

**Fully Roll-to-Roll Gravure Printable Wireless (13.56 MHz) Sensor-Signage Tags for
Smart Packaging**

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Supplementary Information

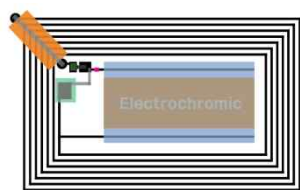


Figure S1. Design of antenna, diodes, capacitors and signage to be printed using R2R gravure.

Optimized reading distance of R2R gravure printed antenna using various length of antenna

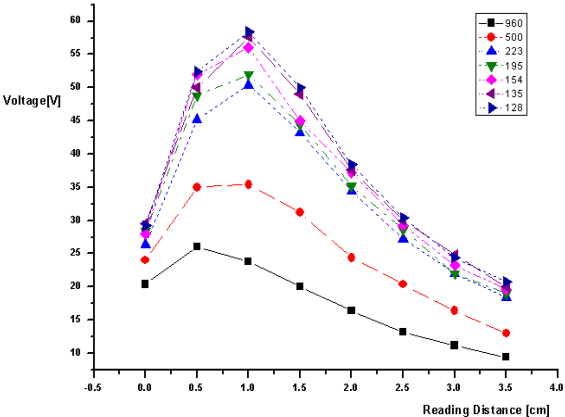


Figure S2. The graph of coupled AC voltages under various reading distances from NFC reader and various end to end resistance of printed antenna (inset shows the end to end resistances with ohm unit).

Optimized R2R gravure printed antenna

Table S1. Values of coupled AC voltages depending on inductances and number of antenna turns as shown in Figure S2.

Turn	V_{pp}(V)	Inductance(uH)
1	4	0.59
2	8	0.74
3	12	0.88
4	20	0.96
5	35	1.05
6	44	1.1

Results of stability tests on printed rectenna

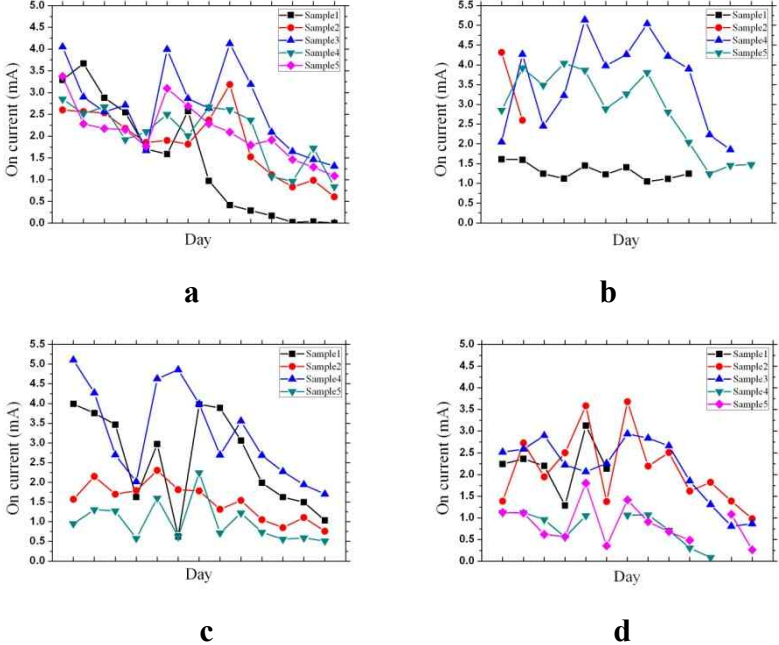


Figure S3. Stability results of on-currents of printed diodes with top electrodes of printed Al inks with various additives of epoxy (a), poly(butyl methacrylate co methyl methacrylate) (b), epoxy with blocked isocyanate group (c), and poly(ethylene terephthalate) (d). All the tests were carried out for 20 days under ambient condition (Instead of measuring output DC voltage, on current of printed diode was used to quick comparison).

The movie of working concept of NFC-sensor-signage

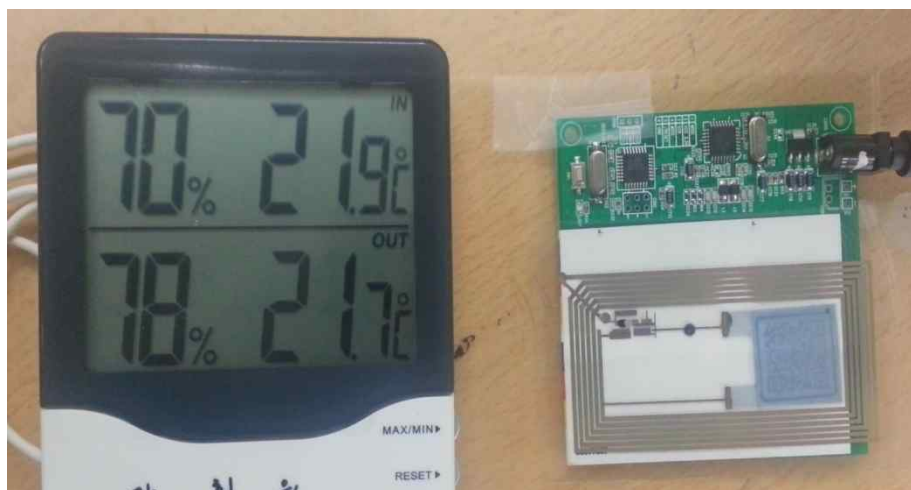


Figure S4. Image of working concept of smart packaging using R2R printed NFC-humidity sensor-signage. Click the image to see the movie file: the QR-Code will be only displayed when the relative humidity of surrounding is reached at 70%.

Scheme for fully roll-to-roll (R2R) gravure printed wireless-QR code-sensor-tags

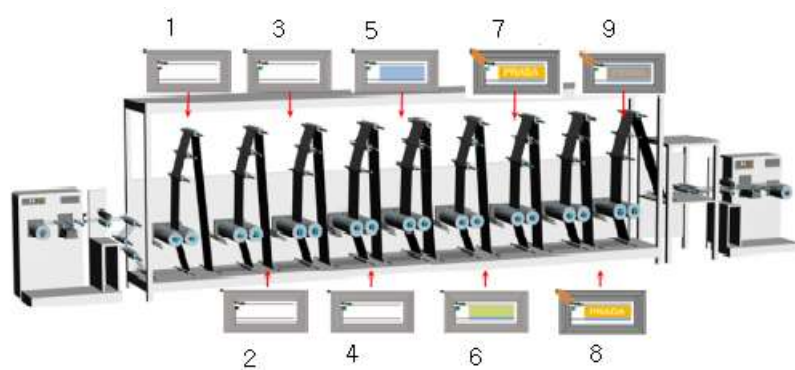


Figure S5. Concept image for fully R2R gravure printed wireless-QR code-humidity sensor-tags through 9 gravure printing units.