R2R Equipment – requirements and vision

Survey results

- The table below is a summary of the answers received in a survey made on preferred manufacturing methods among potential customers and producers. From the table one can tell that Gravure, Screen and Flexo printing are considered the most versatile printing technologies. Offset is an interesting technology but not considered as preferred for any of the applications listed. Technologies are also more or less preferred dependent on the application.

Applications	Gravure		Screen		Ink Jet		Offset		Flexo		Lamination		Coating		Laser ablation		Embossing / imprinting		DPP	
	1's	2's	1's	2's	1's	2's	1's	2's	1's	2's	1's	2's	1's	2's	1's	2's	1's	2's	1's	2's
Electronic circuitry	2	3	2	2	4	1	4	0	3	3	1	2	1	2	1	2	3	1	1	0
Integrated circuits	1	3	2	0	4	1	4	0	3	0	2	0	2	0	1	2	1	1	1	0
Batteries	1	1	2	3	4	0	2	0	2	0	0	2	3	0	1	0	0	0	1	0
Solar cells	4	2	5	0	2	1	5	0	6	0	2	1	2	1	2	1	1	1	1	0
LEDs	3	1	4	0	3	0	5	0	4	1	0	2	3	1	1	1	1	0	1	0
Large area sensors	4	1	4	2	3	2	6	0	4	2	1	1	3	0	2	1	3	0	1	0
Displays	1	1	3	2	1	3	4	0	4	1	1	2	2	1	1	1	2	1	1	0
Total	16	12	22	9	21	8	30	0	26	7	7	10	16	5	9	8	11	4	7	0
WEIGHT	40		40		37		30		40		27		26		25		19		7	

Legend
- Highly relevant
- Relevant
- Relevant
- Interresting

QFD to find the relevant requirements

With customer input QFD provides the relative importance between requirements

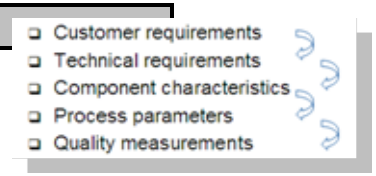
- Customer requirements
- Technical requirements
- Component characteristics
- Process parameters
- Quality measurements

Customer input is only possible with a specific application in mind. Selected application:

- Display on medical package

From customer requirements..

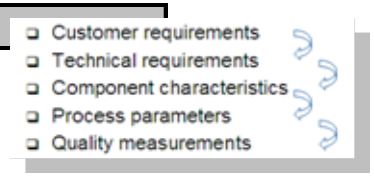
Relative weight	Weight	Demanded quality
15,6	10,0	Shelflife
15,6	10,0	Disposability (Environmental compliance)
12,5	8,0	High contrast
12,5	8,0	Display power consumption (energy conservation)



- Shelf life and disposability have a high absolute weight – customers have expressed that these characteristics have high importance - but also high relative weight because of their many dependencies to the technical requirements – the requirements we can measure.
- The highest graded technical requirements, power consumption and decomposability, translate to the characteristics of the electrodes and electrolyte (high conductivity, redox stability, ion mobility) and to the total mass and hence the thickness of the substrate (weight).
- The technical requirements also translates into requirements on the equipment used, requirements such as Inkjet nozzle aperture (for inkjet) and Screen mesh count (for screen printing)

..to process parameters

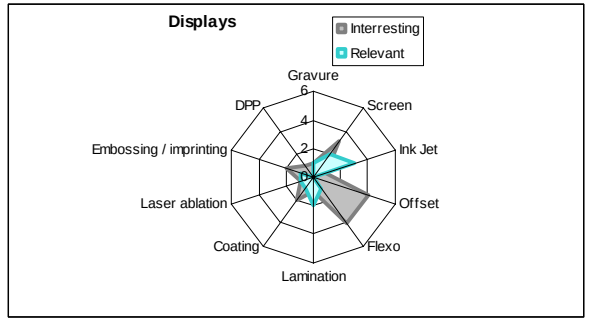
Relative weight	Weight	Demanded quality
48,8	181,2	Hot air curing time
25,1	124,8	Registration accuracy
24	118,9	Deposition thickness
11,8	43,7	UV curing time



- Customer requirements stating environmental impact should be kept low translates in the process requirement that curing times (process power consumption) should be kept at a minimum
- Demands on high conductivity (originating from device low power consumption) result in the requirement on the process to be able to deposit thick layers
- Registration accuracy is crucial if we are to have a working display and derives from requirements on the display appearance, requirements on contrast and resolution
- Component characteristics and process parameters can be used to evaluate which printing technique is most suited for producing the selected application

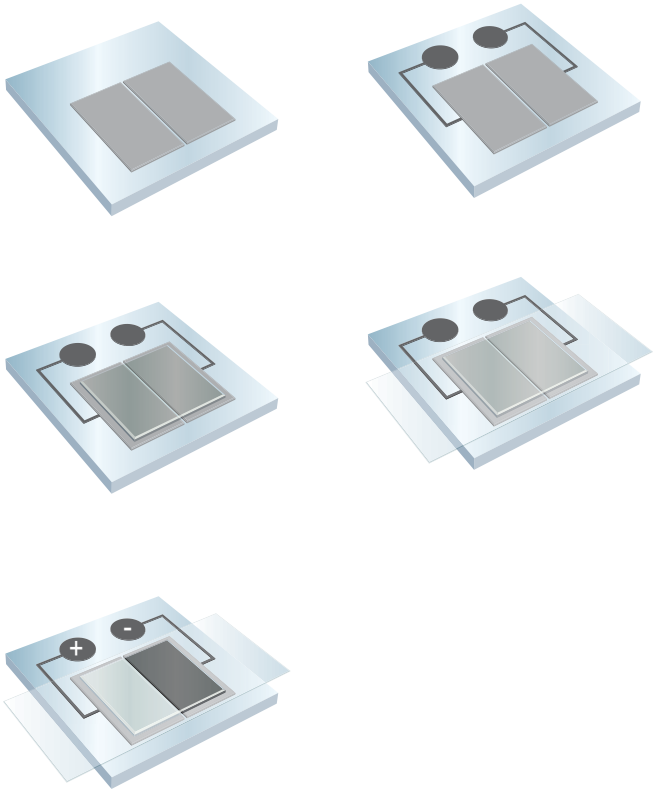
Production method

- From a production viewpoint it is interesting to know what printing technology (what equipment and what process) you need to be able to produce as many as possible different applications
  - If you are an established company you would like to know for what applications you can use your existing equipment
  - If you are a startup you would like to know what equipment you should buy
- For most applications we need more than one printing technology. For instance, even when another technology is preferred for other steps lamination is often needed to provide protection.
- *To print an EC display on a medical package we want to use inkjet for the electrodes and conducting lines since it offers a quick and easy road between the digital design and the printing unit. For the electrolyte though we need a thicker layer deposited and have to use screen printing. The inkjet needs to be enhanced in order to match the speed of R2R printing and the screen printing is required to produce a thick enough layer still having sufficient resolution. Curing speed is crucial in both cases.*



Picture from survey

Printing steps



1. Printing of electrodes
2. Printing of conducting lines
3. Printing of electrolyte
4. Encapsulation
5. Activated by 1.5 to 3 V

Conclusion

- Relevant printing technologies derived from the requirements of a display:
  - For simple element based displays screen printing is sufficient.
  - When it comes to pixel based displays with high fill factor – high resolution and narrow lines are necessary – Ink Jet printing is the choice
- Needs for improvement:
  - Both process and material development is necessary in order to enable roll to roll production
  - Co operation between equipment manufacturers and material suppliers (active inks) are essential for progress

EC display production	**First generation SOTA**	**Second generation target**
Line width	100 to 200 µm line width.	10 to 50 µm
Resistance in conductors	< 500 Ω/□.	< 10 Ω/□.
Registration	Better than ± 50 µm between layers.	Better than ± 5 µm between layers.
Hot air curing	Less than 2 minutes curing time	Hot air curing/annealing less than 3 seconds curing time in roll to toll production.
UV curing	UV curing of electrolyte.	UV curing of electrolyte.
Height	< 40 µm height excluding substrate.	< 10 µm height excluding substrate