Solar Cell Dice Connecting

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1. Introduction

The use of solar cell dice has been gaining importance recently. Solar energy is nowadays used as an alternative source of energy in devices that are expected to work continuously without being connected to electricity grid such as car park ticket machines, mobile phone transmitters etc.

Solar cell usually contain large amount of silicon elements that are interconnected. The types of connections used are serial parallel combinations, in which serial connection prevails.

From the economical point of view it is necessary to keep the electrical and mechanical assembly at low cost of solar cells. The best option is to do it automatically. Furthermore, the connection has to be reliable cheap and weather resistant.

The solar cell dice is made of silicon with an active top layer. The terminals of the electrical connections can be found on both the top and the bottom side. The positive electrical contact in the form of a tape is placed on the bottom side; the negative electrical contact is placed on the top side and contains an alloy that can be soldered with both lead and lead free solders. Examples of solar dices with contacts on both sides are presented in Fig. 1.

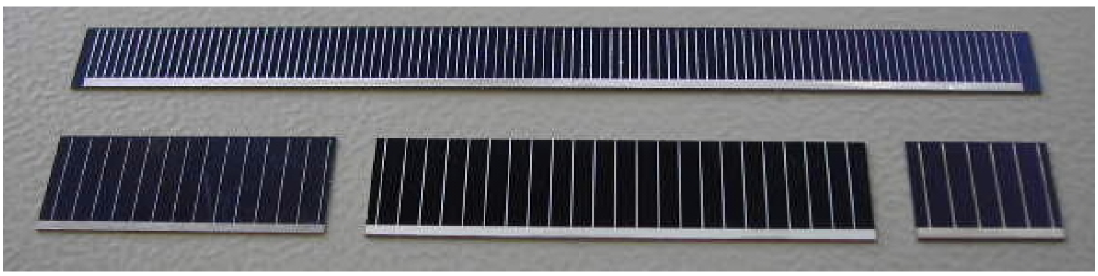
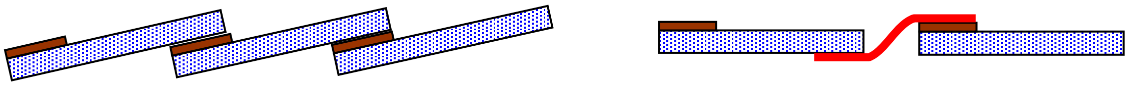


Fig.1: Two side-contacts solar cell dices [1]

According to [1] are solar cell dices usually connected by the so called shingelling or chaining as shown in Fig. 2. The electric connection is realized by conductive glue or by soldering. To ensure a better mechanical endurance of the whole system, it is glued to a suitable board. This board can be PCB.



a) shingelling (tilling) b) chaining

Fig.2: Electrical solar cells connecting

When connecting the silicon solar cells, we developed high effective soldering technologies (soldering by reflow, automatic assembly of solar cell dice). Expected is also the application of the so called "green technology" in which lead free (LF) solders are used.

2. Solar Cell Connecting with Shingelling

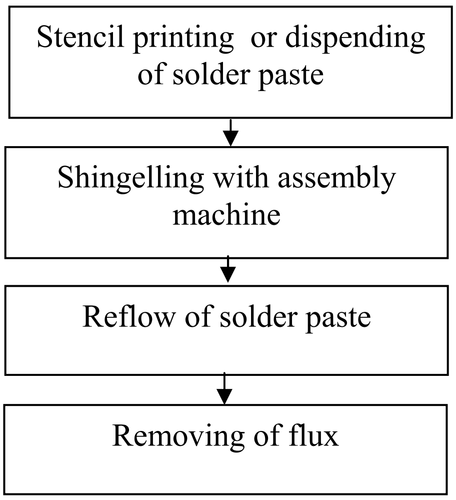


Fig.3: Flow chart of shingelling

We tested the connecting of solar cells with shingelling by reflowed solder paste. The length of the tested solar cells varied between 14.7 and 120 mm. The solder paste was applied by stencil printing or dispending on the contact area. It was applied on the top surface either in continuous stripe or in points. Subsequently up to 23 solar cells were shingelled. Shorter solar cells were asembled with assembly machine. Longer solar cells were assembled manually. Then reflow of solder paste followed and eventually the flux was removed.

Solar cells connected in this way are very fragile and can be for example glued to the PCB.

3. The Assembly and Connection of Solar Cells on PCB (ACSC)

We also tested the system **A**ssembly and **C**onnection of **S**olar **C**ells on PCB (ACSC). When connecting the standard two-side-contact solar cell dice, the connection of the top contact appears to be problematic. The connection was realized by chip resistors 0R as depicted in Fig.4. The sizes of the used chip resistors were 1206 (3.2 x 1.6 mm) and 0805 (2.0 x 1.2 mm).

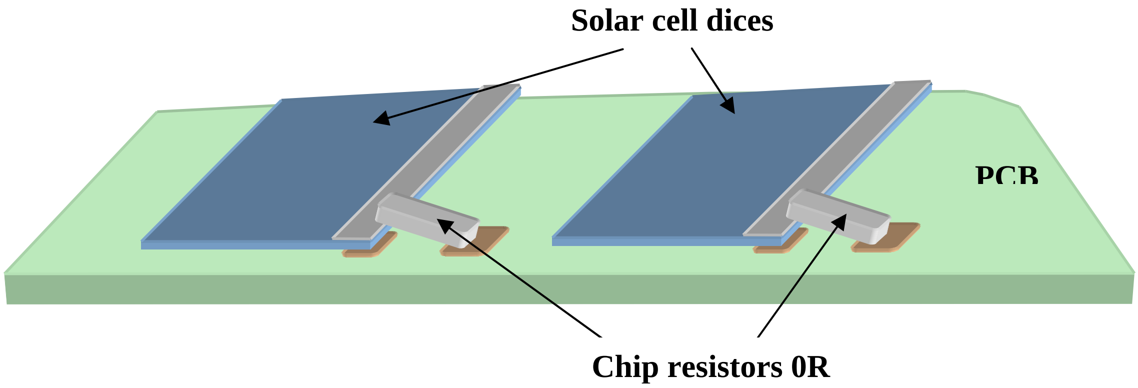


Fig.4. Solar cell dices connecting to the PCB (ACSC)

The solar element could be glued to the PCB to achieved better mechanical stability.

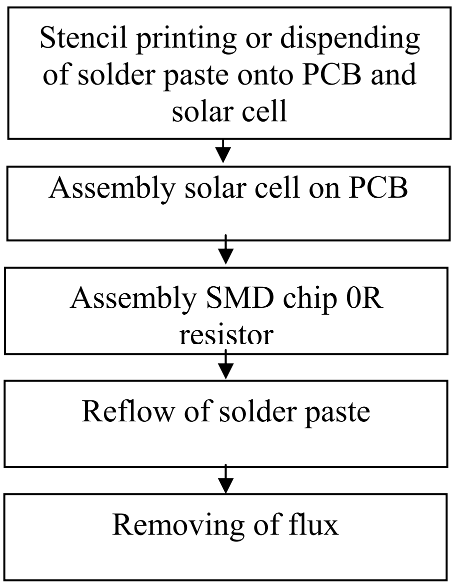


Fig. 5: Flow chart of ACSC

For assembly of solar cells it is possible to apply standard technologies used in PCB assembly – the SMT technology. The solder paste is applied on the top metal contact of the solar cell by stencil printing or dispending. The solar cell is automatically assembled onto PCB with automatic machine. Then the chip resistor 0R is assembled, which after reflow connects the top contact with the PCB. The assembly of contacts with chip packages size 1206 and 0805 has been tested. The flow chart of ACSC is presented in Figure 5.

4. Discussion and conclusion

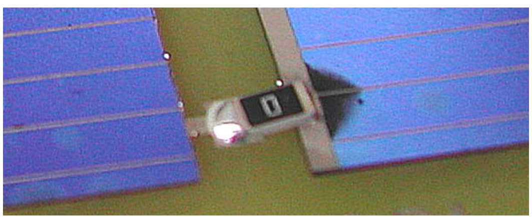


Fig.6: Real view of ACSC with flux residuum.

The electrical effectivity of the solar cell with the discussed connection is significantly influenced by the flux, which is absorbed into the active surface in the area of the connection. The flux needs to be removed by a special procedure.

The use of ultra-sound can not be recommended because it breaks the structure of the solar cell. Real view of ACSC with flux residum is in Figure 6.

Another significant problem is thermomechanical stress of the solar cell, when assembled to PCB printed board. The change of the thermomechanical strain Δε can be expressed in the formula 1. [2] where *h* is the height of the joint and *L* is its distance of solder joint of the system. ΔT is the temperature cycle amplitude and α_c, α_s is the CTE_{xy} of layers (directions x,y). *F* is dimensionless parameter (1 to 1.5). *E* presented in equation (2) for shear stress σ is Young modulus.

$$\Delta\varepsilon = F\frac{L\left|\alpha_c\Delta T - \alpha_s\Delta T\right|}{2h} \quad (1)$$

$$\Delta\sigma = E\Delta\varepsilon \quad (2)$$

Table 1: CTE of connect materials [2]

Material	CTExy [K^{-1}]
FR4 (printed board)	15
Si (solar dice)	4 - 5
Alumina (body of chip resistor)	4 - 7
Metal solder (eutectic SnPb	25
Metal solder LF (SAC)	25

In the connection of silicon solar cell dice on the FR4 material a significant difference CTE (Coefficient of Thermal Expansion in x,y directions) of silicon and FR4 is evident. (see Table 1). The soldered connections have to be at the smallest possible distance.

So far one specimen with 18 solar cell dice size 49.0x13.9mm connected with the help of the ACSC technique has been tested. Without any problems it lasted for 160 temperature cycles with the temperature range between -40 to +150 °C. Before the testing the whole system has been encapsulated in a special material.

The focus of this article is to present the possibilities of linking the silicon solar cell dices by standard technologies used in SMT. Currently; further research is needed in the optimalization of the soldered areas (footprints) for the technique ACSC, with respect to lowering the thermomechanical stress. A simulation of the stress is being carried out with the help of the software ANSYS. The emphasis is on lead free LF technologies for assembly.

5. References

[1] www.solartec.cz

[2] Šandera, J., Design and Reliability of the Connection in and Communication, Brno 20043D Electronic Systems, Ph.D. Thesis, Brno University of Technology, Faculty of Electrical Engineering