pvnanocell

Sicrys™ Copper Inks

Handbook

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1. General Guidelines

1.1 Goal

This handbook provides details on Sicrys™ Cu ink products, with guidance on handling, printing and sintering of the inks.

For additional information, see note at the end of the document.

1.2 Cu Sicrys™ Products

Sicrys™ Cu inks are solvent-based nanoparticle inks, suitable for inkjet printing and sintering by various possible methods (section 1.5). A comprehensive list of Sicrys™ products can be found at www.pvnanocell.com, including ink specification information, data sheets, and MSDS. The information can also be access by sending an email with the specific request to info@pvnanocell.com. The inks mentioned in this handbook include the following:

- Sicrys™ IC25EG-1
- Sicrys™ IC50DM-7
- Sicrys™ IC50TM-8

1.3 Ink Handling

Safety and Handling

- Take proper care of inks as chemicals, read the Material Safety Data Sheet (MSDS) and product labels before using the products.
- Use appropriate equipment and safety measures.
- Keep product container closed when not in use to prevent solvent evaporation and spilling hazard.

Storage

- Sicrys™ Cu inks can be exposed to air for short periods of time without significant degradation (up to ~30 min), because the oxidation rate of the ink under ambient conditions is low. However, it is strongly recommended to refill the bottle with Argon by bubbling it into the ink for several seconds every time the bottle is opened. The bottle should then be tightly sealed before storing.
- Keep ink in a ventilated, dry place, at room temperature, without direct light. Keep bottle properly closed. Solvent evaporation will cause ink deterioration (high viscosity and agglomeration). Storage in freezers is not recommended.
- Water or excess humidity in the ink will damage the ink.

Shelf Life

- Sicrys™ Cu inks are packed under argon. When kept in a closed bottle, the ink is stable against oxidation and will show good jettability for over 1 year.

General Spill Management and Response

Note: Detailed spill management to be found in specific MSDS

- Wear personal protective equipment: gloves, lab coat, goggles.
- Ventilate area of spill.
- Contain the spill by pre-installing trays or absorbent materials. Do not allow material to reach electrical connections.
- If material has spilled, clean first with a dry absorbent-type cloth, and follow if desired with a wet cloth.

Ink Disposal

- Dispose according to instructions in MSDS. Do not dispose into sewage systems.

1.4 Printing

Sicrys™ inks have been designed by PVN to be compatible with many commercially available inkjet print heads. However, the information shared in this handbook pertains to Konica Minolta KM1024, Ricoh Gen3 E3 and Dimatix cartridge print heads. The information hereby shared is provided "As Is", based on PVN experience, and PVN does not warrant its accuracy, completeness or suitability.

Printing and drying of Cu ink may be performed on a stage under ambient conditions within a time frame of up to 30 minutes. Nevertheless, an inert environment may be preferred in order to avoid oxidation.

General Printing Guidelines:

Use suitable inkjet printer and print head (compatible with conductive printing). Follow print head supplier guidance.

Note: Sicrys™ inks have high metal content, therefore high densities, (take this into consideration when adjusting printing parameters such as vacuum meniscus).

Before Printing

- Make sure all electrical connections in the printer are protected so that none of them is exposed to the conductive ink during the printing process. PVN inks are metallic and should not come into contact with electrical connections.
- Clean the ink supply line of the print head with appropriate recommended flushing fluid (or ink specific solvent) to remove contaminants and previous residual inks/solvents. Other solvents/inks may be incompatible with our inks.
- Mix bottle containing the ink (hand shake bottle) before filling the print head.

During Printing

- Work at a head temperature that correlates with print head supplier and PVN recommendations for ink viscosity.
- We recommend wiping the nozzle outlets during the print session with a moistened clean room cloth with the recommended flushing fluid. This will ensure no clogging of the nozzles occurs. A good practice is to perform a wipe every 10 minutes. Follow print head manufacturing guidance.
- Cloth used for wiping the print head must be fibreless and soft (used in clean rooms) so as not to damage the print head. Never use industrial paper towels, toilet paper or sponges.

- Capping, spitting or tickle modes are recommended if ink remains idle between print sessions.

After Printing

- When printing session has been completed, discharge the remaining ink from the print head. Clean the print head with appropriate flushing fluid, performing purges and wipes. Perform this step until the cloth wiping the print head comes out clean, with no remnants of the ink.
- Cloth used for wiping the print head must be fibreless and soft (used in clean rooms) so as not to damage the print head. Never use industrial paper towels, toilet paper or sponges.

Flushing Fluid

- Use appropriate flushing fluid where it is recommended in the handbook.

Cat. #	Recommended Flushing Fluid
Sicrys™ IC25EG-1	Ethylene Glycol (CAS# 107-21-1)
Sicrys™ IC50DM-7	Diethylene glycol monomethyl ether (CAS# 111-77-3)
Sicrys™ IC50TM-8	Triethylene glycol monomethyl ether (CAS# 112-35-6)

1.5 Sintering

Sicrys™ Cu inks may be sintered by various methods:

1. Thermal sintering: Thermal sintering must be performed under inert atmosphere (argon). Recommended conditions are 300°C, 30min, argon atmosphere; with cooling the tracks before exposing to air. Achievable resistivity: ~10^{-4} Ωcm (x70 bulk).

    - When using a convection oven with a thin substrate, hold the substrate in such a way so that it will not move due to air flow.

2. Laser sintering: Sintering conditions should be fine-tuned to the type of laser and specific application. Laser sintering may be carried out in ambient conditions (air), even with some delay between printing and sintering (1-2 days), without lowering the final conductivity. Achievable resistivity: ~6.5 μΩcm (x4 bulk).

    Following are examples of laser sintering process results (not optimized):

Laser wavelength: 532nm

Laser operation mode: Continuous

Laser spot size: 350µm

		Laser Data				Line Dimensions		Resistivity	
INK	Substrate	Scanning profile	Fluence [J/cm^2]	Power [W]	Scan speed [mm/sec]	Width [µm]	Avg. Thickness [µm]	µΩcm	x Bulk (Cu)
IC50TM-8	FR4	Along line	428	1.5	1	75	5	6.5	3.8
			643	2.25	1	75	5	10.4	6.1
			57	2	10	75	5	8.3	4.9
			86	3	10	75	5	13.4	7.9
	Kapton	Along line	23	1	12.5	51	5.6	9.4	5.5
	Glass	Raster in line direction, 0.1mm step	86	1	3.3	312	2.3	14.6	8.6

3. Photonic sintering: Sintering conditions should be fine-tuned to the type of lamp and application. Sintering may be carried out in air, even with some delay between printing and sintering (1-2 days), without lowering the final conductivity.

4. UV flash sintering: UV flash conditions should be fine-tuned to the type and power of lamp.

1.6 Adhesion

Adhesion of Cu Sicrys™ inks has been tested and found suitable for the substrates: Glass, PET, Kapton®, FR4, PC and LCP. Note: when applying ASTM or ISO adhesion standards, make sure the test is relevant to your application (the cut done in the standards is usually not needed for conductive patterns).

2. Printing Guidelines

2.1 Printing conditions for Cu Sicrys™ inks

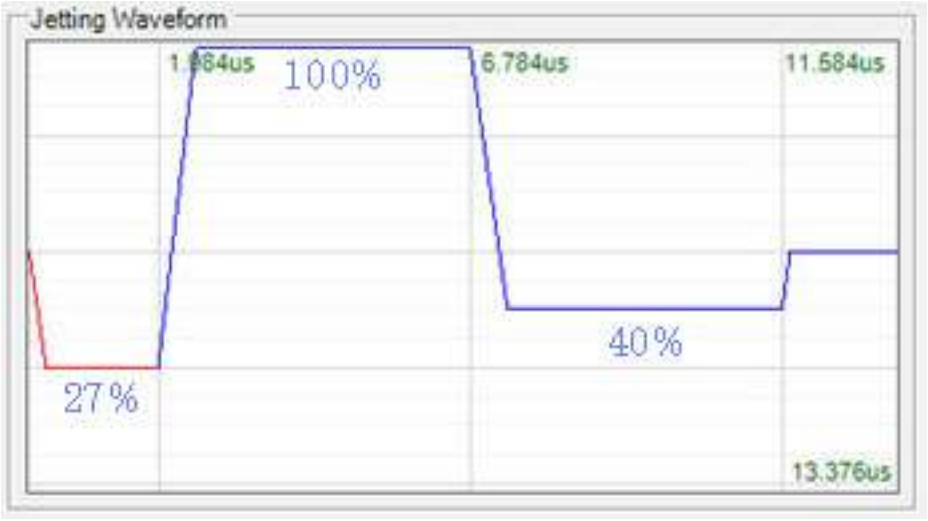
Sicrys™ inks have been designed by PVN to be compatible with many commercially available print heads such as Dimatix, Ricoh, and Konica Minolta (some print head models may not be compatible with conductive solvent inks, print head data sheet should be checked). The information shared in this handbook pertains specifically to Konica Minolta KM1024, Ricoh Gen3 E3 and Dimatix cartridge print heads. In sections 2.1.1, 2.1.2 and 2.1.3, we recommend starting printing conditions for the different inks in these print heads. The waveform printing conditions hereby shared are provided "As Is", based on PVN experience, and PVN does not warrant its accuracy, completeness or suitability. The information is meant to be used as a starting point for the user. It is recommended that the user perform optimization of the printing process in order to accommodate its needs to the specific system and application of interest.

Further information and specifications of each print head are available in the print head manufacturer's website. Please follow the guidelines and instructions of the printer system and print head provider.

2.1.1 Sicrys™ Printing Conditions with DMC-11610 Print Head

Cat. #	Head temp (°C)	frequency (kHz)	Waveform (V)
Sicrys™ IC50TM-8	40	5	35

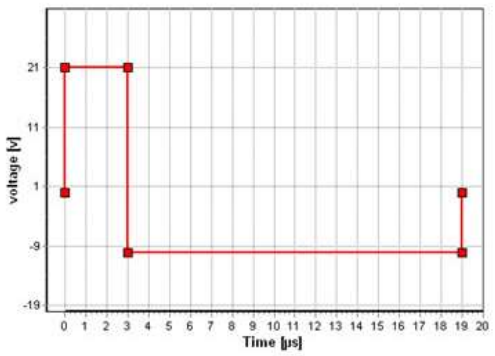
DMC-11610 Pulse Shape:



2.1.2 Sicrys™ Printing Conditions with KM1024 SHB Print Head

Cat. #	Head temp [°C]	frequency [kHz]	Waveform (V,µs)
Sicrys™ IC25EG-1	35	6	(18,3)(-9,12)
Sicrys™ IC50TM-8	35	6	(15,3)(-7.5,12)

KM 1024 Pulse Shape:



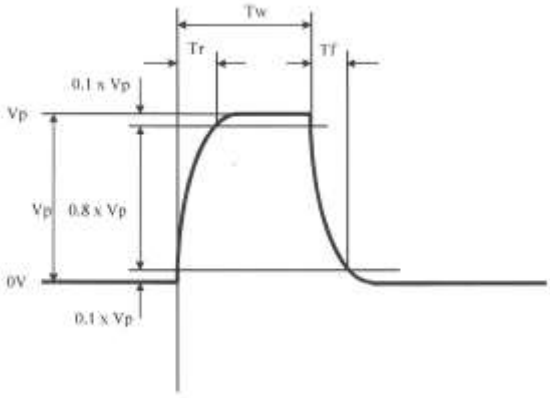
2.1.3 Sicrys™ Printing Conditions with Ricoh E3 Gen3 Print Head

Fire sequence: 3 phase channel
Phase delay time: 35µs

Cat. #	Head temp (°C)	frequency (kHz)	Waveform * Vp (V), Tw (µs)
Sicrys™ IC25EG-1	30	6	24, 7
Sicrys™ IC50TM-8	30	6	19, 8

* The system sets the rise time (Tr) and the fall time (Tf) at 2.8µs (measured between 10 and 90% amplitude) and the slew rate.

Ricoh Gen3 E3 Pulse Shape:



2.2 Printing recommendations for Sicrys™ ink

2.2.1 Printing recommendations for narrow line printing

It is recommended to follow the steps outlined below in order to obtain narrow lines with Sicrys™ ink:

With printed dot shifting:

1. Print dots at low dpi, where dots do not touch.
2. Print additional shifted dots until reaching a continuous line. For best results, wait sufficient time between layers in order to ensure the previous layer has dried.
3. Repeat (1) and (2) until desired thickness is achieved.

Note: Printed pattern thickness determines the final dpi and number of times will repeat (1) and (2).

Without printed dot shifting:

1. Print a single layer at a wide range of resolutions and choose the resolution that provides the narrowest continuous line without bulging characteristics.
2. Print at the chosen dpi from (1) until reaching desired thickness. For best results, wait sufficient time between layers in order to ensure the previous layer has dried.

Additional recommendations:

1. It is recommended to print at a higher resolution in the cross-print direction than in the print direction.
2. Higher substrate temperatures may be used in order to produce narrower lines and decrease drying time.

2.2.2 Printing recommendations to avoid coffee stains

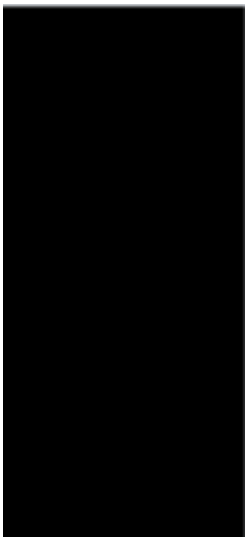
If coffee stain effect is observed in the printed pattern, it is recommended to lower the stage temperature in order to reduce the effect.

2.2.3 Printing recommendations for wide area printing

It is recommended to follow the steps outlined below in order to obtain wide area printing with Sicrys™ ink:

1. Print the first few layers (1-2) at 60% area coverage (60% of desired pattern):

2. Print the remaining layers at 100% area coverage (100% of desired pattern):



2.3 Printer Work Procedures

2.3.1 Printer Startup and Shutdown Procedure with Sicrys™ inks

2.3.1.1 Goals

- Cleaning the print head at the end of each day and before the weekend.
- Maintaining the print head in good condition.
- Allowing easy start up at the beginning of each printing shift.
- Priming the print head.
- Changing between inks.

2.3.1.2 Printer Startup

1. At the beginning of a printing shift, purge all flushing fluid out of the system before introducing ink into the system.
2. Priming the print head:
    - Perform a long purge.
    - Wait 10 sec.
    - Perform a short purge.
    - Adjust the meniscus pressure (Sicrys™ inks are high density inks. Adjust the meniscus pressure accordingly).

2.3.1.3 Printer Shutdown

1. Empty the ink out of the system (according to ink system procedures).
2. Introduce flushing fluid into the system.
3. Purge the print head with alternating pulses of flushing fluid and air. Run each pulse for the duration of 5 sec.
4. Repeat step 3 three to four times or until clear fluid comes out the nozzles.
5. Cap the print head in a solvent-rich environment.

2.3.1.4 Additional Recommendations

- Clean the ink tank from ink before adding the flushing fluid.
- Wait 10 sec between washing cycles.
- Between ink changes in the printer, use shutdown procedure (without step 5) followed by the startup procedure.

2.3.2 For printers with capping (ink can be left in system overnight)

- At the beginning of the day perform long maintenance cycle.
- At the end of the day, perform regular maintenance cycle and perform capping to the print head.

2.3.3 Printer Maintenance Procedure with Sicrys™ inks

2.3.3.1 Goals

- Maintenance procedure to be implemented throughout the printing session.
- Maintaining the print head in good condition.
- Keeping all nozzles running between print runs.
- Opening clogged nozzles.
- Straightening crooked jetting.

2.3.3.2 Maintenance Procedure

1. If required due to missing nozzles or crooked jetting:
2. Perform a wet wipe:
   2.1. Use a lint free wipe, wet with the advised flushing fluid.
3. Perform a nozzle check: Print a test pattern using all nozzles in order to check the nozzle condition.
4. If not all nozzles are firing, repeat step 2.
5. If after 2 wipes nozzles are still missing, perform: short purge and wipe.

For additional questions or comments please contact:

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