PV Nano Cell Ltd.
“PVN”

July 2013

www.pvnocell.com
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 addressed 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

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

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

Nano Copper Ink
First successful ink prototype available
Sales: 2014

Enhanced Solar Inks
Enhanced performance
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 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 *!

PVN Silver
nano dispersion

PVN inkjet
ink

Solar cell inkjet
metallization

Photovoltaic power at grid parity level costs

Nano Silver – 50nm

© PV NanoCell - Confidential
Silicon cell metallization is a major efficiency-limit & cost-determining step in solar cell processing.
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
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).
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.
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 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 replace 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 is leveraging its vast aggregate experience in Nano-metal-inks to become an industry Printed Electronics enabler.
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

PVN becoming the leader in conductive ink for digital printing.
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.
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 < \(2.0 \times \rho_{\text{bulk}}\), low contact resistivity < \(3 \, \text{m}\Omega*\text{cm}^2\) (on 58 - 60 \(\Omega\) emitter).
- Higher efficiencies than screen printing \(\sim +0.5\%\)
- Less silver printed \(\sim 30-50\%\) less.

Inkjet printed cells – by PVN
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 x \( \rho \) bulk.
  - Excellent physical/chemical stability – over 1 year
  - Excellent printability.
- Best cost efficient
  - Applications – Printed electronics.
  - Small volume sales.
Nano Copper ink best results:
- 30% - 25% copper.
- Inkjet printable.
- 70 μm width lines.
- Resistivity's as low as 17 μΩcm (10 bulk), laser sintering, and ~ $10^{-5}$ Ωcm level (200°C).
- Stable to oxidation.

XRD results of PVN’s nano Cu

Fine copper IJ printed line on glass and silver pads
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. 6th 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!

For further contacts:

Dr. Fernando de la Vega, CEO
fernando@pvnanocell.com
Mobile: +972-54-5599061