

FUNCTIONAL PIEZOELECTRIC YARN: TOWARDS OPTIMIZATION OF ZINC OXIDE NANOWIRES GROWTH

Dina Badawy¹, Saeid Soltanian², Peyman Servati², Addie Bahi¹, Frank Ko^{1*}

¹ Department of Material Engineering, The University of British Columbia, 6350 Stores Rd, Vancouver, BC V6T 1Z4, Canada

² Department of Electrical and Computer Engineering, The University of British Columbia, 5500 - 2332 Main Mall Vancouver BC V6T 1Z4, Canada

* Corresponding author: frank.ko@ubc.ca

Supplementary Materials

Table SI: Comparison between different ZnO NWs growth methods available in literature

Deposition method	CVD ¹ , VLS ² & ED ³	CBD ⁴⁻⁷
Growth conditions		
Equipment	Require sophisticated equipment	Require simple heat source : Convention oven ⁸ , Hotplate ⁹ , Microwave oven ¹⁰ , or Autoclave ^{11,12} .
Growth temperature	Require high temperature: for VLS (≥ 880 °C) and CVD (500 °C)	Relatively low temperature < 200 °C
Substrate	Require special conditions for example: ED done on a single-crystal substrate	Substrate independent ^{13,14} and it could be organic or inorganic
Nanowires properties		
Diameter distribution of ZnO NWs	Narrow range	Wide range
Orientation	XRD analysis shows only 002 and 004 diffraction peaks	Have more crystalline defects. XRD analysis shows strong peaks at 002 and 004, but other diffraction peaks such as 100, 101, 102, etc. exists as well ¹⁵

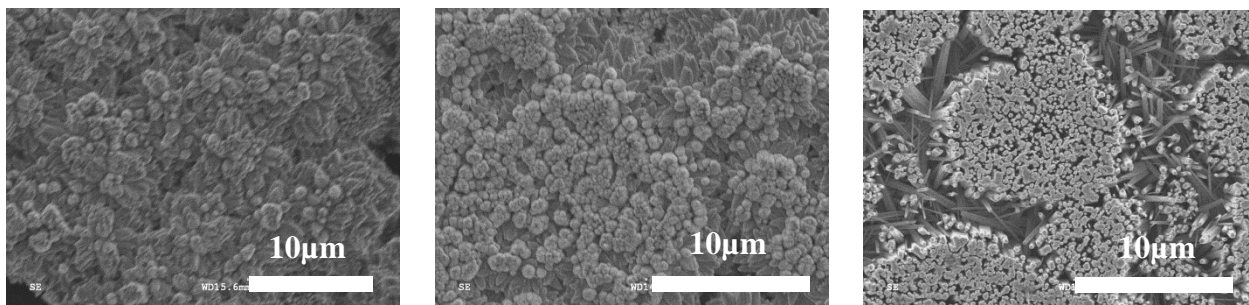
Table SII: Summary of work done on ZnO NWs growth parameters using hydrothermal growth and mediated by HMTA

*The growth heated up using an oil bath which has a higher boiling temperature compared to water.

** Bold writing presents the studied parameters

✓ means reported and ✗ means not reported

No	Ref.	Type of test	Substrate		Investigated Parameters					Reported Characterization				
			Material	Shape	Time (h)	Temp. (°C)	Concentration (mM)			Others	Length	Dia.	L/D	Others
						Zinc Nitrate	HMTA	Ratio						
1	13	One parameter	Si substrates	Flat	0.5-6	90	25	25	1:1	✗	✓	✓	✗	Morphology
2	5	One parameter	ITO glass substrates	Flat	0.33-4	40, 60, 80 and 95	100- 2.5		1:1	Seeding method	✓	✓	✗	—
3	16	One parameter	ITO & Si	Flat	0.5-6	90	50	50	1:1	With/out seeding	✓	✗	✗	—
4	17	One parameter	Si wafer coated with Au & flexible Kapton polymer	Flat	0.5-48	60,70,95	0.1 - 5	—	1:1	Substrate Material	✗	✗	✗	Morphology and density
5	8	Factorial design	Si wafer coated with Au	Flat	3-42	65-94	≈1-100		1:1	Capping agent	✗	✗	✓	—
6	4	One parameter	Substrate free		up to 4	48-95	50-75	25	—	✗	✓	✓	✗	Morphology
7	7	One parameter	Si	Flat	3	90	≤ 30		1:1/4 -1/4:1	✗	✓	✓	✗	Density
8	18	One parameter	ITO glass substrates	Flat	1-4	90-130*	40	40	1:1	✗	✗	✗	✗	Photo electrochemical properties
9	Present work	Factorial design	CY	Yarn	✓	✓	✓	✗	✓	✗	✓	✓	✓	Morphology



(a)

(b)

(c)

Figure S1: SEM micrographs of as grown ZnO NWs at different growth time, (a) 0.5 h, (b) 1.5 h, and (c) 2.5 h respectively. Growth temperature = 90°C, concentration 3:1

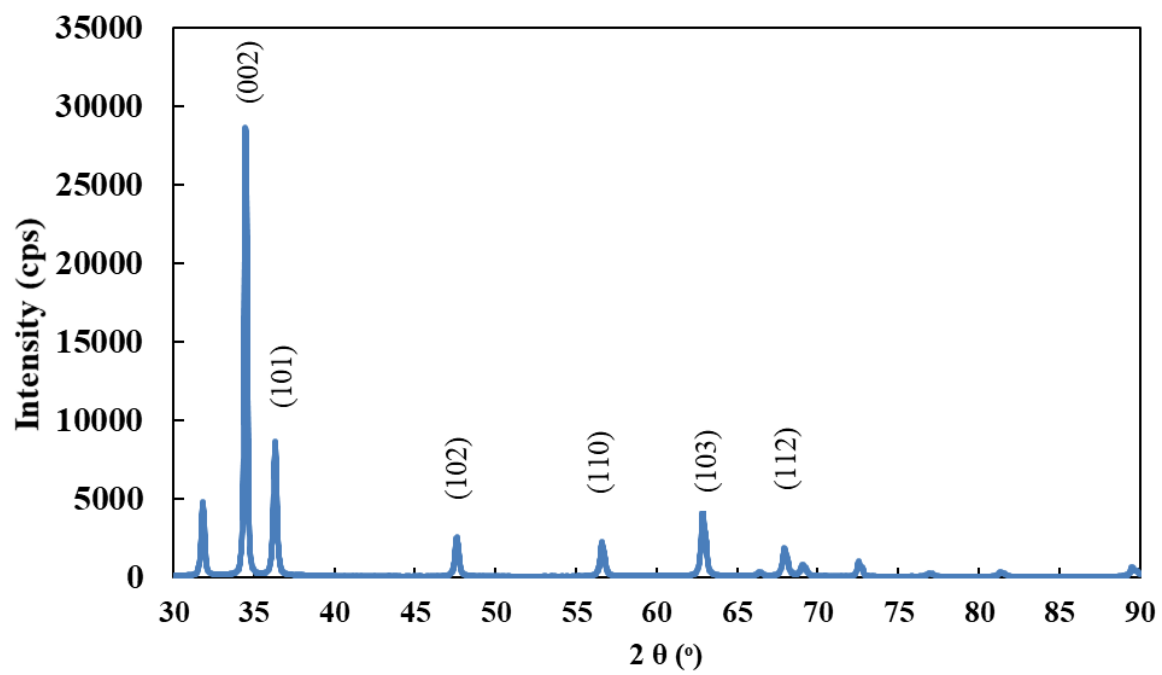


Figure S2: XRD pattern of ZnO NWs grown by hydrothermal technique 903103

Table SIII: The growth parameters study results; cells with similar shading color refers to that they have been done at the same time.

		Concentration ratios	Growth time (h)		
			3	6	9
Temperature (°C)	80	1:1	No growth	No growth	No growth
		3:1	Growth	Growth	Growth
	90	1:1	No growth	Growth	Growth
		3:1	Growth	Growth	Growth

Table SIV: The average length and diameter growth rate for 3:1 precursor concentration ratio

Time interval (h)	Length (µm/h)		Diameter (nm/h)	
	Temperature (°C)			
	90	80	90	80
(0-3)	1.10	0.36	33.28	29.32
(3-6)	1.29	1.63	16.75	25.32
(6-9)	0.25	0.25	23.35	2.21

Table SV: Comparison of the average nanowires' length and diameter between two growth cycles for condition 903103, and 903106 respectively

	903103		903106	
	L (µm)	D (nm)	L (µm)	D (nm)
Growth1	3.56±0.58	151.76±27.88	7.80±4.34	147.23±54.83
Growth2	3.30±0.63	99.85±29.27	7.17±1.66	166.06±47.79

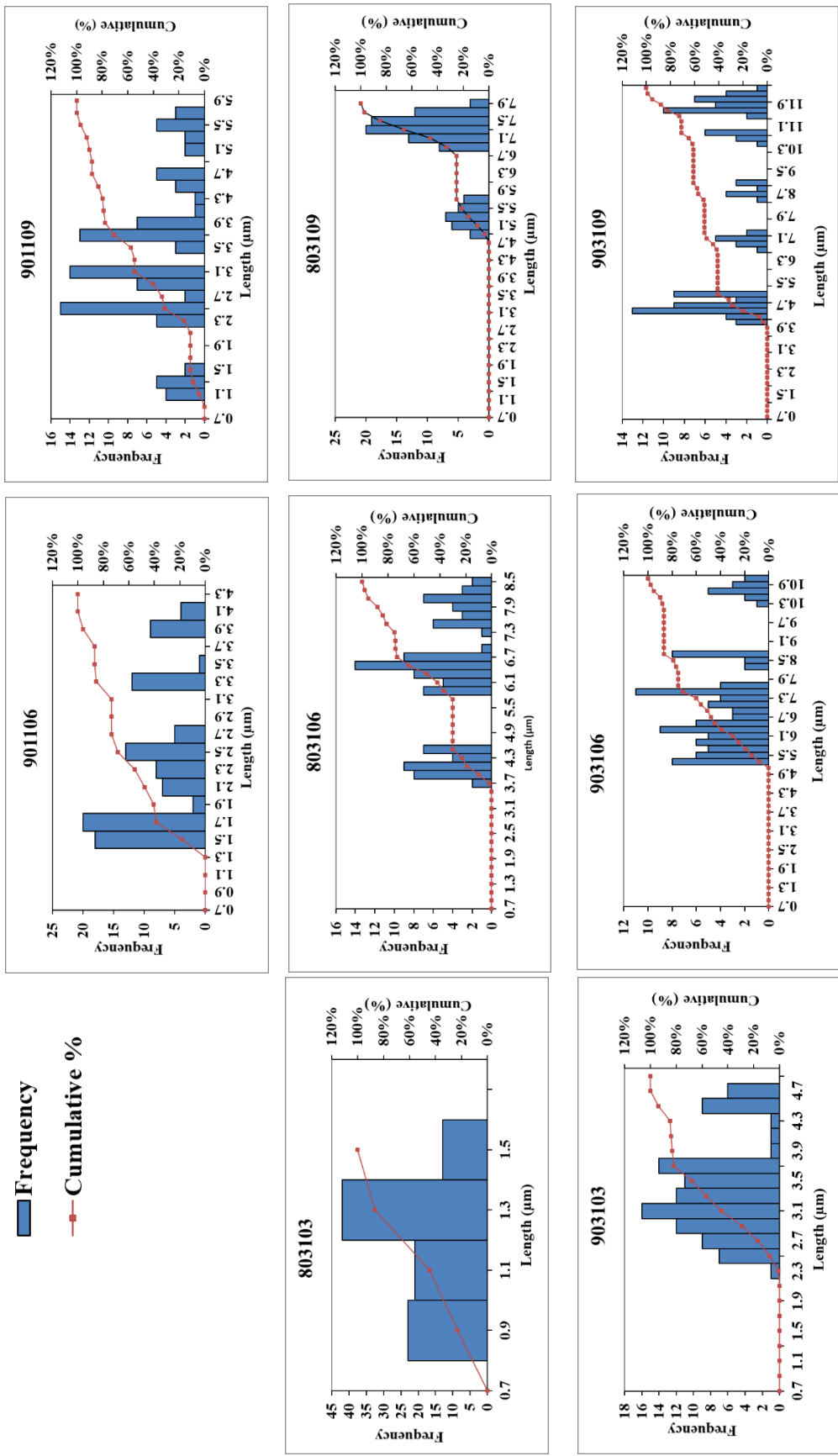


Figure S3: Length histograms for the growth conditions

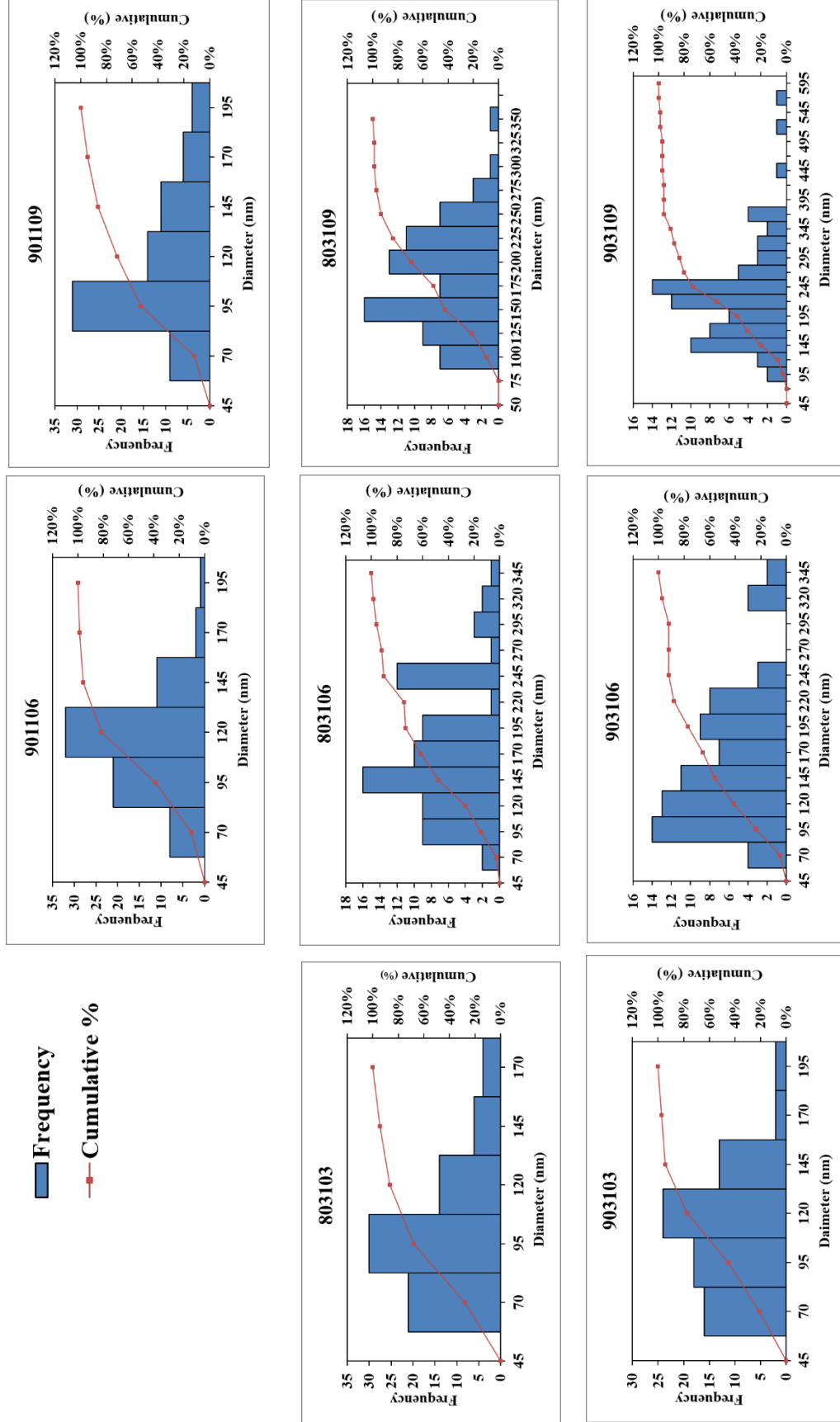
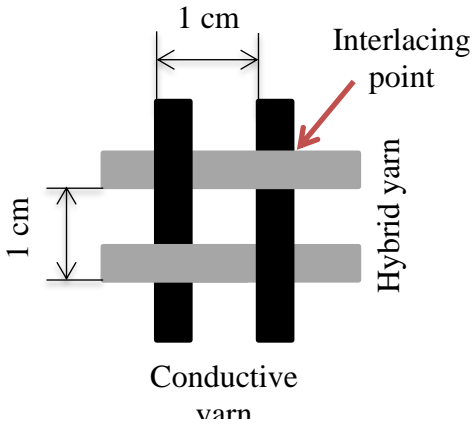
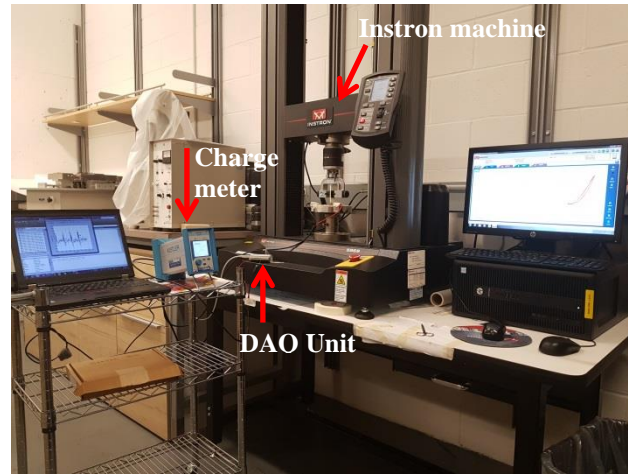


Figure S4: Diameter histograms for the growth conditions



(a)



(b)

Figure S5: (a) Illustrated diagram for the 2x2 woven fabrics, (b) Photograph of the measurement system used to evaluate the piezoelectric properties of the fabricated hybrid yarn.

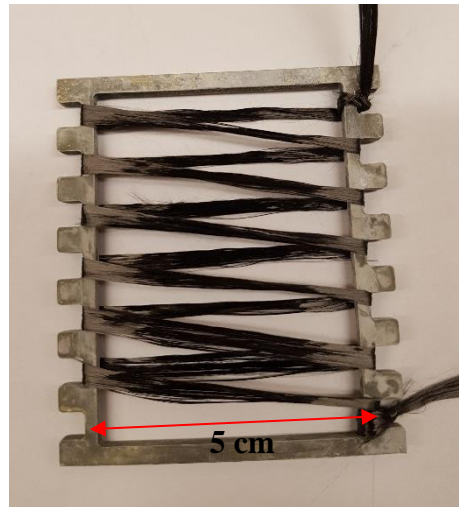


Figure S6: Photograph of the custom-made frame that holds the CY during the growth cycle.

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