advanced dynamic simulation of whole-system PV performance along with comprehensive real-time monitoring of a wide range of building-integrated products in the field to support the development of optimal next generation mass market building-integrated PV products. To this end, CREST collaborates with leading industry partners world-wide including building procurers, architects, developers as well as PV technology and power conditioning equipment manufacturers.

Working with the Solar Industry

With expertise across the board of PV technologies and its range of applications, CREST offers a comprehensive resource for small and larger organisations interested in developing solar products. The Centre possesses a range of solar characterisation and assessment tools and access to state of the art ion and electron optical techniques and surface analysis tools. The team is capable of taking on both short term and longer term R&D projects. Staff training and secondments can also be arranged.

The team at CREST is responsive to commercial pressures and running fast at Loughborough has always been a particular strength. CREST is establishing a useful track record in PV.

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