Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Switchable Disposable Passive RFID Vapour Sensors from Inkjet Printed Electronic Components Integrated with PDMS as a Stimulus Responsive Material

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Further RFID tag design considerations

As dipole antennas are significantly detuned when they are mounted on, or very close, to dielectric or conducting surfaces, the RFID tag performance is often compromised when attached to objects. To overcome this serious limitation, the tag antenna shown in Figure 1 has a wide bandwidth performance such that it radiates efficiently over a significant degree of detuning. The reported design is 87 % efficient when experiencing a frequency detune of 40 MHz and this adequately covers the frequency change expected when the tag is attached to a dielectric surface. The sensing impedance transducer in this design comprises the oval loop (feed loop) in Figure 1. The feed loop acts as a high frequency impedance transformer which converts the antenna impedance to the RFID chip impedance. These impedances are both complex quantities comprising real resistive parts, which should be equal, and imaginary reactive parts, which should be equal in magnitude and opposite in phase. This condition is referred to as the 'conjugate match' and results in maximum power transfer between the antenna and the RFID IC. The maximum power transfer condition for smallest turn-on power is established through the physical dimensions of the feed loop, the conductance of the feed loop track, and the dielectric properties of the material substrate on which it is mounted.

Optimization of printing silver inks onto PDMS

Table SI1. Contact angles and surface energy measurements for PDMS

H_2O	DMSO	Ethylene	Surface Energy mNm^{-1}

		Glycol			
111 ± 3 °	82 ± 1 °	93 ±1 °	EOS	Fowkes	OWRK
			16 ±1	14.7 ± 0.9	14.0 ± 0.2

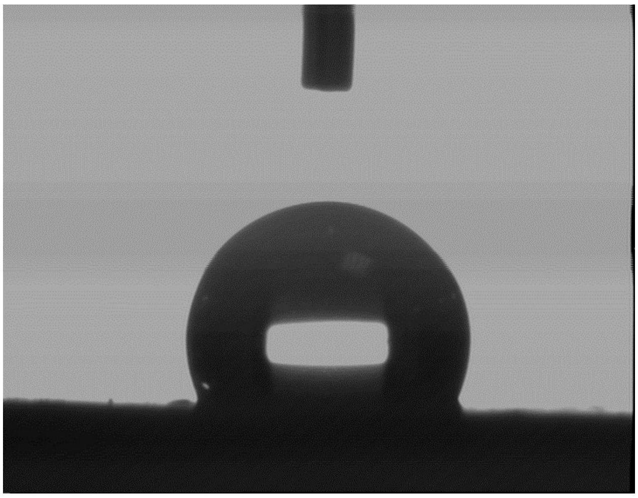


Figure SI1. Water droplet on PDMS, showing a contact angle of approximately 110°.

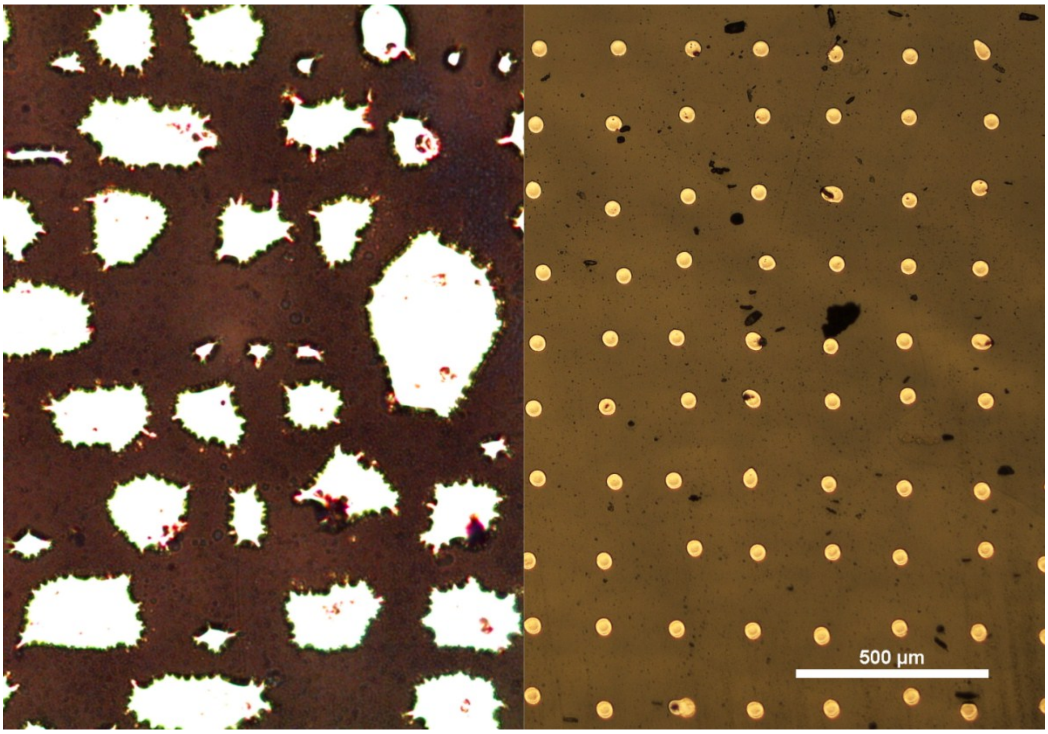
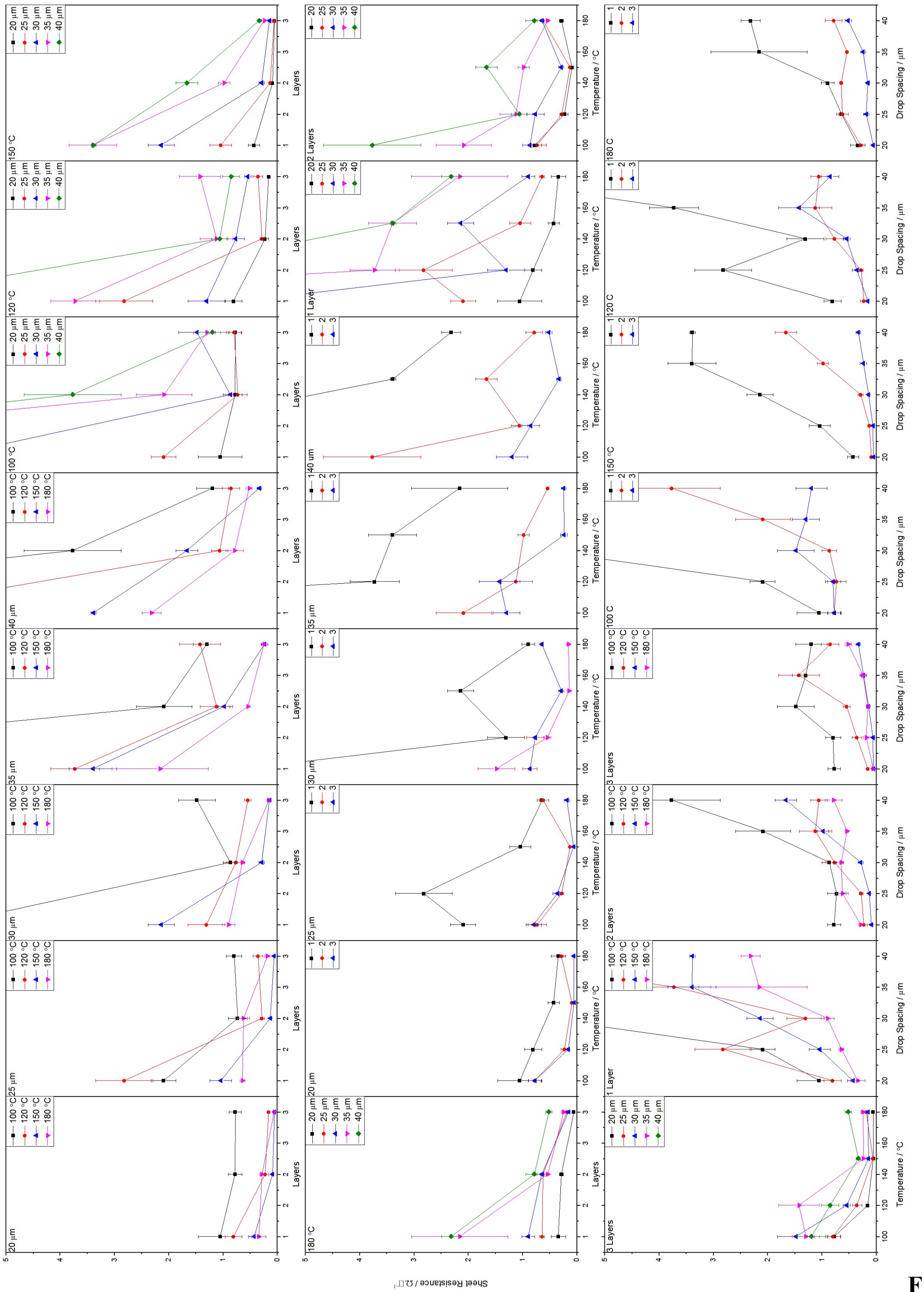


Figure SI2. Droplets of silver on untreated (left) and UV-Ozone treated (right) PDMS substrates.



F**igure SI3.** Full data set of sheet resistance optimization.

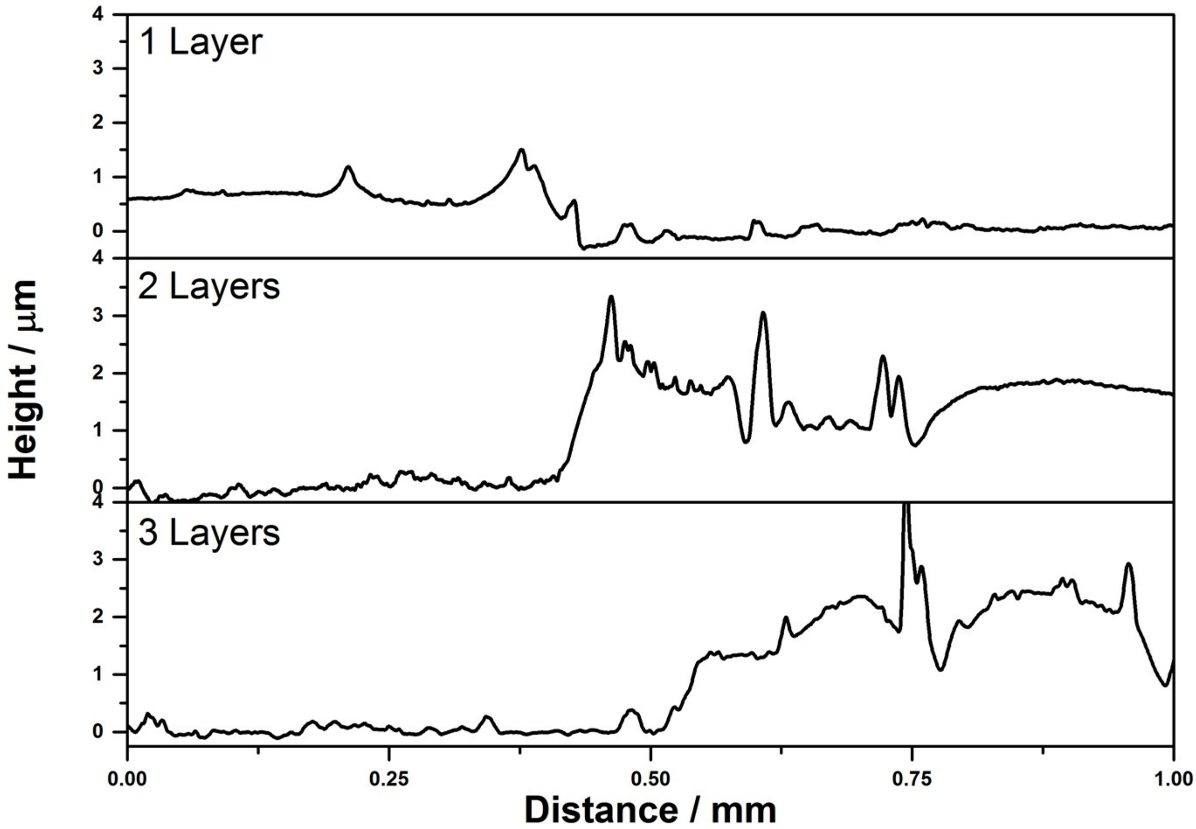


Figure SI4. Height profile for silver on PDMS, average heights are; 1 layer = 670 nm, 2 layers = 1420 nm and 3 layers = 2000 nm.

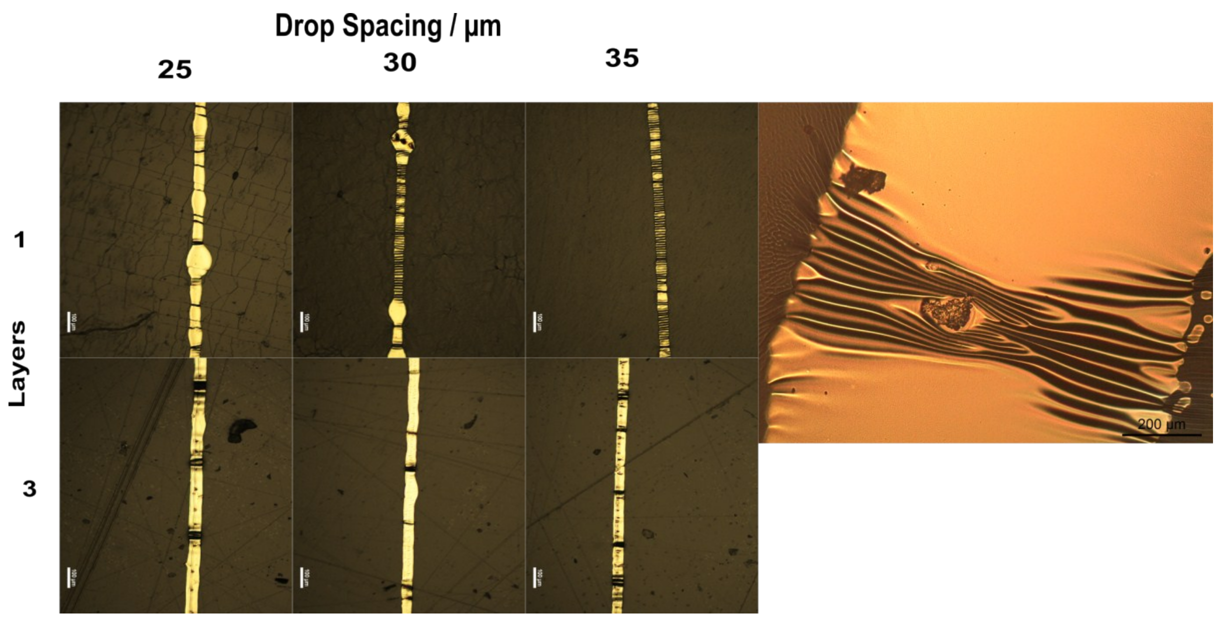


Figure SI5. Influence of drop spacing on line quality for silver ink printed on UV-Ozone treated PDMS. Far right image shows a magnified image of a feed loop after sintering demonstrating the buckling from thermal expansion and contraction.

Table SI2: Resistance measurements of first batch of printed loops to test different number of passes and different sintering lengths. (All printed on rough side of PDMS, sintering at 100°C)

APB225 #	Passes	Sinter Time	Resistance / Ω Manchester		Resistance / Ω Kent
			Before	After	
1	1 pass	15 mins	170	105	109
2			180	180	159
3			230	180	181
4		16 Hours	250	150	133
5			500	530	650
6			430	310	500
7	2 pass	15 mins	X	X	335
8			250	110	167
9			8000	650	520
10		16 hours	4000	820	5500
11			1000000	600	2200
12			600	250	1500
13	3 pass	15 Mins	30	40	38
14			30	60	42
15			40	1500	X
16		16 hours	30	X	360
17			30	250	X
18			30	600	770

Table SI3: Resistance measurements of second batch of printed loops to test different sintering conditions. (All printed on rough side of PDMS, all 3 passes of silver ink)

APB227 #	Sinter Conditions	Resistance / Ω Manchester		Resistance / Ω Kent
		Before	After	
2	None	20000		X
5	None	X		X
9	None	35		X
10	None	40		700
11	None	2000		X
12	None	35		4K
13	None	44000		X
14	None	X		x
16	None	1000		X
17	None	X		X
1	60°C Hot Plate - 14 hours	45	X	X
3	60°C Hot Plate - 14 hours	65	X	X
4	60°C Hot Plate - 14 hours	80	120	28M
6	150°C – 2 hours	30	40	37.2
7	150°C – 2 hours	40	50	34.5
8	150°C – 2 hours	100	100	44
15	150°C – 0.5 hour	60	100	140
18	150°C – 0.5 hour	40	150	9M

Table SI4: Resistance measurements of third batch of printed loops to test smooth side vs rough and the effect of sintering.

APB229 #	Smooth/Rough	~passes	Sinter Conditions	Resistance / Ω	
				Before	After
1	Smooth	1	None	600	
2	Smooth	2	None	62	
4	Smooth	3	None	x	
5	Smooth	3	None	4000	
6	Smooth	3	None	2000	
8	Smooth	3	None	700	
10	Smooth	3	None	25	
14	Smooth	3	None	x	
3	Smooth	3	150°C 1hour	55	50
7	Smooth	3	150°C 1hour	40	15
9	Smooth	3	150°C 1hour	25	36
11	Smooth	3	150°C 1hour	19	7
12	Smooth	3	150°C 1hour	75	13
13	Smooth	3	150°C 1hour	157	9
15	Rough	3	150°C 1hour	36	25
16	Rough	3	150°C 1hour	35	41
17	Rough	3	150°C 1hour	28	25
18	Rough	3	150°C 1hour	42	255
19	Rough	3	150°C 1hour	39	17
20	Rough	3	150°C 1hour	28	17

Table SI5: Resistance measurements of fourth batch of printed loops to test optimized conditions. (All printed on smooth side of PDMS, all 3 passes of silver ink, all sintered at 150°C for 1 hour).

APB229 X #	Resistance / Ω	APB229X #	Resistance / Ω
1	29.2	13	10.9
2	12.2	14	9.9
3	X	15	16.4
4	10.2	16	10.6
5	10.8	17	12.1
6	13	18	34.2
7	12.7	19	19.2
8	11.7	20	10.8
9	10.5	21	9.3
10	10.5	22	18
11	13.7	23	70
12	22.3	24	11.7

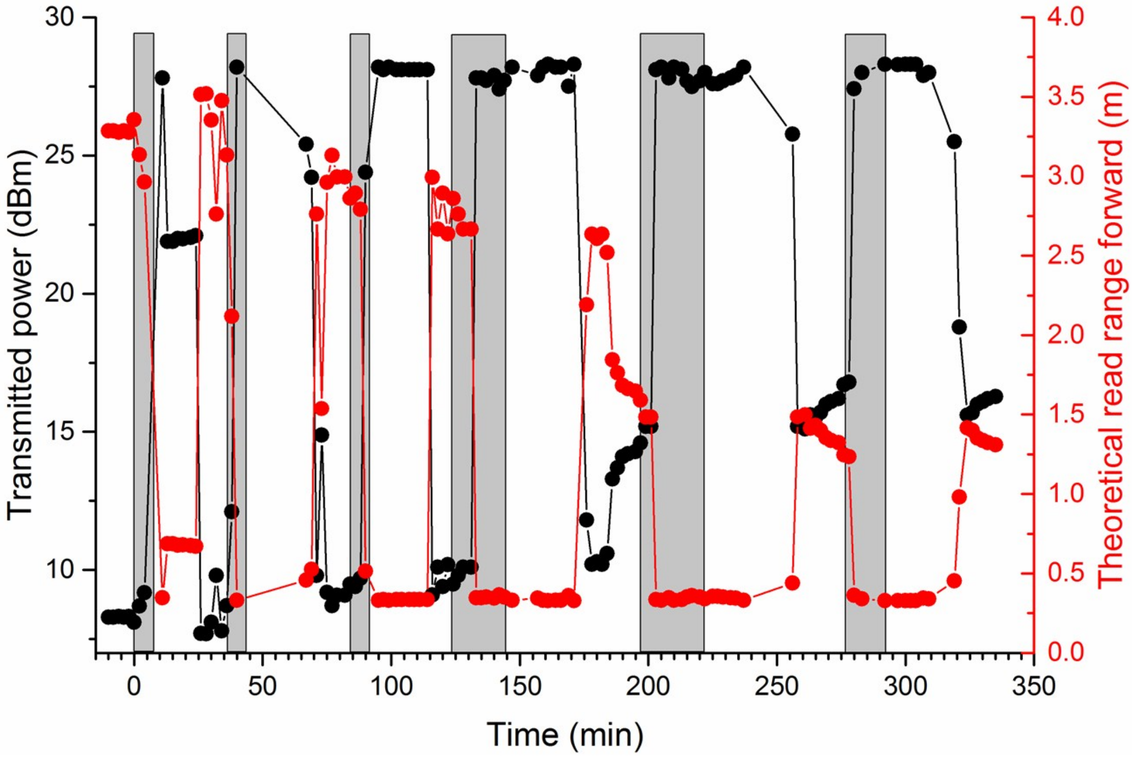


Figure SI6: Transmitted power and theoretical read range for 6 cycles of solvent vapor exposure in DCM.

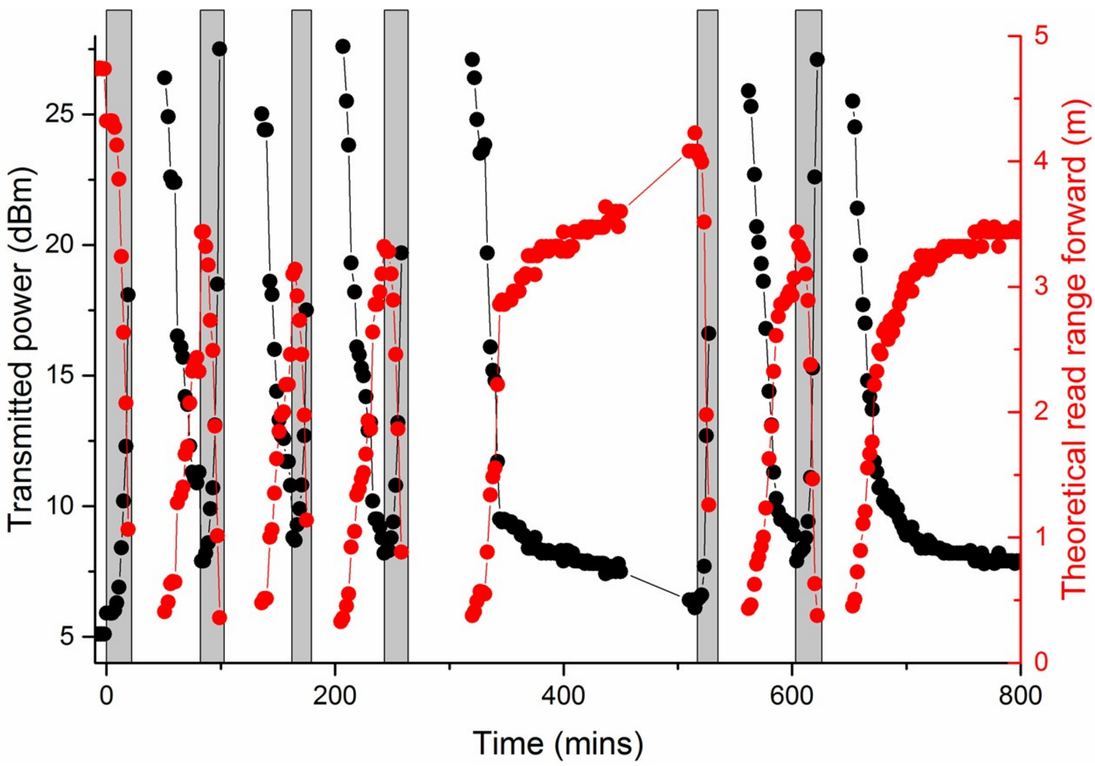


Figure SI7: Transmitted power and theoretical read range for 6 cycles of solvent vapor exposure in ethyl acetate.

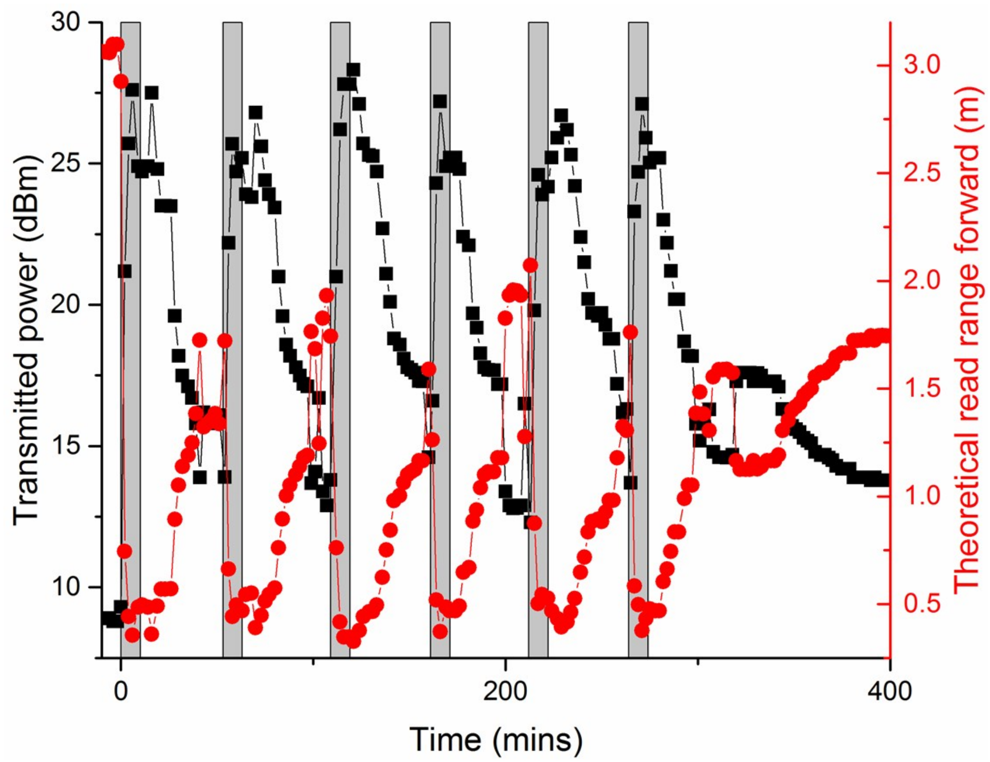


Figure SI8: Transmitted power and theoretical read range for 6 cycles of solvent vapor exposure in acetaldehyde.

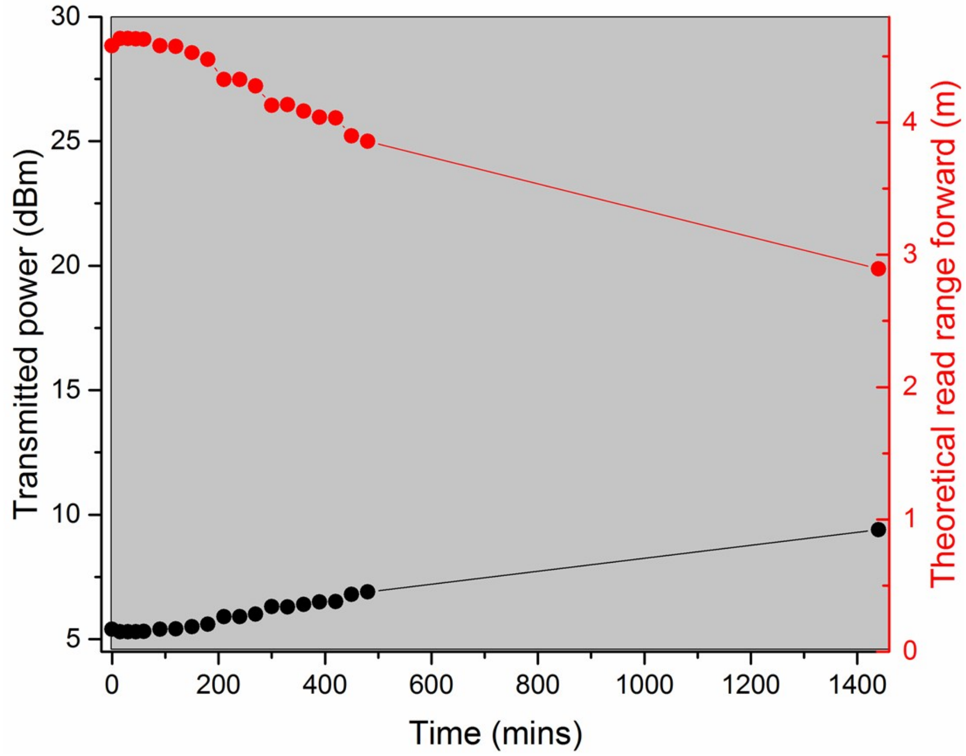


Figure SI9: Transmitted power and theoretical read range for 6 cycles of solvent vapor exposure in xylene.

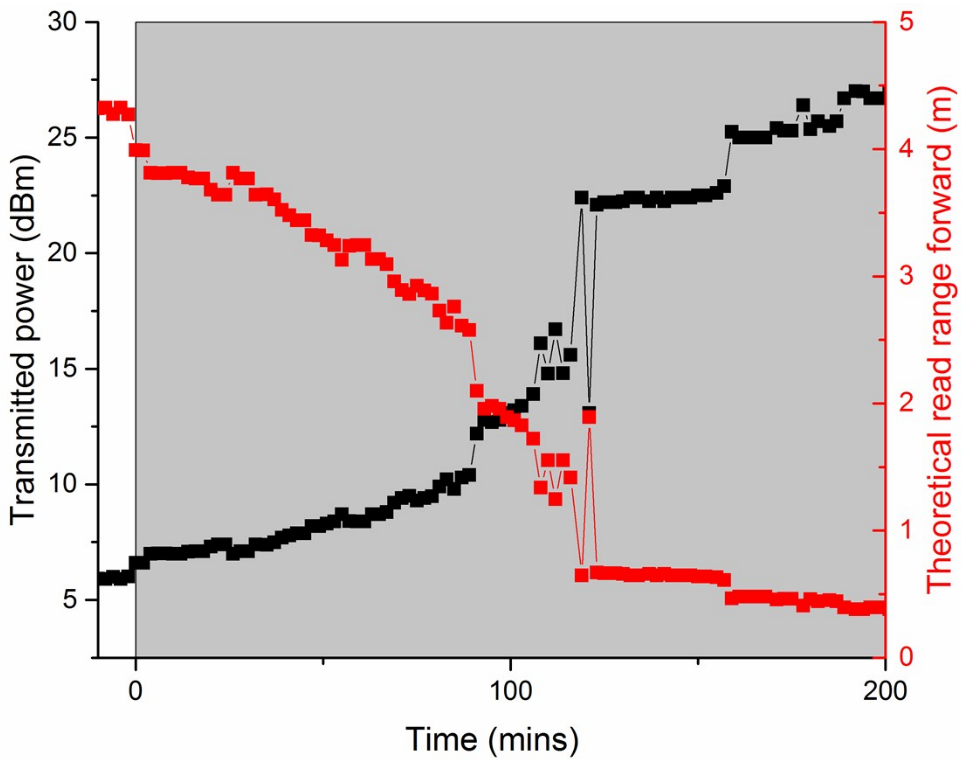


Figure SI10: Transmitted power and theoretical read range for 6 cycles of solvent vapor exposure in propan-2-ol.

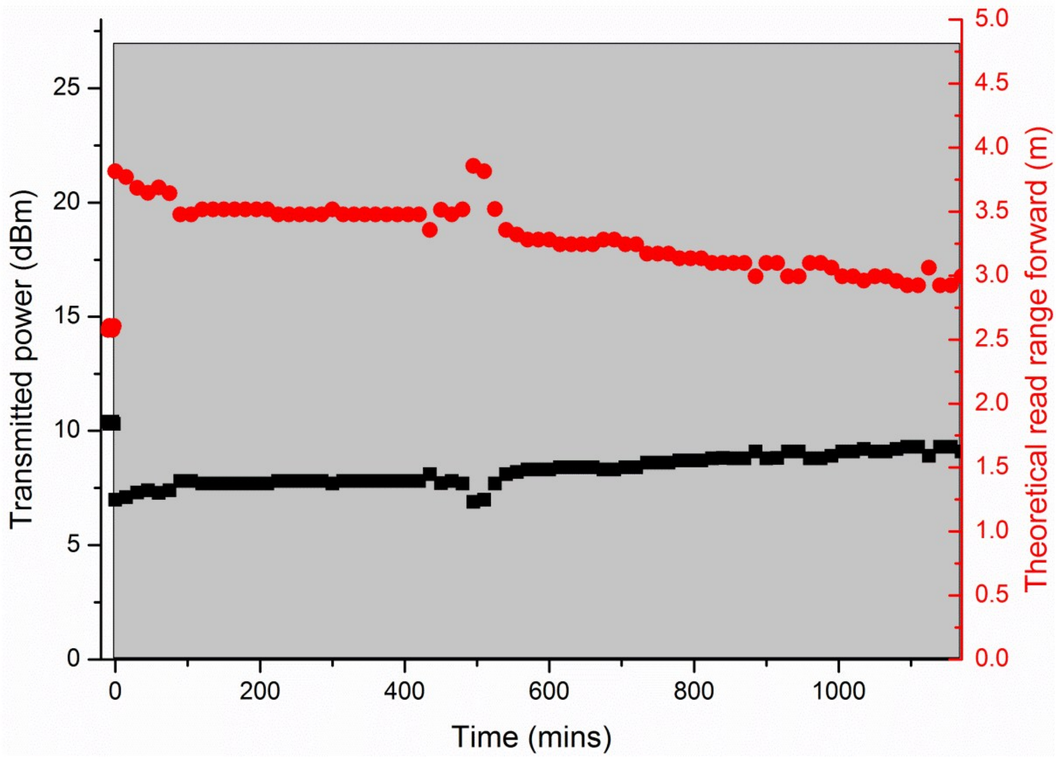


Figure SI11: Transmitted power and theoretical read range for 6 cycles of solvent vapor exposure in acetic acid.

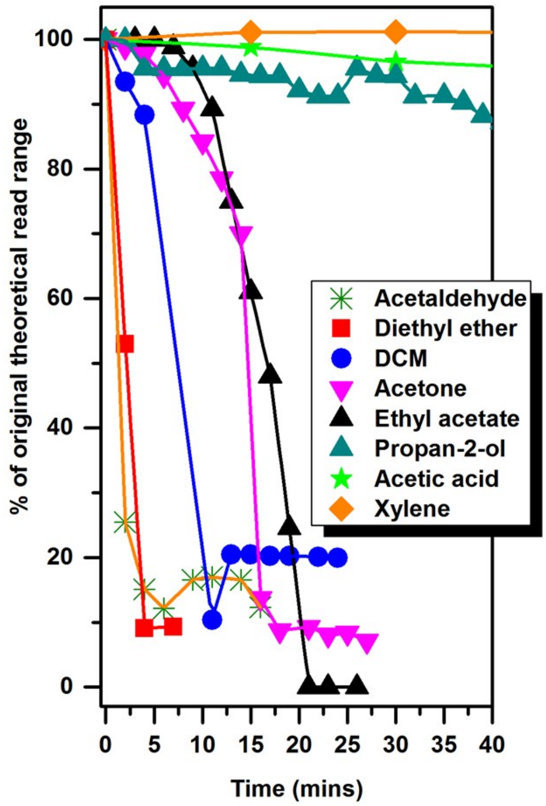


Figure SI12: Normalized change in read range of RFID tags on exposure to each solvent vapor.

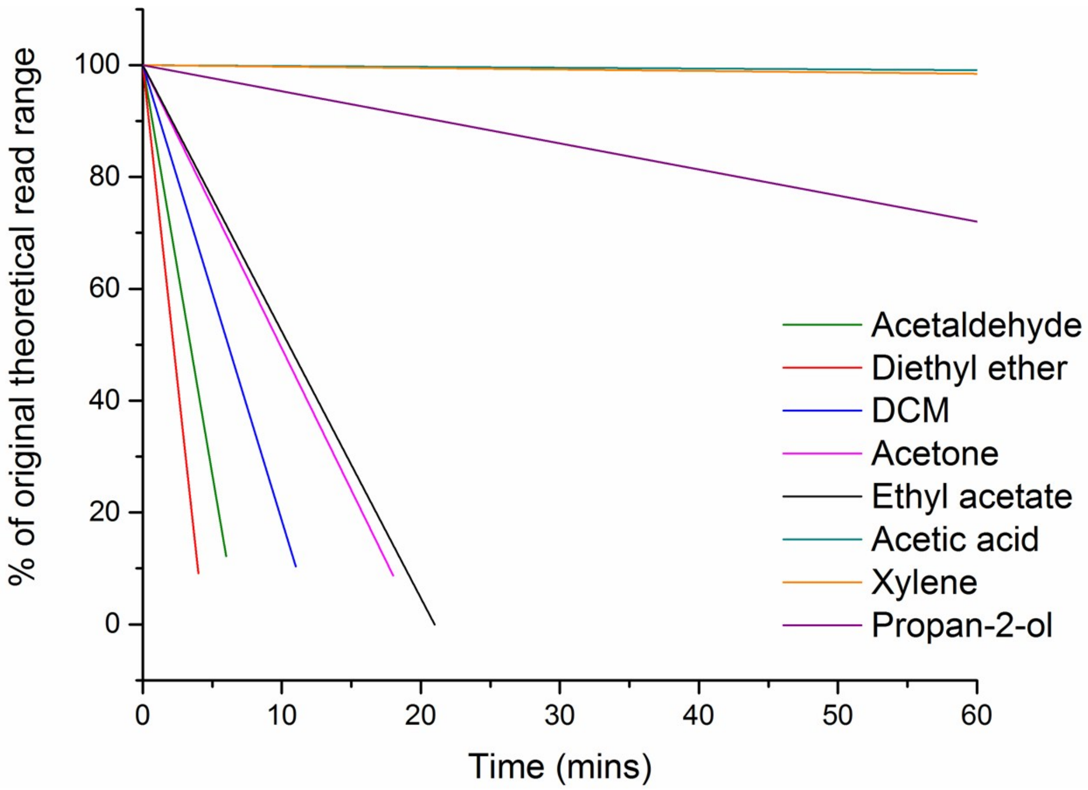


Figure SI13: Plot of time for each RFID tag to reach minimum read range in various solvent vapors.

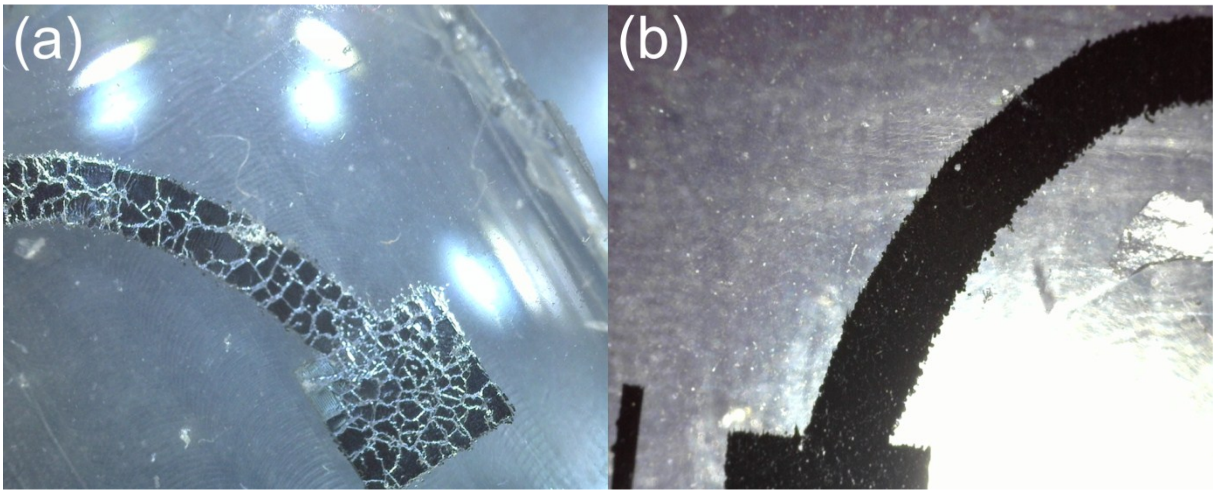


Figure SI14: Microscope images of printed silver loops: (a) a loop after exposure to diethyl ether vapor for 20 minutes; and (b) a loop which has been through complete cycles and has then been left in air for more than an hour.

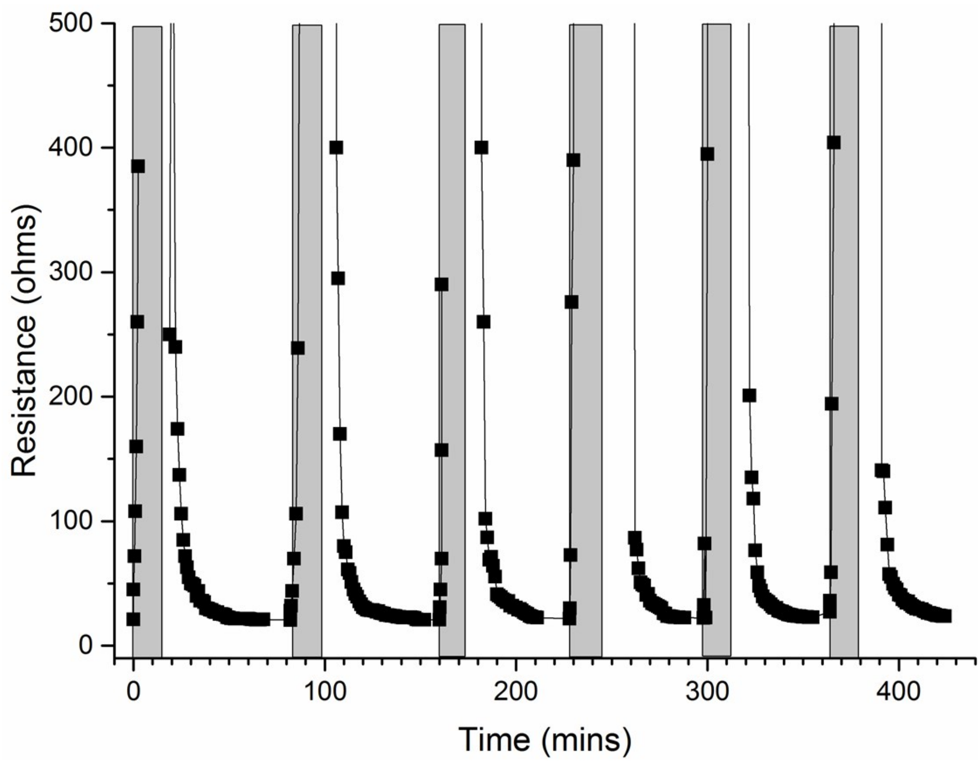


Figure SI15: Resistance measurements for 6 cycles of solvent vapor exposure in diethyl ether.

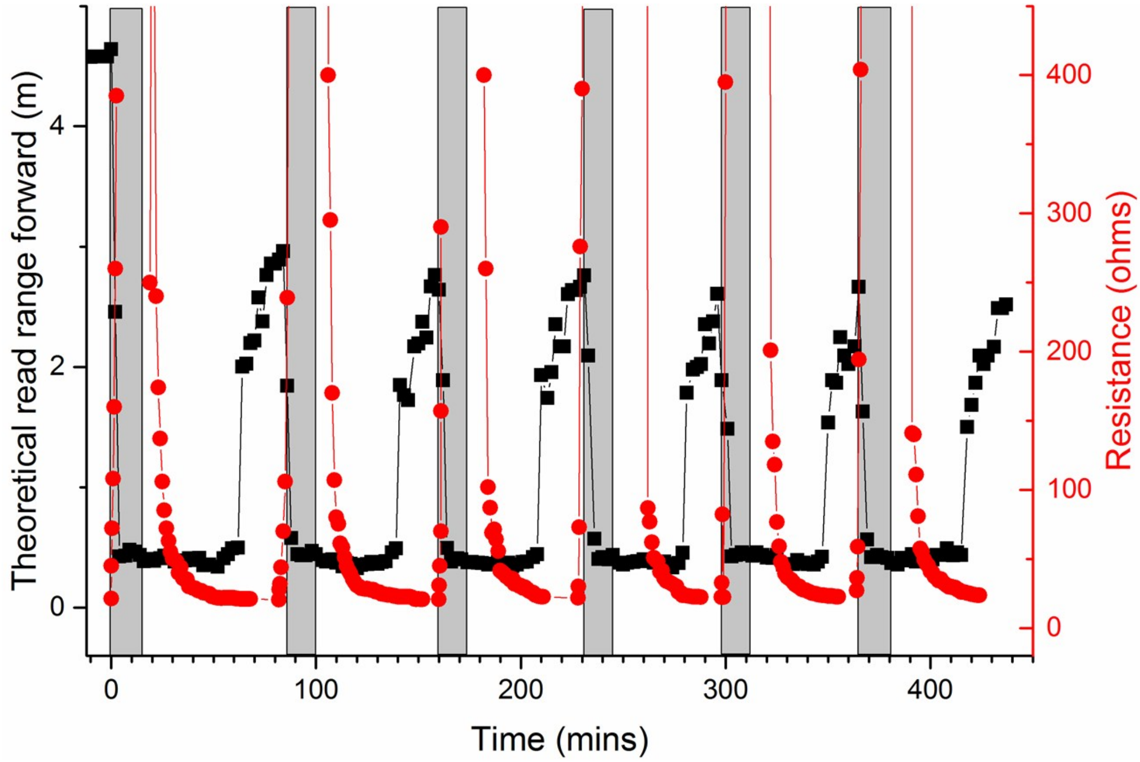


Figure SI16: Resistance and read range measurements for 6 cycles of solvent vapor exposure in diethyl ether.