Conductor films based on AgNWs spin-coated on glass substrates

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TRADITIONAL ELECTRONIC

- Numerous sequence steps
- Expensive
- Produce chemical waste
- High power consumption

Vs

PRINTED ELECTRONIC

- Less steps
- Low fabrication costs
- Large areas
- Simple fabrication
- High volume processing
- Flexible substrates

Printed electronics (PE) is set to revolutionize the electronics industry over the next decade

Transparent conductive thin film electrodes

Widely used for

- liquid crystal display (LCD)
- touch screens solar cells
- flexible displays.

→ ITO (indium tin oxide)

PROS
- High electrical conductivity
- High optical transparency

CONS
- Cracks on flexible substrates
- Require high temperature during thin film fabrication processes
- Expensive fabrication process

Transparent conductive thin film electrodes

The future display and other optic electronic devices will require suitable methods for flexible transparent electrodes to be produced at low cost and in a large scale.

Silver nanowires offer the potential to make transparent coating with high electrical conductivity.

Transparent conductive thin film fabrication

Substrate → soda lime

High volume process → Spin coatings
1000rpm 500rpm/s 30s

Thermal annealing → 20min @150ºC

Target

- Sheet resistance < 50Ω /sq
- Light transmission >90%

→

- Nanowires
- Nanowires concentration
- Number of layers

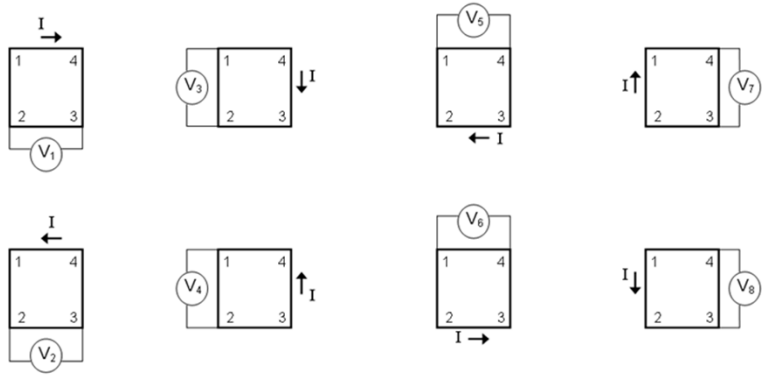
Characterization methods

LIGHT TRANSMISSION.
Spectrophotometer JΛsco.
The measurement has been carried out along the visible range Λ= 390-800

SHEET RESISTANCE.

In order to have a fast measurement, the resistance has been measured by a multimeter

Sheet resistance → Van der Pauw



Ag NANOWIRES

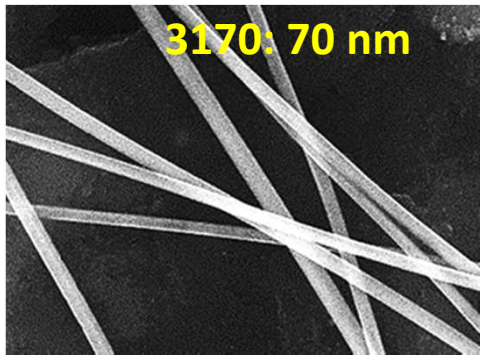
NANOGAP
SUBnmPARTICLES

- Ag nanowires diluted in Isopropanol
    1. DSO377:IPA
    2. DSO324:IPA

	AgNWs DS0377	Ag NWs DS0324
Mean nanowire length	37 µm	37 µm
Mean nanowire diameter	77nm	77nm
Concentration (%wt/wt Ag)	0,98	1,11
VIscosity	16,0cP	17,1cP

- Ag nanowires diluted in H2O , binder and IPA
    3. 3170INK:3170DF

	AgNWs 3170
Mean nanowire length	29 µm
Mean nanowire diameter	68nm
Concentration (%wt/wt Ag)	0.45
Viscosity	100cP



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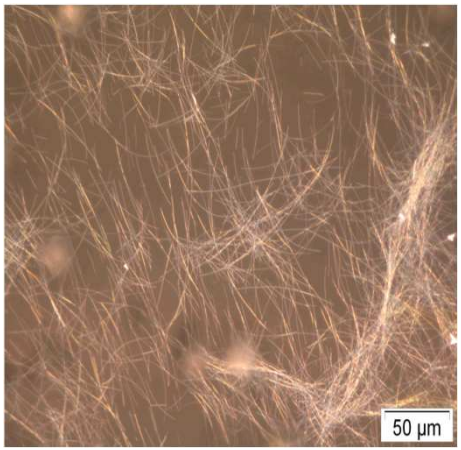
Nw DSO377 and DSO324

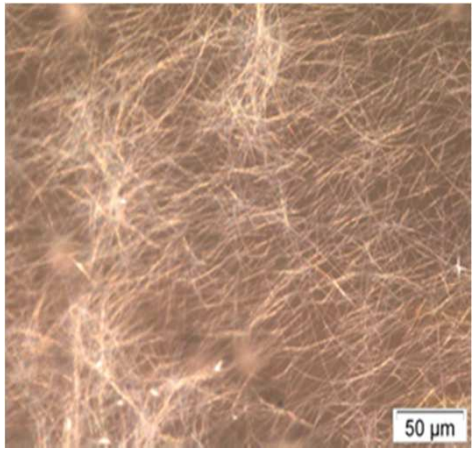
Ag/IPA:IPA	gr Ag/ml solution		LAYERS	DSO377-IPA		DSO324-IPA	
	DSO377	DSO324		Resistance	T%	Resistance	T%
1:0	0,771	0,873	1 layer	43-100Ω	71,06	50Ω	66,02
1:1	0,385	0,436	1 layer	300-600Ω	81,1	400-600Ω	77,66
			2 layers	50-70 Ω	74,72	40-50Ω	71,33
1:2	0,193	0,218	2 layers	66-70Ω	79,97	90-100Ω	76,05
1:3	0,096	0,109	2 layers	100-150Ω	81,59	80-140Ω	79,29
1:4	0,048	0,054	1 layer	200kΩ	84,4	60-400kΩ	84,01
			2 layers	300-400Ω	82,49	300-600Ω	81,4
			3 layers	100-150Ω	77,63	80-100Ω	77,5

Resistance measure no stables

Optical microscope images



DS0377:IPA 1:1 _1 layer



DS0377 1:1 _ 2 layers

Resistance measurements not uniform due to aglomerations presence in the dispersion

Ultrasonic agitation of AgNWs

DSO324

DSO324 after ultrasound bath (14min)

In order to improve the dispersion

↓

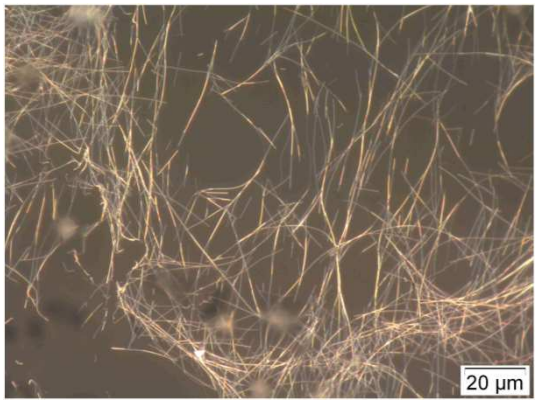
ultrasounds bath for 14min

DSO324 after ultrasound bath (14min)

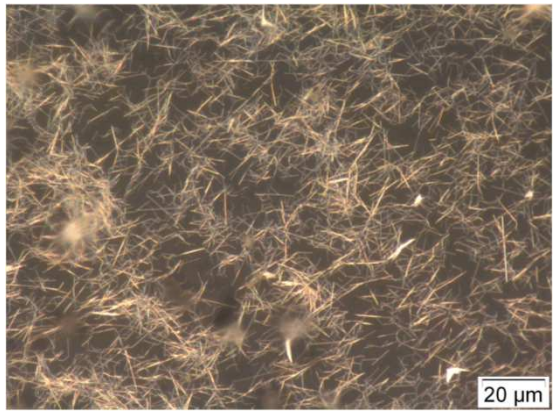
DSO324

Ultrasonic agitation of AgNWs

		DSO324-IPA	
Ag/IPA:IPA	**No. LAYERS**	**RESISTANCE**	**T%**
1:0	1 layer	60-90Ω	66
1:O 14 min ultrasound bath	1 layer	**150kΩ**	



DSO324



DSO324 after ultrasound bath (14min)

CONCLUSIONS

- Ultrasound bath breaks the nanowires.
- Longer nanowires are needed in order to reduce the sheet resistance of the layer

Nw 3170INK

	AgNWs 3170
Mean nanowire length	29 µm
Mean nanowire diameter	68nm
Concentration (%wt/wt Ag)	0.45
Viscosity	100cP

NANOGAP
SUBnmPARTICLES

3170INK → Ag wires in 3170DF
3170DF → Water, cellulose binder, IPA

Ag3170INK: 3170DF	No Layers	DRY	Resistance	T%	Substrate pretreatment	Vol. ink	Layer thickness	Roughness
1:0 (4,41µgrAg/ml)	1 layer	air	22Ω	79,63	etch O 5min	200µl	95,55	6,62
	2 layers	air	11Ω	65,91	etch O 5min		218,94	12,08
	1 layer	air	21Ω	80,05	xxx		90,44	7,78
	2 layers	air	11Ω	67,7	xxx		157,58	10,46
1:1 (2,21µgrAg/ml)	1 layer	air	60 Ω	88,89	etch O 5min	200µl	88,83	4,65
	1 layer	90ºC 5min	51Ω	87,39			84,02	6,92
	2 layers	air	25 Ω	81,42			178,2	7,29
	2 layers	90ºC 5min	29 Ω	83,74			145,8	13,58
1:1 (2,21µgrAg/ml)	2 layers	air	30Ω	83,6	etch O 5min	400µl	199,49	6,32
	2 layers	90ºC 5min	30 Ω	84,18			154,72	7,4
1:1 (2,21µgrAg/ml)	1 layer	air	50Ω	88,92	xxx	200µl	84,24	3,79
	1 layer	air	70Ω	88,76		400µl	95,13	3,79
	2 layers	air	20-30Ω	80,03		400µl	203,53	6,44
1:2 (1,1µgrAg/ml)	1 layer	air	196Ω	91,57	xxx	400µl	101,19	3,94
	2 layers	air	40Ω	87,29			159	10,48

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Nw 3170INK

Ag/water: 3170DF	µg Ag / ml solution	No. Layers	Sheet resistance (Ω/sq)	T%
1:0	4,41	1 layer	9,8±0,3	79,9±0,3
		2 layers	4,7±0,8	67±1
1:1	2,21	1 layer	49±14	88,5±0,7
		2 layers	14±2	83±2
1:2	1,1	2 layers	64,9	87,29

Target

- Sheet resistance < 50Ω /sq
- Light transmission >90%

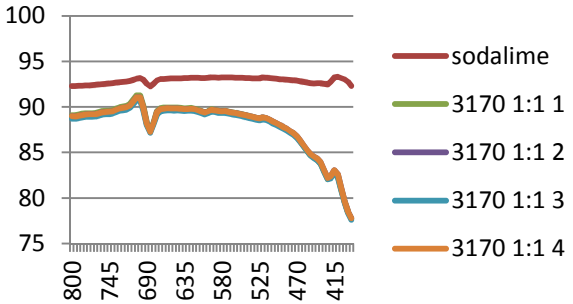
Nw 3170INK

3170INK: 3170DF	µg Ag / ml solution	No. Layers	Sheet resistance (Ω/sq)	T%
1:1	2,21	1 layer	49±14	88,5±0,7

FUTURE WORK

- Look for an other glass substrate with better transparency in order to improve the global optical transparency

Soda lime T% 92,2%



- Reduce the error in the sheet resistance value

Conclusions

- A good dispersion is necessary. Agglomerations do not allow to obtain a uniform film
- Ultrasound bath breaks the nanowires.
- Longer nanowires are needed in order to reduce the sheet resistance of the layer
- The ink diluted in water with lower Ag concentration presents lower sheet resistance thanks to the good dispersion

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