Institution: PHYESTA (Physics at Edinburgh and St Andrews)

Unit of Assessment: UoA 9 - Physics

Title of case study: A Wearable Light Source for Ambulatory Treatment of Skin Cancer and Acne

1. Summary of the impact

Impact: Health and Economic Gains:
Research has led to a wearable light source that provides a new way of treating many skin cancers and acne. The treatment is safe, convenient, and easy to use bringing benefits to patients and healthcare providers. In addition it brings economic benefits to Ambicare Health Ltd, the company commercialising it.

Significance
For skin cancer treatment, the device gives effective treatment with much reduced pain. The simplified treatment procedure allows more patients to be treated in a clinic session. For acne, the device provides a convenient at-home treatment without the application of drugs or chemicals.

Beneficiaries:
Skin cancer and acne sufferers, the clinics that treat them and Ambicare Health Ltd.

Attribution:
The work was led by Professor Ifor Samuel (PHYESTA) working with Professor James Ferguson (Ninewells Hospital, Dundee).

Reach:
The wearable light source has changed treatment in the UK and the Netherlands. The skin cancer treatment is in regular use at more than 25 clinics, and the acne treatment at more than 250 clinics.

2. Underpinning research

Research in optoelectronics has been a major activity in PHYESTA in recent times. An important aspect of Prof Samuel's work since 2000 has been organic semiconductor optoelectronics, including organic light-emitting diodes (OLEDs). OLEDs are compact visible light sources with the potential to be flexible. They consist of thin layers of organic semiconductors in between suitable contacts. Research in the Organic Semiconductor Centre covers many aspects of these devices – materials, photophysics, device physics, optical design and applications. Materials research focuses on solution-processed materials such as conjugated dendrimers and polymers. Photophysics concerns the formation and nature of the excited state responsible for light emission. Device physics includes charge injection and transport, and optical design concerns light out-coupling and ways of manipulating it. This research has led to understanding of the factors controlling OLED efficiency and routes to improve it, together with the capability to make efficient devices to a high standard [R1, R2].

It is known that light, in combination with a photosensitiser can be used to treat many cancers, a process called photodynamic therapy (PDT). In the case of skin cancer, a cream is applied to the lesion to be treated, and the cream is metabolised to the photosensitiser. The photosensitiser is then illuminated by a powerful light source (often a laser) leading to the tumour being destroyed. This procedure gives very good cosmetic outcome, though requires spending a day at the hospital and can be painful. The need for specialised equipment means that relatively few centres (7 in Scotland) are able to offer this treatment. A discussion with Prof Ferguson, Head of Photobiology at Ninewells Hospital led to the idea of using a wearable (and disposable) light source instead of the current bulky and expensive hospital-based light sources, and a patent on this invention was filed late in 2001 [R3], and an alternative implementation filed in 2006 [R4].

In subsequent research, a major part of which was supported by proof of concept funding from Scottish Enterprise, wearable light sources suitable for medical use were made in St Andrews and evaluated at Ninewells hospital, The concept of an ambulatory light source for medical and cosmetic purposes was implemented using both organic and inorganic light-emitting diodes [R4]. The former gives a more compact light source and more uniform illumination; the latter is easier to manufacture in a conventional electronics factory. After initial clinical evaluation [R5], the OLED device was successfully used in a pilot trial that showed equivalent effectiveness and much-reduced pain in the treatment of skin cancer [R6].

The above research was a major part of research recognised through the award of the Beilby Medal and Prize to Prof Samuel. This medal is awarded by the Institute of Materials, the Royal Society of Chemistry and the Society for the Chemical Industry for materials research of exceptional practical significance. International recognition of its practical significance came through the Organic Semiconductor Centre winning the Academic R&D award at Printed Electronics USA, the world's largest printed electronics meeting.

Personnel:
Key PHYESTA researchers involved were Professor Ifor Samuel (2000-Present) with Dr Miguel Camacho Lopez (PDRA 2002-2003) and Andrew McNeill (PDRA 2003-2007)

3. References to the research

The quality of the underpinning research is best indicated by R1, R2 and R6. *[Number of citations]*

[R1]	J.P.J. Markham, S-C. Lo, S.W. Magennis, P.L. Burn and I.D.W. Samuel , "*High efficiency green phosphorescence from spin-coated single-layer dendrimer light-emitting diodes*", Applied Physics Letters **80**, p. 2645, (2002), DOI: 10.1063/1.1469218, URL: tinyurl.com/kyqmcng, *[172]*
[R2]	S.C. Lo, N.A.H. Male, J.P.J. Markham, S.W. Magennis, P.L. Burn, O.V. Salata and I.D.W. Samuel, 'A green phosphorescent dendrimer for light-emitting diodes',Advanced Materials, **14**, p. 975 (2002) DOI: 10.1002/1521-4095(20020705)14:13/14<975::AID-ADMA975>3.0.CO;2-D URL: tinyurl.com/mfqg55v, *[250]*
[R3]	I.D.W. Samuel and J. Ferguson, '*Therapeutic light-emitting device*', UK patent application GB20010027581 filed 17/11/2001 and associated international applications
[R4]	I.D.W. Samuel, J. Ferguson and A.P. McNeill, 'Light-emitting device for use in Therapeutic and/or Cosmetic Treatment' UK patent application GB20060008315 filed 27/06/2006 and associated international applications
[R5]	H. Moseley, J.W. Allen, S. Ibbotson, A. Lesar, A. McNeill, M.A. Camacho-Lopez, I.D.W. Samuel, W. Sibbett and J. Ferguson, '*Ambulatory photodynamic therapy: A new concept in delivering photodynamic therapy*', British Journal of Dermatology, **154**, p. 747 (2006), DOI: 10.1111/j.1365-2133.2006.07145.x, URL: tinyurl.com/k2ttz5h, *[25]*
[R6]	S.K. Attili, A. Lesar, A. McNeill, M. Camacho-Lopez, H. Moseley, S. Ibbotson, I.D.W. Samuel and J. Ferguson, '*An open pilot study of ambulatory photodynamic therapy using a wearable low-irradiance organic light-emitting diode light source in the treatment of nonmelanoma skin cancer*', British Journal of Dermatology, **161**, p.170 (2009), DOI: 10.1111/j.1365-2133.2009.09096.x, URL: tinyurl.com/n8ctfv2, *[23]*

4. Details of the impact

The research on OLEDs including device fabrication capabilities provided the opportunity to make compact wearable light sources for skin cancer treatment. In order to realise this vision (as mentioned briefly above) we applied for and received a "proof of concept" grant from Scottish Enterprise to make a demonstrator device whose initial evaluation was conducted at Ninewells Hospital. Further support from Scottish Enterprise, led to the fabrication of further devices in St Andrews, which were used in a

pilot trial demonstrating the potential of OLEDs for the photodynamic therapy of skin cancer.

In order to enable the above research to be widely used, the prototype devices made in the research outlined above needed to be developed into a form suitable for regulatory approval and manufacture. The regulatory approval of a medical device is a major task requiring extensive design and testing to appropriate standards and so is both expensive and time consuming. In order to address this, a spin-out company, Ambicare Health Ltd was formed, and £2M of venture capital raised a the start of 2008.

This funded the development of skin cancer and acne products following the ISO13485 standards for medical devices and leading to CE marking of both devices, thereby enabling them to be sold in all countries of the European Union [S1]. In addition the skin cancer treatment has regulatory approval in Australia, a major market for skin cancer treatment. A further £2M of venture capital has been raised since to support the manufacture and marketing of these products. The product for skin cancer treatment is called "Ambulight" and the acne treatment is called "Lustre" [F1]. The official unveiling of the Ambulight product led to a wide range of press and media interest and featured in many major UK and international newspapers and on popular TV shows. [S2]

The research has led to health and economic benefits. The economic impact to date is primarily in the form of licence, assignment and royalty fees paid by Ambicare Health and totalling [text removed for publication]. By simplifying treatment, and increasing the number of patients treated per clinic (see below), there are also economic benefits to the treatment provider (e.g. NHS) but we have not been able to quantify these.

The healthcare benefits of Ambulight are described in a letter by the Joint Head of Photobiology at Ninewells Hospital [F2], who was not involved in the development of the device, but has been performing research on its effectiveness and is in charge of delivering Photodynamic Therapy at the hospital. In the letter she explains that conventional PDT is an effective treatment, but the light sources "*include expensive lasers and relatively cumbersome static polychromatic, predominantly LED sources*". She explains "*there are limitations with hospital-based PDT and these include the fact that only a limited number of patients can be treated in any one clinic session because of the availability of specialised hospital-based light sources; the patient needs to wait for a 3 hour period whilst the cream is in place and therefore this involves at least a half-day visit to the hospital' the high intensity of the light delivery using the hospital sources causes pain which in approximately 16-20% is severe. ……. Pain has resulted in patients discontinuing treatment prematurely and therefore not having effective therapy …..It also limits the wider acceptance of PDT. …Hospital-based irradiation also requires that the patient must lie still. Eye protection is needed for both the patient and staff..*"

The Ambulight device overcomes these limitations, providing a convenient and comfortable treatment with advantages for both the patient and the treatment provider. She explains "*The Ambulight device has revolutionised many of the problems we have with conventional PDT. It is a portable, wearable light source with battery pack. This means that it is ideally suited for patients who are mobile and/or keen to have treatment at home. It also considerably reduces the amount of time that the patient must attend the hospital and reduces the amount of input from staff such that the through-put of the clinic can be greatly increased.*" [F2]

She explains that Ambulight is effective and addresses the problem of pain in conventional PDT. For example she comments on a recent study conducted in which "*we have reported on 53 patients with 61 lesions …who were treated with Ambulight PDT and, again, pain scores were low, but importantly efficacy at one year follow-up was high with 84% of lesions being clear."* [F2]

She adds "*Thus to summarise, Ambulight PDT is extremely convenient, easy to use, associated with low levels of discomfort and is highly effective for the treatment of these superficial non-melanoma skin cancers and dysplasia. The use of these devices allows greater through-put and efficiency of the PDT clinic and thus has major benefits both for the patients, allowing them a comfortable, portable, effective home-based treatment, but also for the running of the PDT clinic. The treatment procedure is simplified and the number of patients that can be treated in any given clinic session increased. With regard to the bigger picture, Ambulight PDT certainly enhances the wider acceptance of PDT in the community as pain had been a limiting factor for some referrers to the service. Ambulight PDT now has a very important role in our own PDT services and my understanding is that it has now been taken up in many centres. Feedback indicated that 27 centres in the Netherlands are now using Ambulight PDT, and*

uptake is ongoing in the UK. Thus, it has made a significant impact in terms of change of practice in how we deliver PDT." [F2]

The Principal Scientist at Ambicare Health has also written confirming the above points about Ambulight Multi [F1]. He also explains the Lustre product: "*Lustre is a wearable light source for acne treatment with blue light. Acne has a major impact on the lives of many sufferers, and in a clinical trial we have shown that Lustre offers major advantages in reducing lesions. The advantage of Lustre is that it enables acne to be treated in the comfort of the home, and without drugs or chemicals.*"

He adds "*Blue light therapy for the treatment of acne has been around for many years, however existing treatment typically come in one of two forms; torches that are held to the face by the user, or lamps that shine remotely onto the skin. Both are highly inconvenient, particularly in a home setting and consequently users are highly unmotivated to use them. This leads to low treatment compliance and ultimately poor efficacy. Lustre in contrast, is a light weight wearable device that allows users to get on with their lives; this ease of use promotes compliance and ultimately efficacy. This is very appealing to acne sufferers and doctors treating them. At present Lustre is being sold mainly in the Netherlands and the UK. It is in regular use in over 250 clinics in the UK."* [F1]

He also comments "*In 2012 the Lustre Pure Light device won the Aesthetic Industry Awards, Product innovation of the year.*" [F1]

5. Sources to corroborate the impact

[F1]	Factual statement by Principal Scientist, Ambicare Health Ltd. *Corroborates the history of the translation of the device into a commercial product. Describes acne treatment device.*
[F2]	Factual statement by Consultant Dermatologist, Ninewells Hospital, Dundee *Corroborates the clinical use od devices devloped and impacts of the skin cancer treatment.*
[S1]	www.ambicarehealth.com/lustre_blog/ambicare-announces-partnership-agreements-and-ce-marks/ *Corroborates the CE marking of the Ambicare devices.*
[S2]	www.ambicarehealth.com/in-the-press/ *Corroborates the press coverage of the Ambulight device.*