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Supplementary information

ENCAPSULATING AND INKJET-PRINTING FLEXIBLE CONDUCTIVE PATTERNS ON FLUOROELASTOMER FOR HARSH HYDROCARBON FLUID ENVIRONMENT

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S1. Fabrication process

A 2.0-inch x 2.0-inch (50.8 mm x 50.8 mm) FKM sheet was used as a substrate for inkjet printing. Figure 1 illustrates the fabrication process flow.

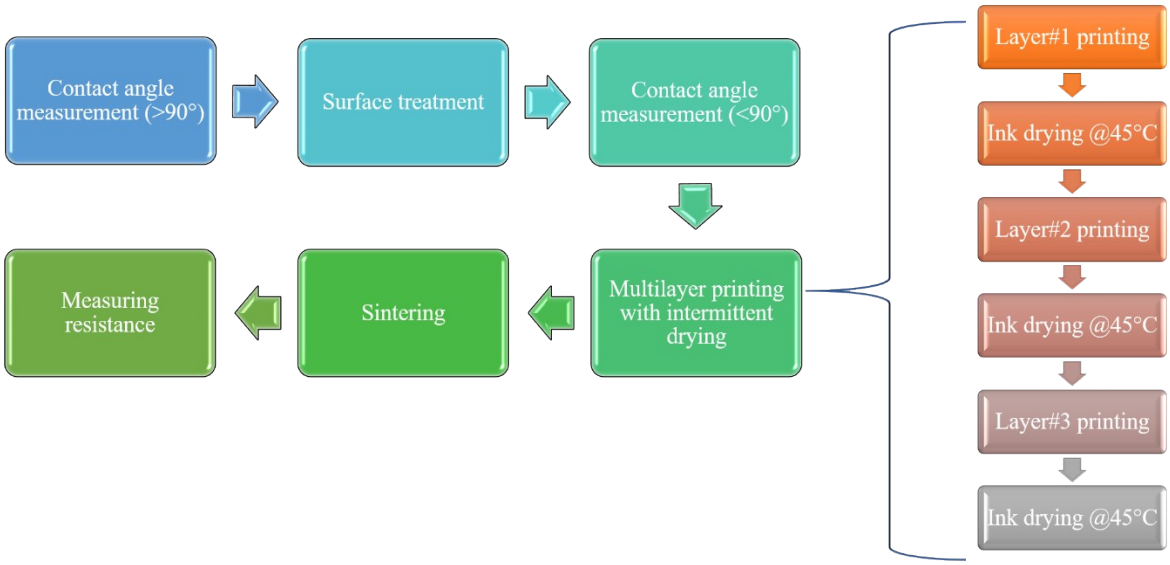

Figure 1. Fabrication process flow.

The contact angle of DI (de-ionized) water on the substrate was measured using a goniometer (ramé-hart instrument co. USA). Since this surface was hydrophobic, with contact angles >90°, we treated the substrate with a corona treatment using a laboratory air corona treater BD-20AC (Electro-Technic Products, Inc, USA) with treatment parameters listed in Table 1.

Table 1. Corona treatment parameters.

Lab corona treater	
Operating Parameter	Range
Output Voltage	10000 to 48000 V
Frequency	4 to 5 MHz
Input Voltage	115V,50/60Hz
Current	0.35 A
Power	40.25 W

Operating Duration	Continuous
Distance between Electrode and Surface of the substrate	1/8 in. to 1/4 in.
Treatment Time	8 mins

The contact angle was measured again after the surface treatment to ensure it is <90°. Figure 2 shows the corona treatment of the FKM surface and a change of contact angle after the conversion from hydrophobic to hydrophilic surface.

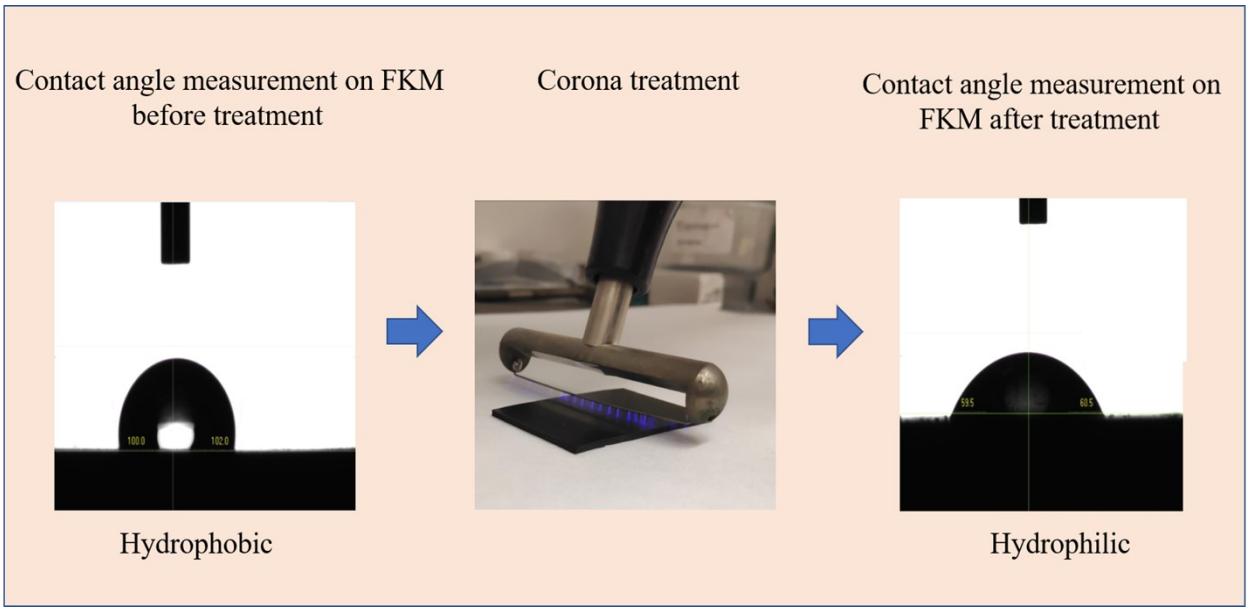

Figure 2. Contact angle measurement on FKM before and after corona treatment.

We optimized the printing process by printing multiple layers with intermittent drying. In this process, we printed the first layer of the ink and allowed it to dry on the printer stage before printing the second layer and so on. For our sample, we printed three layers with intermittent drying at 45°C. After printing three layers we started sintering at 150°C for 90 mins.

S2. Neutral axis calculations

Material	Thickness (μm)
Ag	1.000
FKM	1587.5

Material	E (GPa)	Poisson	E plane
Ag	83	0.365	130.70866
FKM	0.0069	0.5	0.0117211

Y1 = 793.75; Y2=1588.04; Y3= 2382.34; n2= 9478.84; n3= 1

$\bar{y} = 1588.05\ \mu m = 1.59\ mm$, slightly greater than the thickness of substrate (FKM).

S3. Cross-sectional structures using fluoroelastomer as an encapsulant.

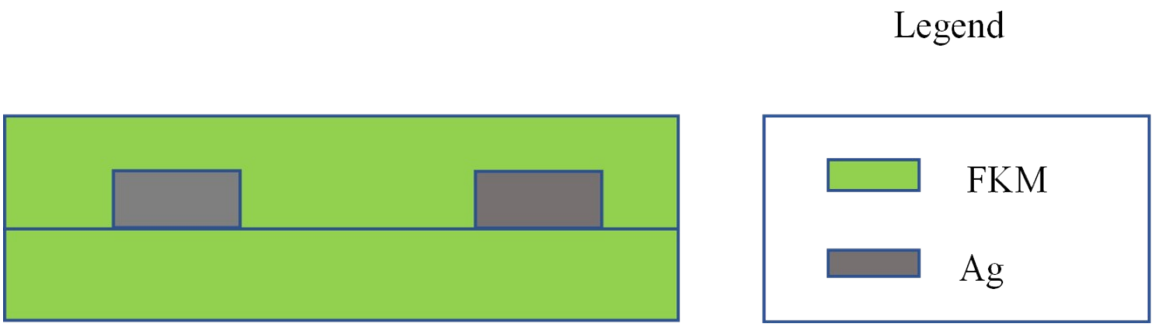

Figure 3. Silver pattern printed on/and encapsulated with FKM.

S4. Thickness of the printed pattern in the encapsulated samples after the test

Sample	Average thickness (μm)
1	0.989
2	1.136
3	0.979
4	0.938
5	1.04

S5. FKM, PDMS, and PET weight study.

% Weight change of the substrate in oil at 150 C			
Week	FKM	PDMS	PET
1	1	4.05	12.5
2	1	5.45	16.7
3	1.66	weight study stopped.	
4	1.66		
5	1.66		
6	1.66		
7	1.66		
8	1.66		
9	1.66		
10	1.66		
11	1.66		
12	1.66		
13	1.66		
14	1.66		
15	1.66		
16	2		
17	2.23		
18	2.51		
19	2.66		
20	2.66		