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Proceeding Paper

Nexus between Building-Integrated Photovoltaics (BIPV) and Cultural Heritage: Optical Characterisation of Screen-Printed Traditional Symbols on Solar Cells †

Samuel A. Awuku [1,*], Amar Bennadji [2], Firdaus Muhammad-Sukki [3], Radhakrishna Prabhu [1] and Nazmi Sellami [3]

1 School of Engineering, Robert Gordon University, Aberdeen AB10 7GJ, UK; r.prabhu@rgu.ac.uk
2 Van OlstBorg, Hanz University of Applied Sciences, Groningen, Zernikeplein 7, 9747 AS Groningen, The Netherlands; a.bennadji@pl.hanze.nl
3 School of Computing, Engineering & the Built Environment, Merchiston Campus, Edinburgh Napier University, 10 Colinton Road, Edinburgh EH10 5DT, UK; f.muhammadsukki@napier.ac.uk (F.M.-S.); n.sellami@napier.ac.uk (N.S.)
* Correspondence: nanaawuku021@gmail.com

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Abstract: This preliminary study adopts a screen-printing technique to transfer traditional Adinkra symbols onto monocrystalline solar cells. The study reveals that custom patterns for the top contact design of solar cells are achievable through direct screen-printing. The printed cells were cured at 200 °C for 30 min and optically assessed through the Leica wild M3Z Microscopic scanner under 50 µm, 100 µm and 200 µm. It was noticed that the outlines of the printed symbols were not as smooth and bonded as compared to the original cells which could potentially have a negative impact on the overall efficiency of the cell.

Keywords: building-integrated photovoltaics (BIPV); aesthetics; Adinkra symbols; optimisation; screen-printing; solar cell performance

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1. Introduction

Recent policies and legislative frameworks on promoting renewables in the built environment have given rise to the adoption of modern solar applications such as building-integrated photovoltaics (BIPV) [1]. Ordinarily, this appears congenial; however, it threatens the preservation of most historic towns, cities, protected landscapes, and buildings [2]. Building rehabilitation and preservation as part of pre-industrial architectural heritage has become a widely researched area especially as the push for energy-efficient building components increases [3]. Technically, because BIPV are replacing essential building components such as façade, roofs, and windows, it is expected to concomitantly achieve their aesthetics and energy-producing capability. However, the major challenge is that in areas of high cultural values, BIPV are expected to function beyond their regular energy-producing abilities and aesthetics. If premium attention is placed on preserving cultural and architectural heritage, then BIPV must be designed to contain traditional symbols, which mostly have a deep philosophical meaning to the locals [4].

The idea of integrating traditional symbols in BIPV design is new; however, our previous studies have shown that it promises to boost BIPV adoption, especially in high-cultural societies [5]. This preliminary study demonstrates the use of screen-printing techniques to transfer traditional symbols (Ghanaian Adinkra symbols) onto monocrystalline solar cells and their optical characteristics.

2. Screen-Printing Method

Screen-printing is a traditional process which involves the use of force to push ink usually through an organdie mesh onto a substrate to create a pattern, text, or illustration [6]. The idea is to create a stencil with the notion of making the negative image area impervious to ink. Ink is only allowed through the positive area, which registers on the substrate.

The process involves tightly stretching the organdie fine mesh onto a wooden or metal frame, after which a stencil is created. Stencils can be created from a wide range of approaches and materials. These include fabric, stencil paper and greasy paint. Stencils can be applied on a screen in diverse ways. For instance, they can be placed directly under the screen for printing or transfer the design onto the screen by using a photo-sensitive paint. Once the design has been transferred, the squeegee can be used to force the ink through the mesh onto the substrate. Key stages of screen-printing include the organisation of general materials, pattern creation, conductive paste preparation, substrate preparation, curing, and cell characterisation.

2.1. Organisation of General Materials

2.1.1. Ink and Substrate Preparation

The conductive silver paste was used for printing. It was stored in an air-tight container at room temperature and stirred to ensure a uniform mixture before printing. The substrates (RESERV 626) were processed through acid texturization to ensure they had an isotropic textured surface. Cells were tested for mechanical discrepancies; however, the same cannot be said for electrical performance.

2.1.2. Pattern Creation

This study adopts different types of top contact patterns which are created by the Adobe Photoshop and Illustrator software. In all, three traditional symbols were selected and modified using design principles for the experiment. The symbols were mainly selected based on their layout and replicability. The symbols adopted for the experiment were "Nea Onnim no sua" (He who does not know learns), "Dwennimmen" (humility and strength and "Gye Nyame" (Except God). Some areas of the patterns were made to connect and overlap to improve the flow of current through the cell. Design techniques such as half drop, side by side and repetition were adopted [7]. The positive and negative ratios of the images were between 21% and 29%.

The designed patterns were transferred onto a screen. The screen was made of a square wooden frame with mesh tightly stretched to fit all four edges. The screen was then coated with a thin layer of light-sensitive photo emulsion. A dark room was required for this activity due to the light sensitivity of the chemical. The screen was allowed to dry and placed on the shooting box with the design ready for transfer. It was later exposed to light and rinsed.

2.1.3. Thermal Curing

The curing process involves heating the printed solar cell to a specific temperature for a certain amount of time to ensure that the ink is fully cured and adheres to the substrate. In this study, an oven was used and printed cells were cured at 200 °C for 30 minutes to ensure compatibility and solid bonding.

2.2. Screen-Printing Steps

The steps followed to ensure a successful setup for the screen-printing are summarized in Figure 1.

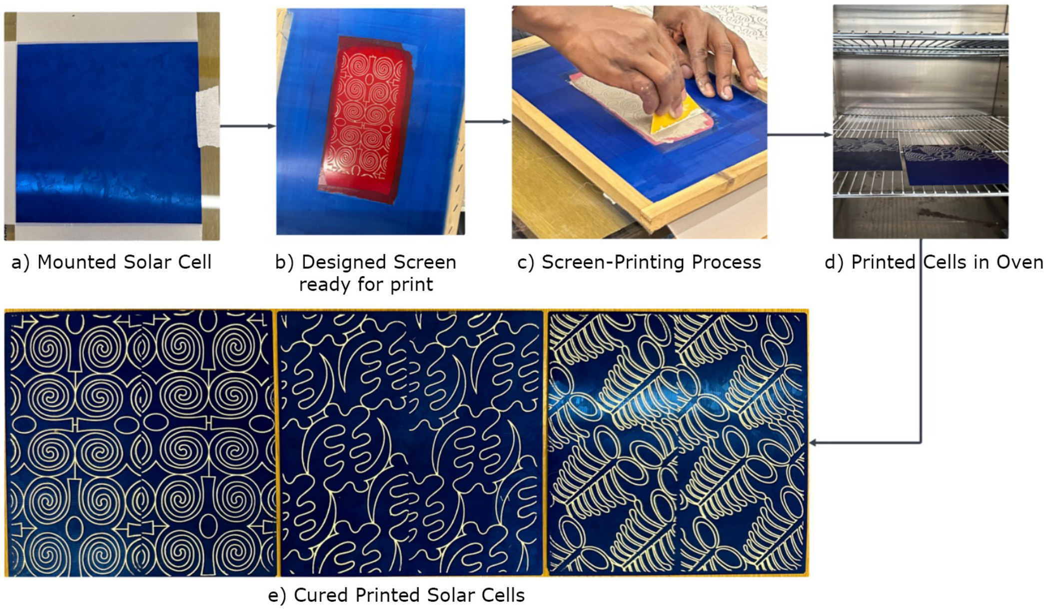

Figure 1. Diagrammatic illustration of the screen-printing process.

3. Optical Characterization by Leica Wild M3Z Microscopic Scanner

Evaluation of the microscopic scanning of the printed solar cell is a crucial step in the production and study of solar cells. Its primary objective is to evaluate the printed top contact for consistency, quality and printing flaws. Figure 2 shows line widths of 50 µm, 100 µm and 200 µm, respectively, which shows consistent print and perfectly bonded ink.

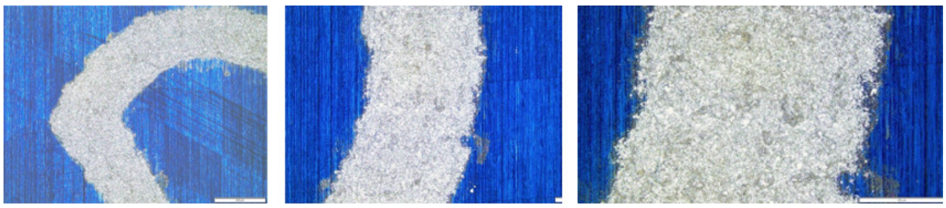

Figure 2. Microscopic image of printed lines on solar cells—50 µm, 100 µm and 200 µm.

The print quality as shown above appears to have continuity and bonding, which are essential for cell efficiency. A clear difference though is the fact that they do not appear as smooth and even as the original cell.

4. Discussion

As shown above, it is possible to print custom shapes and patterns on solar cells. Although the idea of using different methods for solar cell printing is not new, [8] this is the first time a study is exploring the printing of traditional symbols on solar cells.

Using the screen-printing technique to transfer traditional symbols onto solar cells is an innovative and novel approach that combines art with modern sustainable building technology. Three Adinkra symbols were successfully printed on monocrystalline solar cells and cured at 200 °C. The outcome was aesthetically appealing; however, the printed solar cell appeared different from the conventional cell. The printing appears slightly imperfect and characterised by thicker line widths. Overall, this experiment shows that creating custom-made top contact patterns is feasible and can potentially blend art and technology for tailored solar cell designs.

5. Conclusions

Screen-printing approach was adopted to test the feasibility of printing traditional symbols on solar cells. The outcome reveals that screen-printing is viable for transferring custom top contact designs onto solar cells. Although a mere assessment of the printed cells revealed perfect and uniformly bonded metal particles, the microscopic characterisation indicated imperfect bonding. This tends to affect the electrical characterisation of the solar cell. This study therefore recommends a further investigation into the electrical optimisation and characterisation of printed solar cells to establish the commercial viability of this novelty. This study is expected to promote the adoption of BIPV especially in cultural societies.

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