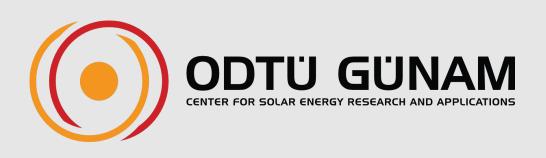


Screen Printable Fire Through Nickel Contacts for Crystalline Silicon Solar Cell

Veysel Unsur, Ph.D.^{1,2}

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NECMETTIN ERBAKAN UNIVERSITY

Outline

D Motivation

□ Approach

-Paste Preparation

-Wafer Preparation

-Printing

D Results

-Electrical Performance

-Microstructural Analysis

G Future Work and Conclusion







The total supply of Ag demand is about to lack meeting the demand!

Environmental impact of Ag is greater than the alternatives.

Alternatives such as nickel are evenly distributed around.

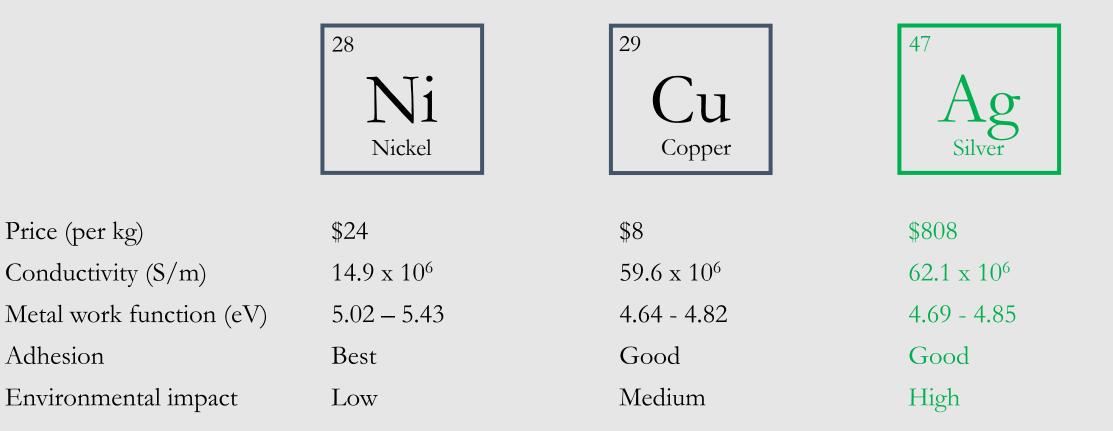
Silver Supply/Demand S	ummary				[1]
	2012	2016	2020	2022	2030
Total Supply (MOz)	1,008	1,046.9	953.0	1,030.3	1075.6
Electrical and Electronics	270.9	308.9	304.1	353.3	435.7
Total Industrial	445.2	475.3	464.9	539.6	628.5
Jewellery/Bar/Coin	439.9	400.4	354.8	481.0	524.2
Photovoltaics	55.0	93.7	101.0	127.0	251.2
Total Demand	978.8	979.4	880	1,101.8	1252.2
Price (per ounce)		\$17.17	\$20.69	\$21.76	\$80-\$120







Motivation: What are the alternatives?









Ni has higher resistance to oxidation compared to Cu

Ni has higher resistance to humidity (corrosion) compared to Cu

Ni has better adhesion to Si than Cu

Ni has no diffusion into Si during high temperatures like Cu



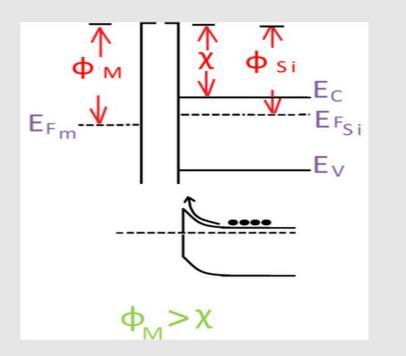




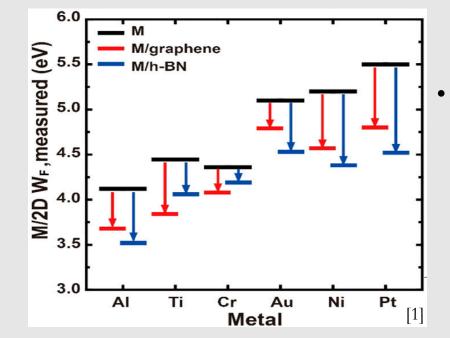
Approach: Requirements for a Ni based contacts

1- Good ohmic contact formation

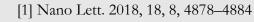
- Ni has a work function of over 5 eV •
- c-Si has the electron affinity of 4.05eV



• To avoid Schottky contact formation, the metal work function is tuned



There's a flow of 6 electrons from 2D material to the metal that lowers the metal work function





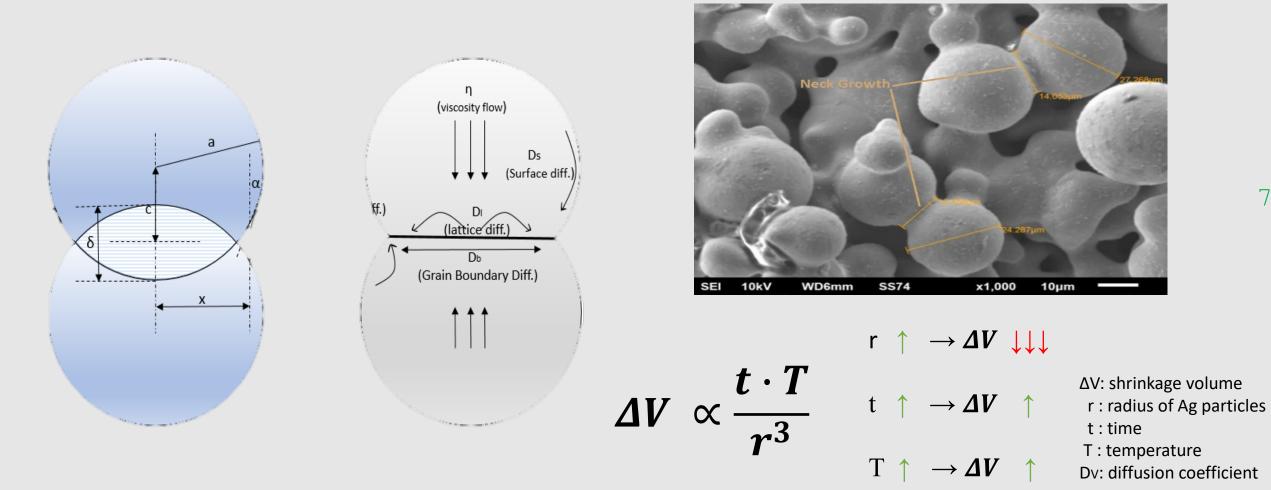






Approach: Requirements for a Ni based contacts

2- Low series resistance - finger resistance - sintering









Approach: Requirements for a Ni based contacts

3- Low diffusivity into Si

- Ni atom clusters are bigger than Cu which doesn't allow moving through interstitial sites in the Si lattice
- Ni has moderate solubility in Si compared to Cu that has high solubility
- The binding energy between Ni and Si is stronger than Cu/Si

4- Adhesion

• Relatively strong binding energy between Ni and Si provides good adhesion

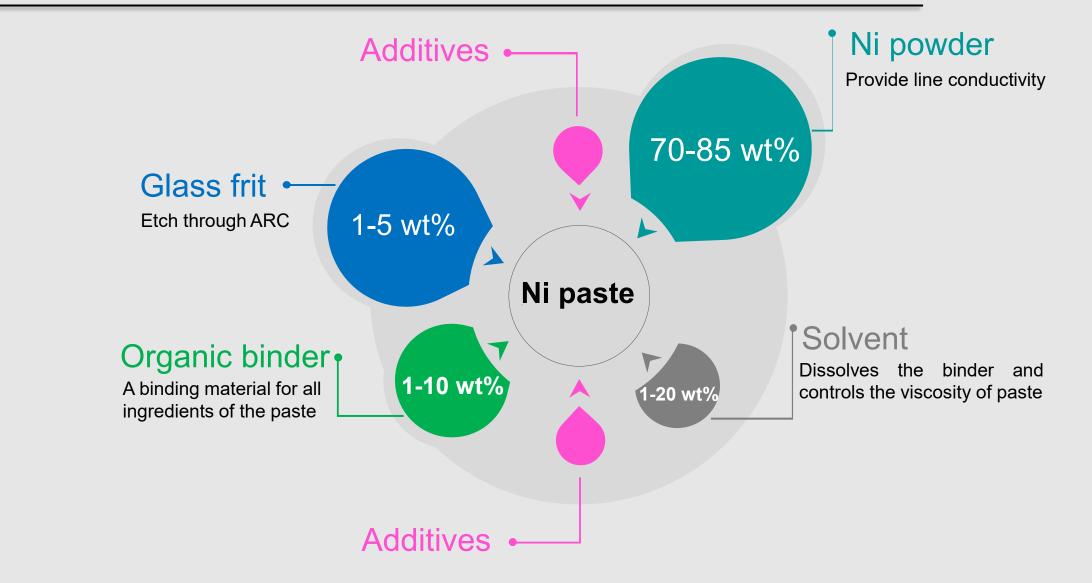






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Approach: Paste Preparation



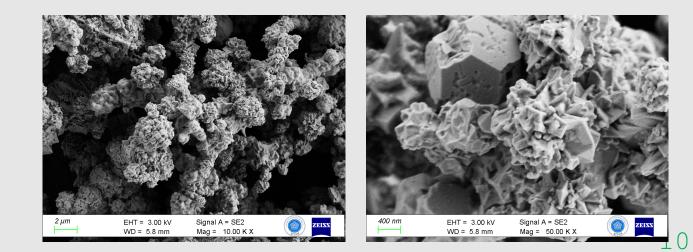




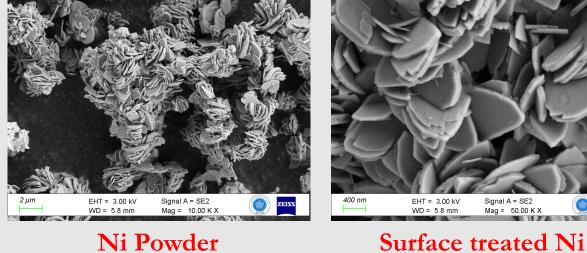


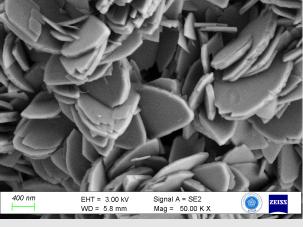
Approach: Metal Powder

- The metal particle size is below 1µm •
- To increase the surface energy of the • Ni particles, the surface is treated



	Diameter at	Diameter at	Diameter at
	10.00 %	50.00 %	90.00 %
Min.	0.112	0.463	1.402
Max	0.113	0.470	1.425
Mean	0.112	0.466	1.414
Standard deviation	0.001	0.004	0.011
CV	0.511	0.758	0.806
	0.113	0.470	1.425
	0.112	0.466	1.414
	0.112	0.463	1.402













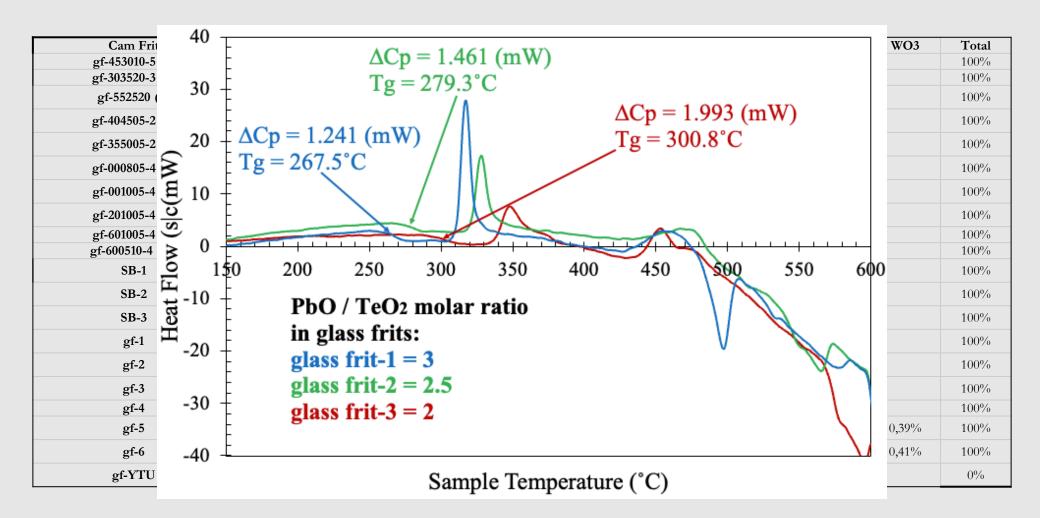
Approach: Glass Frit

Cam Frit	Тд	PbO	SiO2	Al2O3	TeO2	B2O3	Bi2O3	ZnO	MgO	WO3	Total
gf-453010-5 (1)		45%	30%	10%	5%	3%	3%	2%	2%		100%
gf-303520-3 (2)		30%	35%	20%	5%	5%	5%				100%
gf-552520 (3)	215,42 C	55%	25%	20%							100%
gf-404505-2 (4)	216,96 C	40%	45%	5%		6%		4%			100%
gf-355005-2 (5)	223,11 C	35%	50%	5%		6%		4%			100%
gf-000805-4 (6)	215,52 C		8%	5%	40%	6%	33%	8%			100%
gf-001005-4 (7)	189,1 C		10%	5%	45%	10%	25%	5%			100%
gf-201005-4 (8)	174,81 C	20%	10%	5%	25%	10%	25%	5%			100%
gf-601005-4 (9)		60%	10%	5%	10%	5%	5%	5%			100%
gf-600510-4 (10)		60%	5%	10%	5%	5%	10%	5%			100%
SB-1	300,8 C	40%	5%		20%	10%	15%	10%			100%
SB-2	279,34 C	50%			20%	10%	10%	10%			100%
SB-3	267,54 C	60%			20%	10%		10%			100%
gf-1	279,29 C	60%	10%	5%	10%	5%	5%	5%			100%
gf-2	258,30 C	60%	5%	10%	5%	5%	10%	5%			100%
gf-3	241,73 C		2%	2%	5%	20%	35%	36%			100%
gf-4					65%		15%	20%			100%
gf-5	268,61 C	24,34%	15,07%	0,89%	45,39%		8,36%	5,56%		0,39%	100%
gf-6	284,86 C	25,28%	15,66%	0,92%	41,25%		10,70%	5,78%		0,41%	100%
gf-YTU	273,97 C										0%









• The resistance of the glass frit is in the range of $10^{-8} \Omega \cdot cm$ at room temperature!

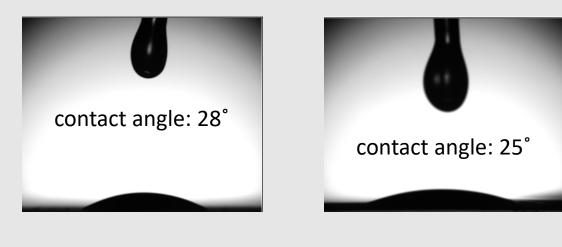






For the Organic vehicle:

- As solvents: Terpineol, Texanol and Butyl Butyrate
- As binders: Ethyl Cellulose or PVP
- As thixotropic agents: Castor Oil or Polyamide Wax
- As surfactants: Sorbitan Triolate



DUIMAN	VTJG 2.1	1.0.3-9			VISC	.03111.0	ATA RE	PORT			
		ORMATION									
Test Start: 17	/01/23 16:35 V (1.000000)		Test End: 1 S/N: 86036	7/01/23 16:35			Tester: Adn Model: DV			FWV: 2.1.8.3-9	
Spindle RV-0)6 (6)		S/N: 0	100			SMC: 100.0		SRC: 0.000	YMC: 0.000	
Global Limits	s: None		Temperatur	e Offset: None				e Control: No		Accessory: None	
File: Internal Notes: None	Memory/17.01	1/5 RPM Spindle 6.vdt					Test Data S	aved: 17/01/23 1	16:36	Test Data Saved by: Administrator	
	-										
Test Meth	od File Name: Un	1.00		7	thod Saved On				The Marked O	be noted Theorem	
Test Method Instructions:	File Name: Un	saved Test		Test Me	thod Saved On	-			Test Method C	reated By:	
		re Data Collection	D		0.0	n	_	Develop	QC Limits		
Step Speed (#) (RPM	i Temperatu (°C)	re Data Collection Type	(hh:mm:ss)	Avg Duration (hh:mm:ss)	at step end	Type Oper. V		Density (g/cm ³)	QC Limits Type Low High Unit		
1 5.0	25.0	Single Point	OFF	OFF	OFF	Time = 00:00		0.0000	None		
D		-									
Results Test Averagin	na:										
	Viscosity	Torque	Speed	Shear Stress	Shear Rate	Temperature	Density	Accuracy			
0	(cP)	(%)	(RPM)	(dyne/cm2)	(1/s)	(°C)	(g/cm3)	(+/-cP)			
	0.00	0.0	00.0				0.0000	0.00			
Step Averagi	ng:										
Step	Viscosity	Torque	Speed	Shear Stress	Shear Rate	Temperature	Density (a(amil)	Accuracy			
	(cP) 60800	(%) 30.4	(RPM) 5.0	(dyne/cm ²)	(1/s)	(°C) 23.2	(g/cm ³) 0.0000	(+/-cP) 2000			
Gel Time (mm:ss)		Total Time (mm:ss)	Peak T (°C)	emp	Peak Temp T (mm:ss)	ime					
00:00:00.0		00:00:30.0	0.0,*C		00:00:00.0						
DATA											
SAMPLE	VIJG 2.1 RUN INFO	1.8.3-9	Speed (RFII) 5.0	Shear Stress (dyne/cm ²)	Shear Rate	Temperature (°C) 23 OSITY	(g/cm ³) 0000 ATA RE		nde	x < 9.(17/01/2
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ODTÜ GÜNAM





Approach: Metal Paste





glass frit

2

Metal Paste





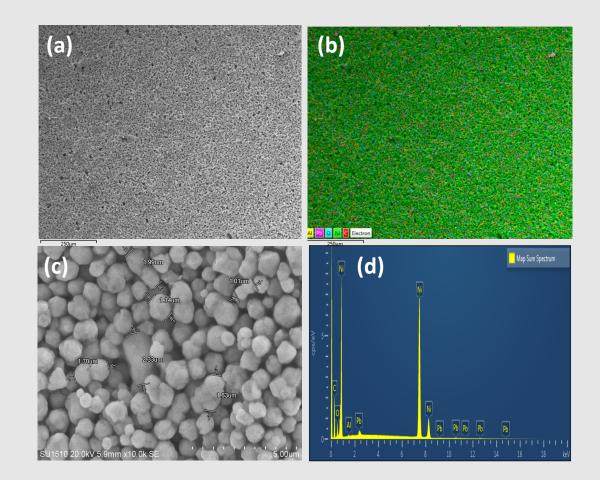


organic vehicle

14

Approach: Metal Paste

 All the prepared components: Metal Powder
 Glass Frit
 Organic Vehicle
 are then three roll milled



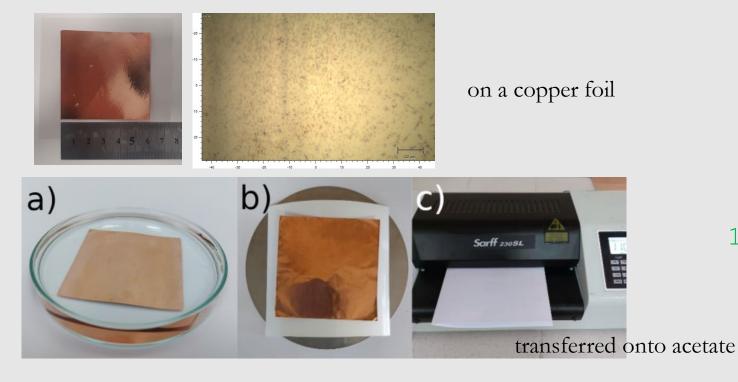


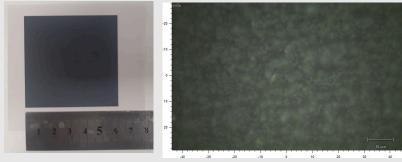




Approach: Graphene

- Graphene is grown on a copper foil
- Then it is transferred via a simple laminator on the wafer
- Optical images show somehow evenly distribution of graphene





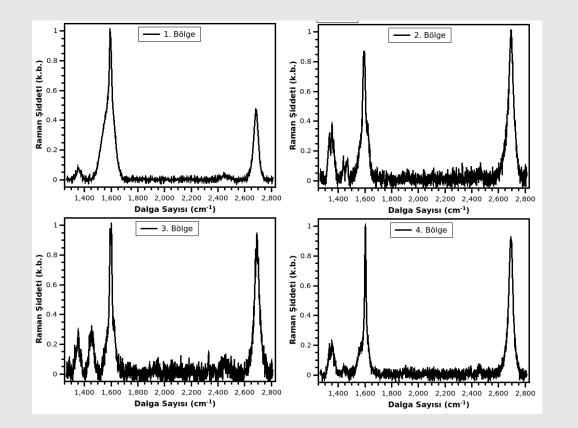
transferred onto the wafer

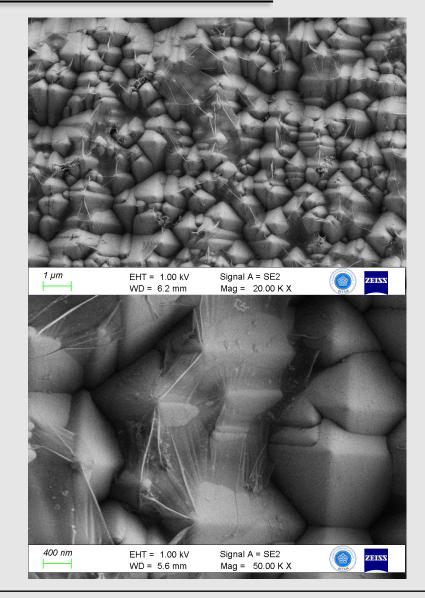






Approach: Graphene







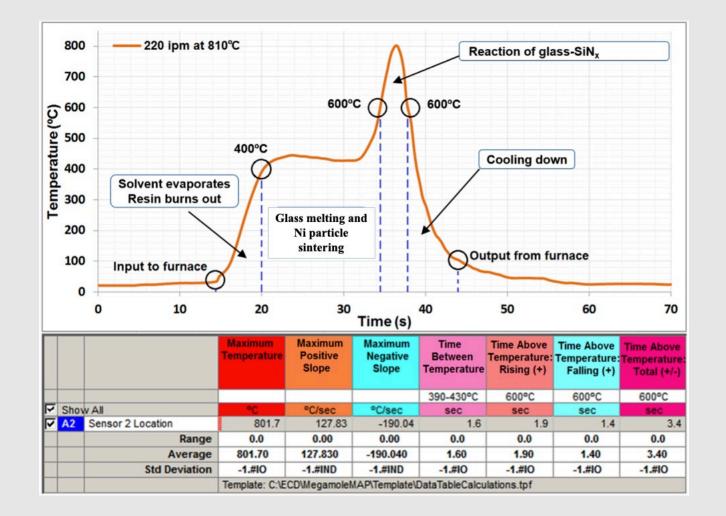




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Approach: Screen Printing and Firing

- The metal pastes then printed onto the wafer with the graphene layer on top
- The cell are finally fired with the similar temperature profile



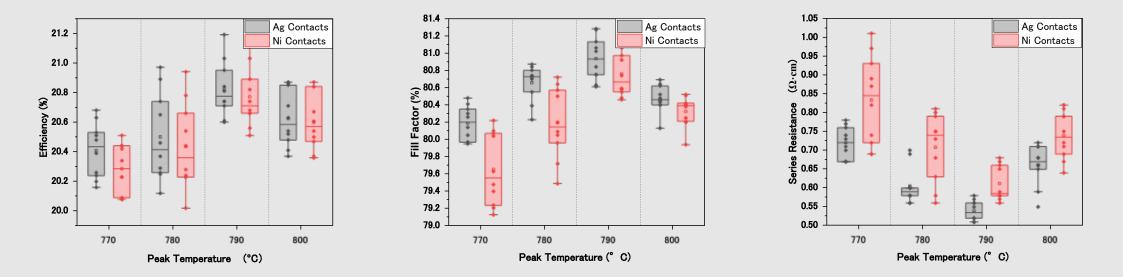






Results

Electrical Measurement



- The mean lateral finger resistance for the Ni contacts is $1.1\Omega/cm$ while the Ag contacts yielded $1\Omega/cm$.
- The mean contact resistance for the Ni contacts is $5.2 \text{ m}\Omega \cdot \text{cm}^2$ while the Ag counterpart is $4.8 \text{ m}\Omega \cdot \text{cm}^2$



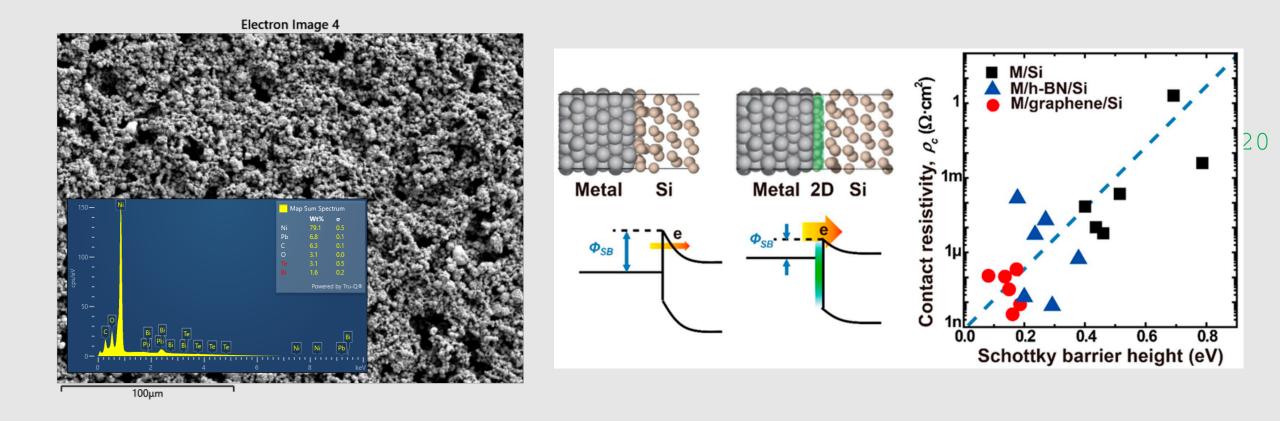




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Results

Microstructure analysis

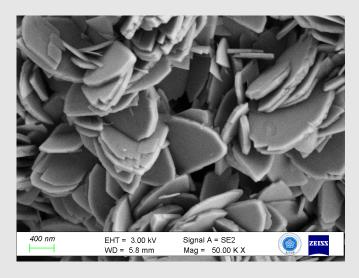




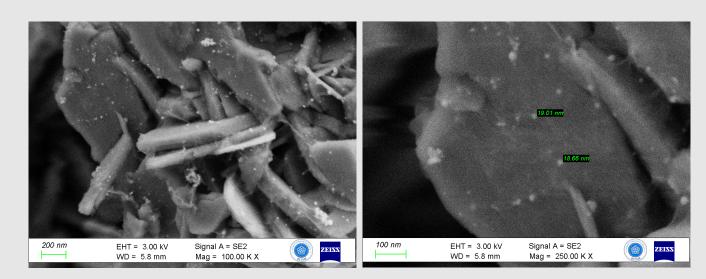




- This study is a proof of work on screen printable Ni contacts.
- The challenge is to have the graphene layer transferred onto the Si before metallization.
- To avoid this, doping the graphene onto Ni powder creates the same effect on the metal work function



Surface treated Ni



Surface treated Ni with doped powder





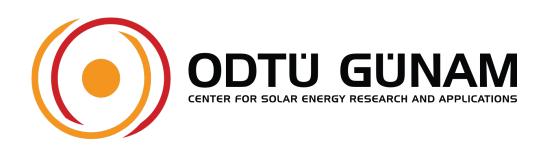




Thank you for your attention!

Questions?

Veysel Unsur, Ph.D.^{1,2}





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