

**PV Nano Cell Ltd.**  
**“PVN”**

**July 2013**

- ❑ PVN envisages positioning itself to become the world leader in inkjet inks for electronic applications.
- ❑ PVN aspires to assist making a “greener” world improving the global environment through the development and implementation of nano based technologies and materials. The first market adressed is the photovoltaic industry.

**Picture: Contact-less printing of conductor lines in a photovoltaic wafer with PVN's ink, courtesy of the Fraunhofer Institute (IKTS)**

# PV Nano Cell Ltd - PVN

## Background/status



- ❑ Israeli innovative company active from end 2009.
  - ❑ Highly professional and dedicated team.
- ❑ Commercial sales of first product and developing next line of products.
- ❑ Establishing a JV in China.
- ❑ Successfully scaling up the nano-based inks production process.
- ❑ Focused on inkjet inks for solar metallization and general conductive inkjet inks.
- ❑ In advanced stages of qualifying inkjet metallization inks – aiming to start commercial sales by end of 2013.
- ❑ Raised seed capital from Terra VP, and B round (\$ 3.7 M) just closed: Infinity IP Bank (China) , Israeli Electric Company, Terra VP, and private investor (Belgium). Ministry of Industry (OCS) and Ministry of Energy support.

- ❑ Twice gained the Eureka Label



# PVN Roadmap – Main Products



Solar Cell Inkjet  
Metallization



**Enhanced Solar Inks**  
Enhanced performance  
Sales: 2014

**Nano Silver Solar Ink**  
Final development &  
Qualification stage  
Sales: 2013

Printed Electronics Inkjet  
Conductive Printing



**Nano Silver Dispersion  
& General Ink**  
Qualified product  
Up Scaling Process  
Sales started 2010

**Nano Copper Ink**  
First successful ink  
prototype available  
Sales: 2014

**Nano Wires Coatings**  
R-2-R process TCO  
replacement  
Sales: 2015-6

□ PVN is partnering with industry and academy to speed up market penetration of its products.

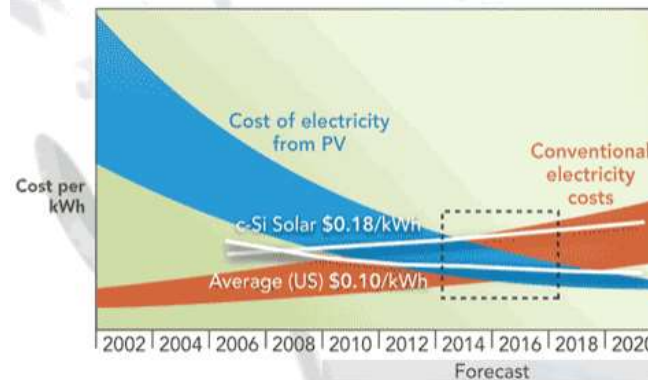
□ First target market – Photovoltaics, Printed Electronics following.

# The Need:

Photovoltaic power costs to reach grid parity levels



Holy Grail : Sustainable  
Grid Parity



- ❑ The main goal for the PV industry is to lower costs and reach a sustainable world wide grid parity.
  - ❑ expanding the PV industry to become a substantial power source up from less than 0.2% today.
- ❑ Quick cost reductions of silicon based cells can and will be achieved mainly through reducing materials costs and increasing cell efficiency.

## The Sun, the unlimited Green Energy Source



- The Photovoltaic (PV) industry harvests the sun energy.
  - 40 minutes sun radiation = the global annual electricity consumption!
- PV is the fastest growing power-generation technology.
- A > \$ 90 B growing market (2012) getting close to grid parity.

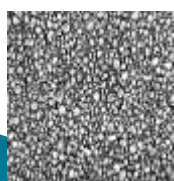
## □ PV Nano Cell Ltd. is an enabler in the industry !

- Enabling up to a substantial \$/W cost reductions \*



Photovoltaic power at grid parity level costs

PVN Silver nano dispersion



Nano Silver - 50nm



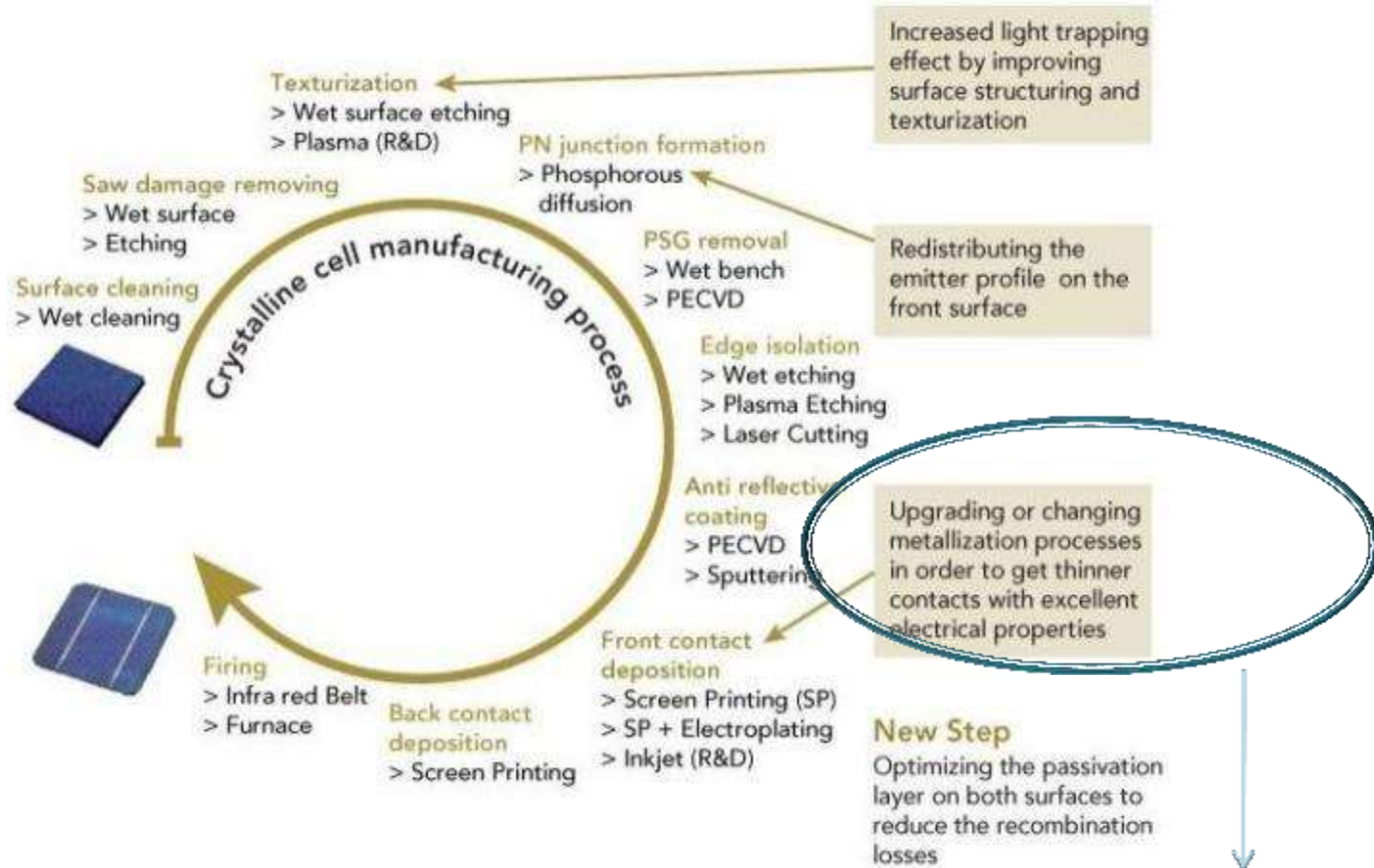
PVN inkjet ink



Solar cell inkjet metallization



# Technology Barrier



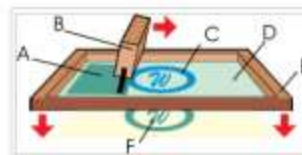
Silicon cell metallization is a major efficiency-limit & cost-determining step in solar cell processing

# Technology Barrier

## Metallization



- ❑ Present technology – Screen Printing.
- ❑ **Inkjet Metallization Technology - Breakthrough Solution**
  - ❑ Less silver
  - ❑ Higher efficiencies
  - ❑ No breakage
  - ❑ High printing accuracy
  - ❑ Low operation costs
- ❑ **Inkjet printing needs unique nano materials based inks**
  - ❑ **PVN is the inkjet metallization enabler**





# Solar cell metallization

## Breakthrough Solution - Inkjet



### □ **Technology breakthrough – inkjet printing**

- Inkjet printing metallization requires unique inks:
  - Low viscosities (< 20 cP).
  - High metal concentrations.
  - Anti reflectant etching additives (mostly glass frits).
  - Small particle size additives (nano metal particles).
  - Special surface tension and rheology requirements.
  - High stability (no sedimentation or agglomeration).

### □ **PVN inks are the inkjet printing metallization enablers**

- PVN has unique technologies for producing cost efficient high quality nano metal inks, a must for inkjet metallization inks.
  - PVN has exclusive license for optimized GF for solar metallization inks (developed by the Fraunhofer IKTS Institute).

# Photovoltaic Market

All forecasts predict continuous growth



- ❑ The market shows continuous growth through the last 5 years.
- ❑ Every forecast predicts substantial PV market growth for the next decade.
  - ❑ As grid parity is reached the growth is expected to speed up.
  - ❑ Expanding the use of PV as a power source, above the 0.2% as of today.
  - ❑ As emerging economies adapt PV technologies.
- ❑ >90 % of installations – Silicon based solar cells.
- ❑ Prices \$/W have dropped substantially the last two years.

# Photovoltaic Market

## Inkjet metallization – The Opportunity



- ❑ Big changes occurring in the industry nowadays (2011-2013):
  - ❑ Steep price reductions.
  - ❑ Vertical consolidation & companies going bankrupt.
  - ❑ China's role as PV producer increasing, to around 60%.
  - ❑ PV power generating industry continues growing, specially in Far East. China plans to install 20 - 40 GW PV systems in the next your years.

### ❑ Changes are due to:

- ❑ Big inventories which are been reduced.
- ❑ Production overcapacity and silicon/wafer price reductions. [126]
- ❑ Lower prices in China which may be not sustainable (NREL Oct. 2011). [124]



❑ As a result there is a big pressure to lower costs quickly through new technologies → IJ metallization!

Not silicon related.

# PVN Solar Cell Inkjet Metallization Inks

## Value Proposition



- ❑ PVN is a market enabler for inkjet printer producers & substantial cost reduction enabler for solar cell manufacturers.
- ❑ PVN inkjet solar metallization inks benefit:
  - ❑ Lower silver usage
  - ❑ Narrow patterns.
  - ❑ Higher efficiencies.
  - ❑ As screen printers (contact printing) are replaced by IJ will enable a reduction in silicon usage (thinner wafers).
    - ❑ enabling achieving a sustainable grid parity.
- ❑ PVN is positioning itself to become the leader in the field.
  - ❑ Additional applications are following.

# PVN Conductive Inkjet Inks

## Printed Electronics - Nano Silver & Nano Copper Inks



PVN is leveraging its vast aggregate experience in Nano-metal-inks to become an industry Printed Electronics enabler.



### Printed Electronics Market Outlook

- Market analysis from IDTechEx and other organizations forecasts an explosive growth in the market size for printed electronics in the next 10 years.
  - From \$1.9 billion in 2009
  - To \$57 billion in 2019...!

#### The market for printed and potentially printed electronics in 2009



36% Predominately Printed

18% Flexible

#### The market for printed and potentially printed electronics in 2019



76% Predominately Printed

73% Flexible

Source: IDTechEx

4/13/2010

Printed Electronics Europe 2010

10

# PVN Inkjet Metallization Inks

## Printed Electronics - Value Proposition



- ❑ PVN is a market enabler for inkjet printer producers & substantial cost reduction enabler for Printed Electronic applications.
- ❑ PVN inkjet conductive inks benefits:
  - ❑ Digital, high resolution, small patterns printing.
  - ❑ Enhanced electrical properties leading to a substantially reduction of metal quantity needs.
  - ❑ Flexible substrates electronics enabler.
  - ❑ Nano Copper based inks lower price versus Silver inks.
- ❑ PVN is positioning itself to become the leader in the field.

### Printed Electronics – Inkjet Nano Silver & Nano Copper Conductive Printing

- Touch screens
- PCB's
- RFID
- OLEDs
- Displays
- e-paper
- Sensors
- many others

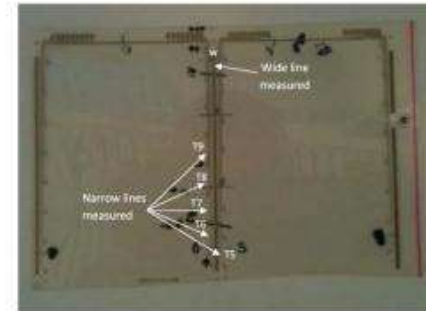


Figure 1. Touch screen sample showing wide and narrow lines measured.



PVN becoming the leader in conductive ink for digital printing.

# Customer Traction

## Market Qualification



□ PVN's Nano Silver and Nano Copper General Inks have been qualified and/or are in process of qualification by:

- Commercial companies (under NDA).
- Fraunhofer IKTS Institute.
- Holst Center.



- Proven inkjet printability, wide printer range.
- Proven high ink stability.
- Enhanced properties.



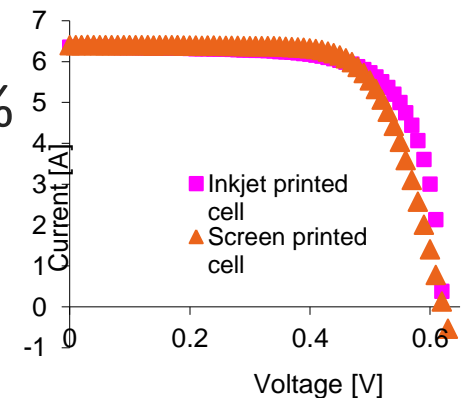
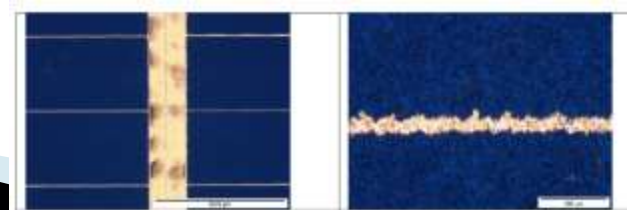
# Customer Traction

## Inkjet Metallization ink - Status



□ Solar silver inkjet metallization ink, low contact resistance, in advanced qualification process by the leading players in the field, equipment and cell producers.

- Low viscosity at 50% metal loading.
- Good printability and stability.
- Proven narrow pattern printing.
- Low resistivity  $< 2.0 \times \rho$  bulk, low contact resistivity  $< 3 \text{ m}\Omega \cdot \text{cm}^2$  (on 58 - 60  $\Omega$  emitter).
- Higher efficiencies than screen printing  $\sim + 0.5\%$
- Less silver printed  $\sim 30\text{-}50\%$  less.



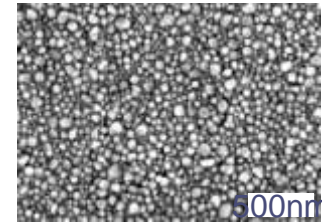
Inkjet printed cells – by PVN

# Customer Traction

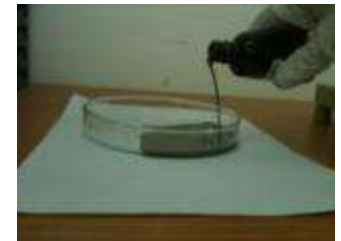
## General Inkjet Conductive Silver inks - Status



- PVN Nano Silver Inks – outstanding properties
  - Unique chemistry and unique particles (Silver, copper compatible).
  - Qualified ink.
  - Low viscosity at 50% metal loading.
  - Proven narrow pattern printing.
  - Enhanced electrical properties:
    - Low resistivity  $< 2 \times \rho$  bulk.
    - Excellent physical/chemical stability – over 1 year
    - Excellent printability.
  - Best cost efficient
    - Applications – Printed electronics.
    - Small volume sales.



Nano Silver –  
50nm



# Product Portfolio

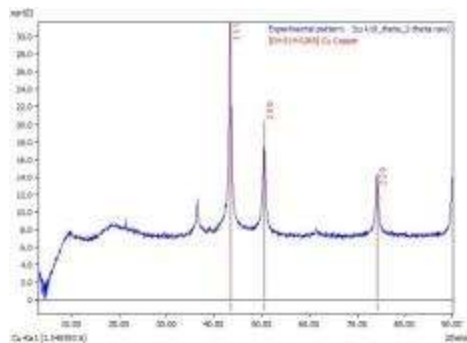
## Nano Copper Based Inks



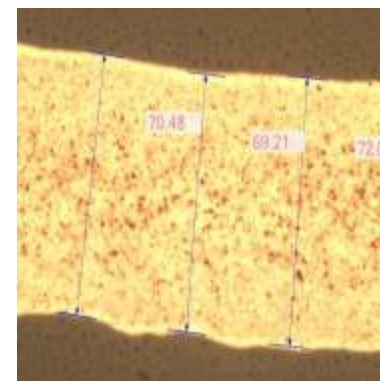
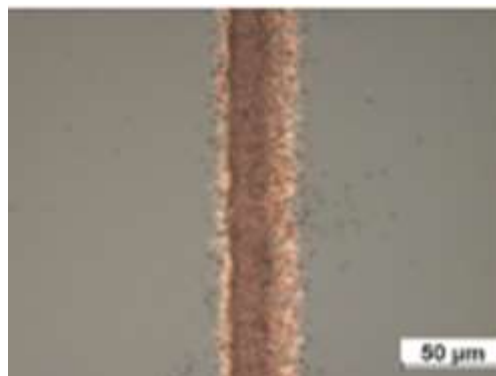
Fine copper IJ printed line on glass and silver pads



- Nano Copper ink best results:
  - 30% - 25% copper.
  - Inkjet printable.
  - 70  $\mu\text{m}$  width lines.
  - Resistivity's as low as 17  $\mu\Omega\text{cm}$  (10 bulk), laser sintering, and  $\sim 10^{-5}$   $\Omega\text{cm}$  level (200° C).
  - Stable to oxidation.



XRD results of PVN's nano Cu



# PVN Product Portfolio

## Nano Copper Based Inks



### □ Why nano Copper?

- Electrical properties are similar to Silver's.
- 100 times cheaper than Silver metal - cost driver!

Silver Bulk Price\*

~ 920 - 1300 \$/kg

Copper Bulk Price\*\*

~ 7 -10 \$/kg

- Silver price has doubled in the last year, becoming the most expensive material, after silicon, in cell manufacturing and expensive in printed electronics applications.

### □ Nano Copper based inks:

- As of today – not available commercially.
- PVN proved feasibility to produce stable nano copper dispersion.

## □ PVN portfolio

- Stable Dispersions of Nanometric Silver Particles” (article) - PCT filled, Dec. 6<sup>th</sup> 2011 PCT/US11/63459) – submitted NOW in US, Europe, Russia, China, India, Israel, Brasil, Japan & Korea.
- A patent application licensed from TAU “Metal Nanowire Thin-Films” (process) PCT/IL 2009/000842- submitted in many countries, in Europe already allowed.
- A joint patent application with TAU “Conductive nanowire films” (article & process) filled March 1, 2012, No. 61/605,421 PCT stage, receive positive examiner report.
  
- Soon will be filling additional patent applications.

# PVN's Offer



- ❑ PVN a reliable inkjet metallization ink provider:
  - ❑ Competitive pricing.
  - ❑ High quality inks.
  - ❑ Enhanced inks pipeline in process.
- ❑ PVN is seeking:
  - ❑ Customers.
  - ❑ Strategic partners, investors.
  - ❑ Development partners:
    - ❑ To enhance PVN products.
    - ❑ To develop additional real market applications.
    - ❑ To develop new processes to implement PVN technologies.
  - ❑ Will be glad to discuss further with you!

# Thank you!

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**Contact Us**