

## Printed Sun Sensors for Satellites

N. Marjanović, J. Disser, F. Zanella, J. Schleuniger, A. Mustaccio, R. Ferrini, M. Schnieper

The developed sun sensor comprises inkjet printed organic photodiodes, printed resistors and capacitors, high-end Si-based SMDs and operational amplifiers on a flexible circuit board. The fabricated flexible sun sensor is suitable for pico / nano satellites since it is extremely thin (~2 mm) light weight (<2 g) and cost-effective (potentially one order of magnitude cheaper than state-of-the-art products). The sun sensor demonstrates i) the potential of hybrid technology by offering a new way of system integration (coupling printed and Si-based electronics), ii) a new possibility for system designers (smart PCBs), iii) using electronically functional materials (e.g. printable Ag-inks), and iv) extends the current range of products where flexibility counts (e.g. wearable, bendable electronics).

This paper describes an innovative electronic system assembly approach, namely hybrid integration which combines printed electronic components with/on flexible circuit boards (FCBs) equipped with conventional Surface-Mounted components (SMDs). Technology-wise, a clear benefit was derived from the combination of the advantages of both large area printed electronics based on solution processes (e.g. flexibility, light weight, cost effectiveness, etc.) and SMDs with high-end functionalities and robustness.

The sun sensor described here consists of four single organic photo diodes (OPDs)<sup>[1]</sup> with common bottom contact (thin Al-layer), printed active polymer-based layer and individual top contacts (a semi-transparent thin Au-layer). Other stand-alone components such as resistors, capacitors, thermistors, and OPDs were designed, printed and characterized by CSEM on HIGHTEC's pre-patterned polyimide (PI) substrates (Figure 1).

The selected printed stand-alone components were used to size the preliminary front-end circuit on standard printed circuit board (PCB).

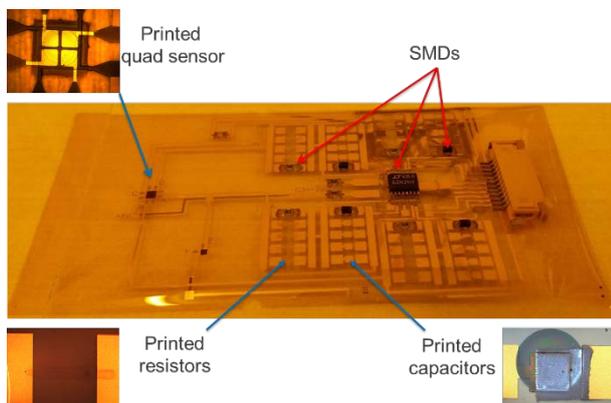


Figure 1: Components printed on FCB with embedded SMDs – first step towards demonstrator.

The flexible circuit board (FCB) design relies on the connection-on-demand approach which consists in putting stand-alone printed and SMD components side-by-side. The connection of the selected printed/SMD component to the whole system is done after characterization of the printed component through

inkjet printed conductive ink. This approach allows enhancing the production yield and minimizing the system integration risks.

Purchased stiffeners and spacers ensure a fixed illumination configuration while the illumination aperture was opened by laser drilling. In order to easily fold the PI foil, pre-perforation was also performed by laser drilling. In order to operate the sun sensor demonstrator CSEM realized a computer interface with a data acquisition card from National Instruments.

Finally, CSEM and HIGHTEC AG fabricated and folded the sun sensor demonstrator addressing the unique properties of the hybrid technology (Figure 2) in terms of volume, flexibility and weight.

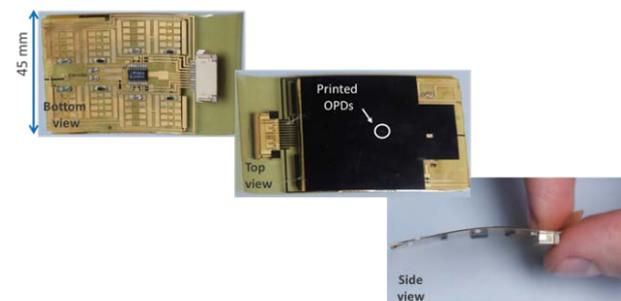


Figure 2: Assembled and folded flexible sun sensor demonstrator.

The validation was performed with a green laser manually aimed at each of the 4 cells while the light spot position and light incident angle are calculated by a custom-made software. The calculated position follows well the illuminated pattern and the sun sensor is validated for incident angles comprised between  $-80^\circ$  to  $80^\circ$ .

The resulting hybrid sun sensor is

- extremely thin (thickness of the embedded SMD)
- extremely light weight (<2 g)
- cost-effective (projected cost significantly lower than current solution)

This example of hybrid technology offers new possibilities to the system designers (towards smart PCBs), material providers (printable functional inks) and extends the current range of products (e.g. wearable, flexible electronics).

<sup>[1]</sup> G. Maiellaro, *et al.*, IEEE Trans. on Circuits and Systems — I: Regular Papers, Vol. 61, No. 4, pp.1036-1043, April 2014.