

# LOW TEMPERATURE PHOTONIC SINTERING FOR PRINTED ELECTRONICS

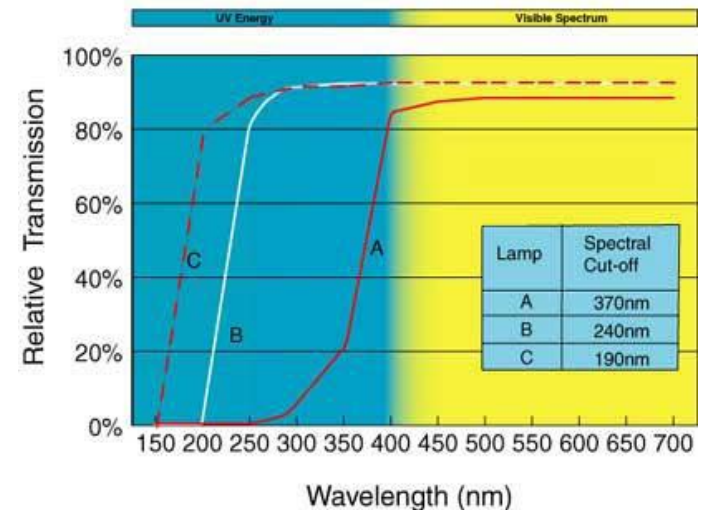
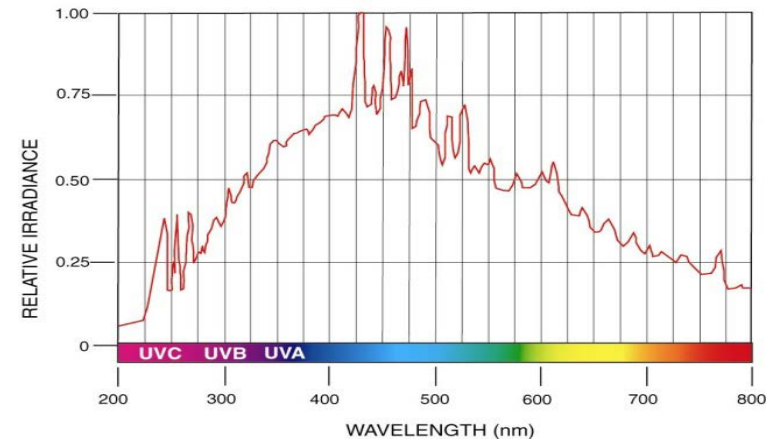
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XENON - Intrinsiq  
Workshop June 2015

# Topics

- Introduction to Pulsed Light
- Photonic sintering for Printed Electronics
- Sintering different materials
  - Silver
  - Copper
  - Gold
- R&D tools for Ink Development
- Roll to Roll Production Equipment
- Thick film sintering challenges
- Strategy for rapid process development
- Satellite test facilities
- Concluding Comments

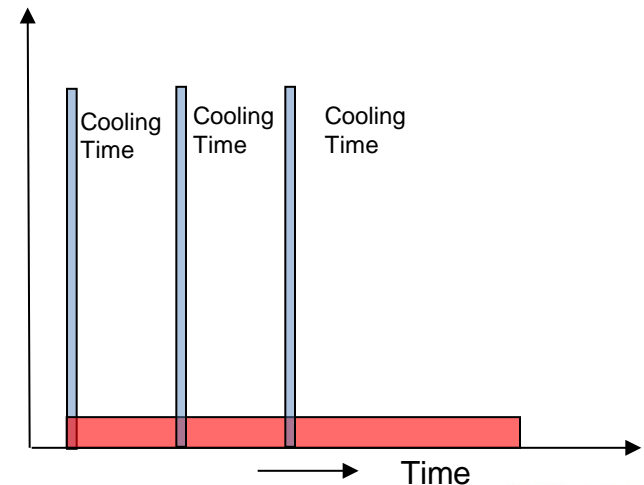
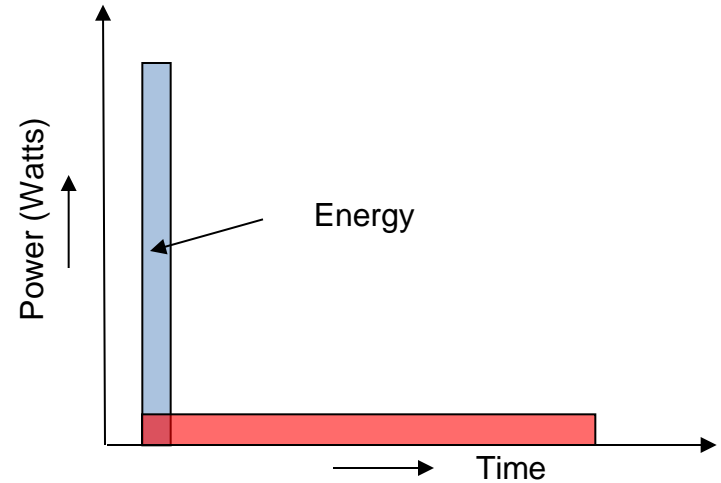
# Flash Lamps

- Xenon flash lamps have a broad spectrum of Light from deep UV to IR.
- Typically used for Curing and Sterilization where high photon energy is required
- When Xenon gas is broken down due to a high energy field it goes from being an insulator to a conductor
- Excitation and recombination of ions within the arc plasma creates light.
- The envelope used can determine the spectral content of the lamp
- Lamps can explode due to excess energy through lamp
  - Typically operate at 10% of explosion energy



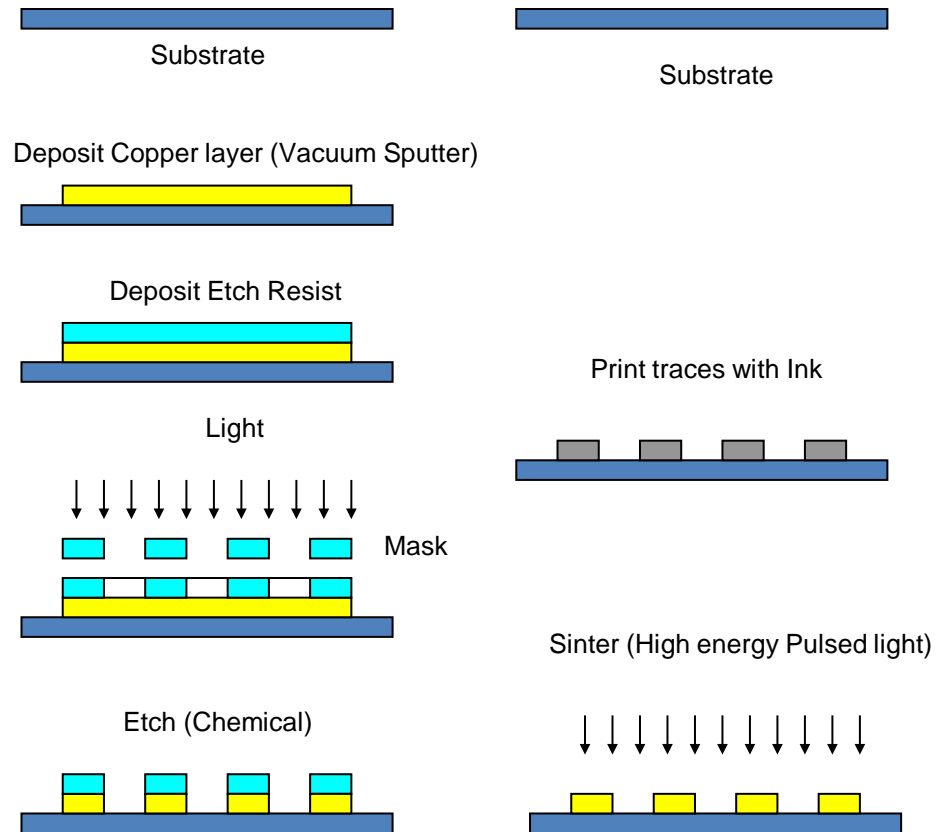
# Pulsed vs. Continuous

- If we try to expend 100 Joules of energy we can do it in two ways
  - 10 Watt lamp for 10 Seconds or
  - 1 Megawatt pulse for 1 micro second.
- Continuous systems like mercury or halogen lamps cannot deliver these kinds of peak power.
- High peak power means the system is more efficient at delivering useful energy
- Intensity attenuates as it penetrates into a material so peak power phenomenon allows for deeper penetration depths
- Shorter pulse duration means that the process can take place quicker
- Pulsed is instant on-off. It is harder to do that with continuous systems
- Pulsed systems can be frequency adjusted to allow time for cooling



# Current Printed Circuit Process

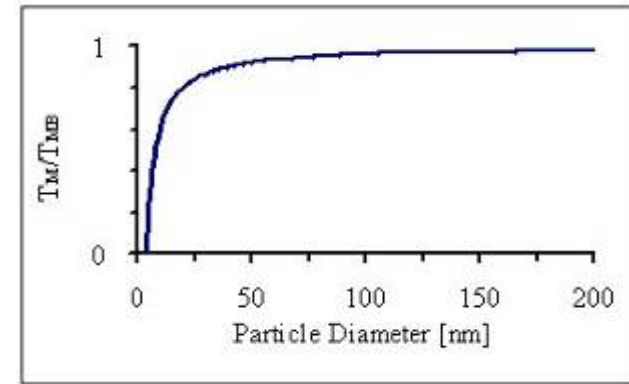
- Current process for printed electronic system requires multiple process steps
- They do not lend themselves to Reel-to-reel Systems
  - Flexible substrates
  - Low Temperature Substrates
  - Complex steps
- A simpler process would be to print conductive traces and cure to form conductive traces



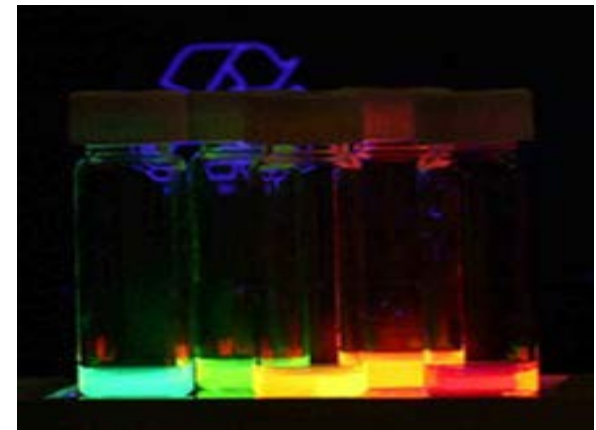
Comparison of Standard Printed Circuit Manufacture and Photonic Sintering

# Photonic Sintering Basic

- Low temperature sintering of metal inks are possible because when particles become small their melting point is reduced. This phenomenon is called “Melting Point Depression”
- When particles become small their absorption characteristics change
- Nanotechnology is where particles are in the range of 1 to 100nm in size and it is at this particle size that these special effects take place
- Nano conductive inks can absorb light and sinter at a low temperature.
- Once sintered they behave like bulk material



Melting point depression of Gold nanoparticles



Quantum Dots are same material but with different size which changes color

# Advantages of Photonic Sintering

- Conventional method of sintering conductive inks is to use low temperature ovens
- The time to achieve sintering is many minutes and not suited to Roll to Roll process
- Photonic sintering can take place in fractions of seconds
- Photonic sintering is a non contact process
- It requires no additional chemicals or special environment
- It is a low temperature process allowing use of low temperature flexible substrates like paper and PET
- It is easy to configure for different ink types, substrates and printing process.
- It can be fitted inline with an existing process without taking the space required for ovens or off-line solutions.

# XENON Corporation-An Introduction

- We manufacture High Energy Pulsed Light systems for industry
- We have been established since 1964
- Have developed lamps for laser pumping
- Our Markets Include:
  - Optical disk manufacture
  - Pulsed UV sterilization
  - Food enhancement
  - Surface treatment
  - Photonic Sintering
- We manufacture our own Lamps and Electronic systems
- We build “the engine” that integrates into industrial systems that need to run 24/7
- Pulsed light is our expertise we pick up where other sources cannot compete in terms of energy, peak power and low temperature



# Products: Sinteron 500

- Used for Sintering Silver inks
- Fixed Pulse Width
- Voltage Adjustment



# The Sinteron 2010 (S-2100)

## Introduces Active Control

- Programmable Pulse width 100-2000 $\mu$ s
- Voltage Adjustment
- 2000 Joules /Pulse
- Suitable for Copper Applications



# The Sinteron 5000 (S-5000)

## Our First R2R Offering

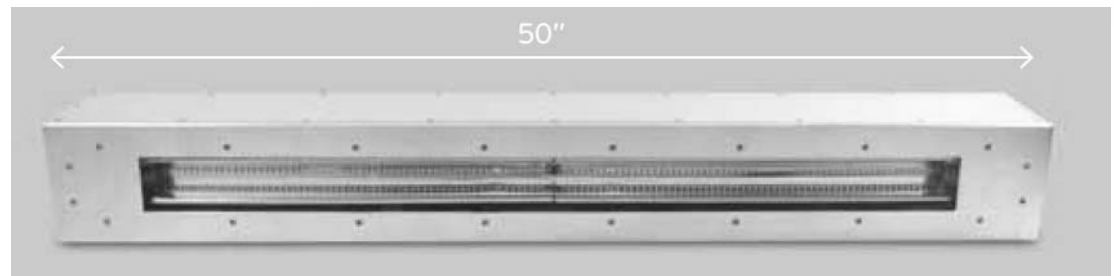
- Integrated Controller for lamp synchronization
- 10 Lamp System
- Integrated Conveyor
- Integrated Cooling
- Touch screen Computer based
- Modular Design for Integration into OEM Equipment



# The Sinteron 5100 (S-5100)

## World's First Meter Wide R2R System

- Integrated Controller for lamp synchronization
- 4x 1 Meter Lamp System
- Touch screen Computer based
- Modular Design for Integration into OEM Equipment
- Up to 5J/cm<sup>2</sup>



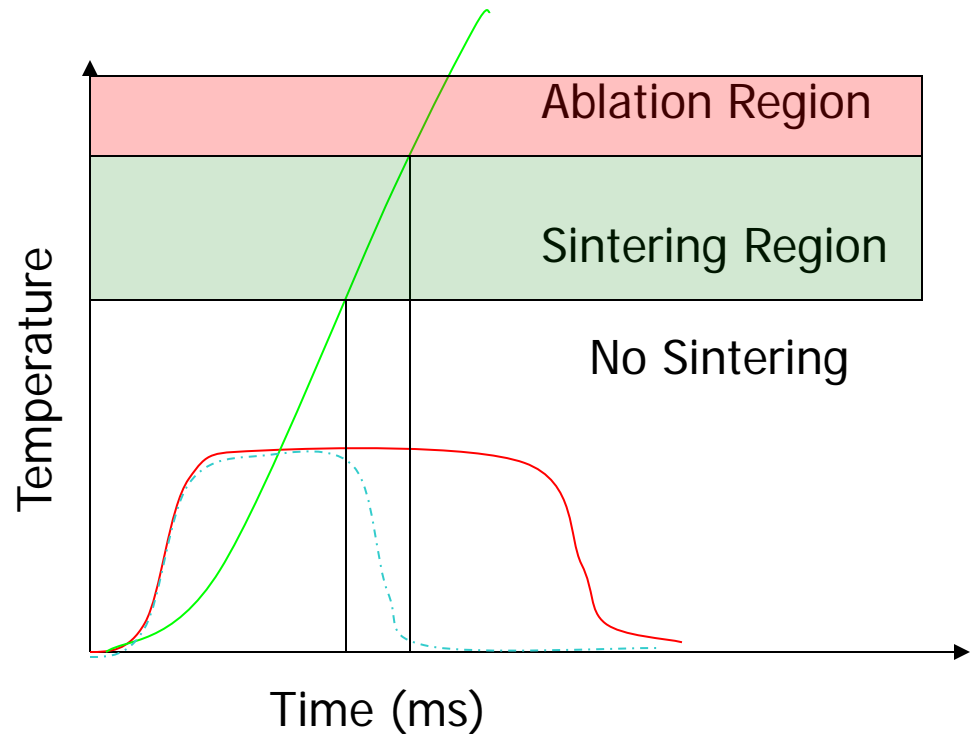
# S-2300 Dual Pulse System

- Touch screen PC based Interface with recipe storage, programming and control
- A single pulse with two independent Level Control



# Thermal Aspects of Sintering

- For many conductive inks there is a temperature range that sustains sintering action.
- Above the range we ablate the ink
- Below the sintering region there is no change
- The original Sinteron tools were designed to produce a flat uniform intensity output with time
- This means that the operational window is small and we cannot process thicker films

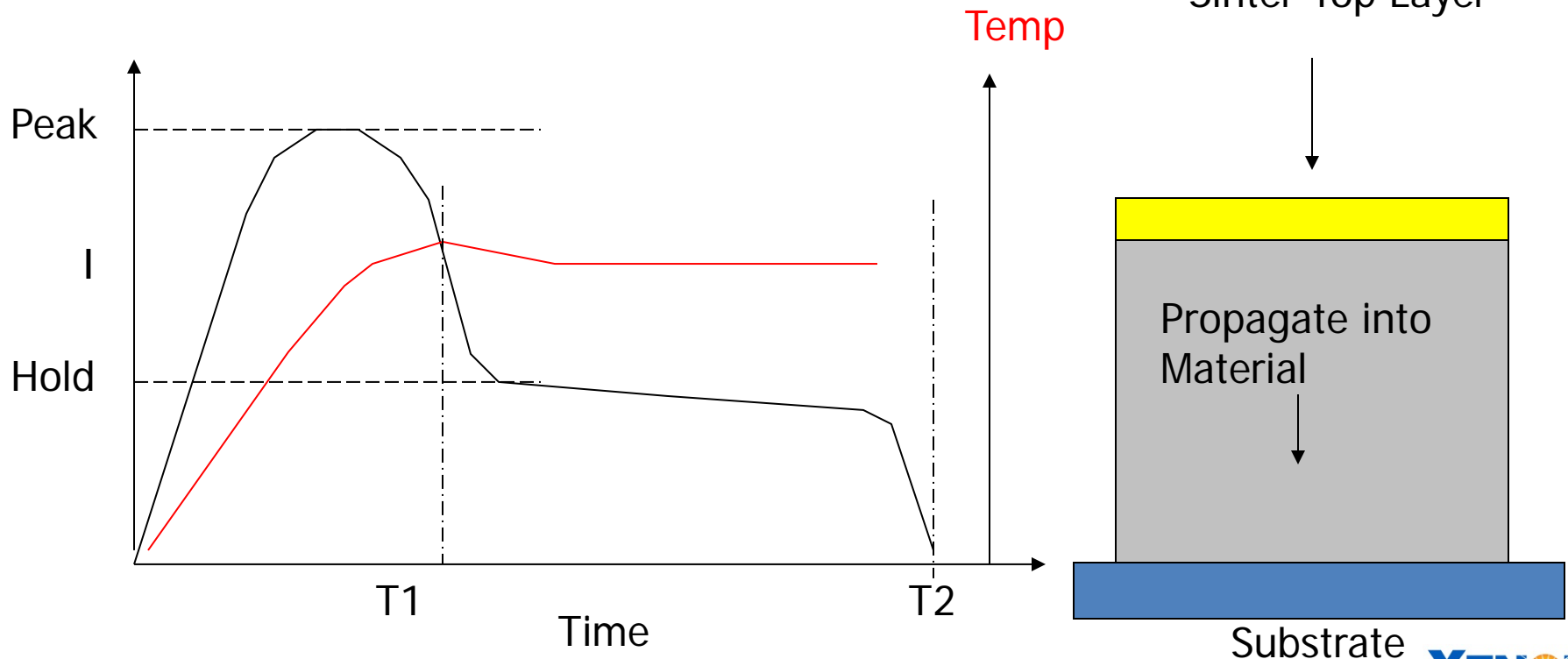


# Thermal Management for Sintering

- The Sinteron devices generate a flat pulse output.
  - This gives us a uniform relation with time and energy
  - However this is not optimal for thermal management
- For Thermal management of Sintering we need two features of a pulse
  - One to bring the material to sintering Temperature
  - Second to hold the temperature for penetrating into material
  - This is essential for deep and even cure

# Enter the Sinteron S-2030

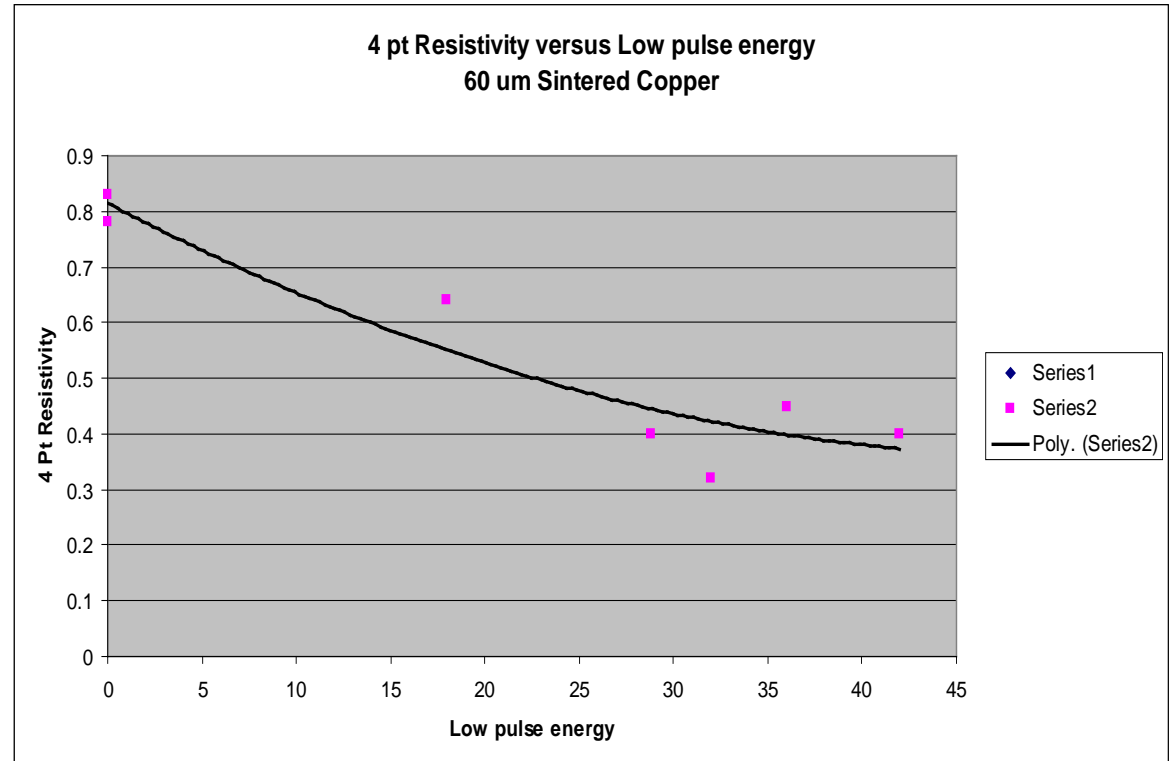
- This system has a dual pulse profile where each pulse can be controlled independently





# The Dual Pulse Advantage

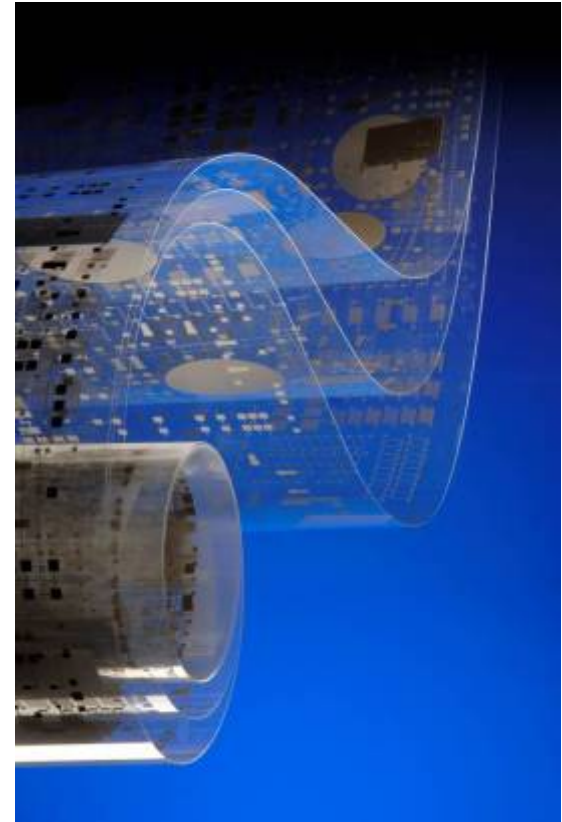
- We bar rolled Copper ink on a paper substrate.
- We adjusted the Sinteron with a single pulse profile to get the best resistivity value
- We used the S-2030 and adjusted the second pulse profile
- We achieved better than 50% improvement in final resistivity
- We have observed better adhesion, and a wider operating parameter range based on this technique.



# Roll to Roll Challenges

Roll to roll applications have unique requirements

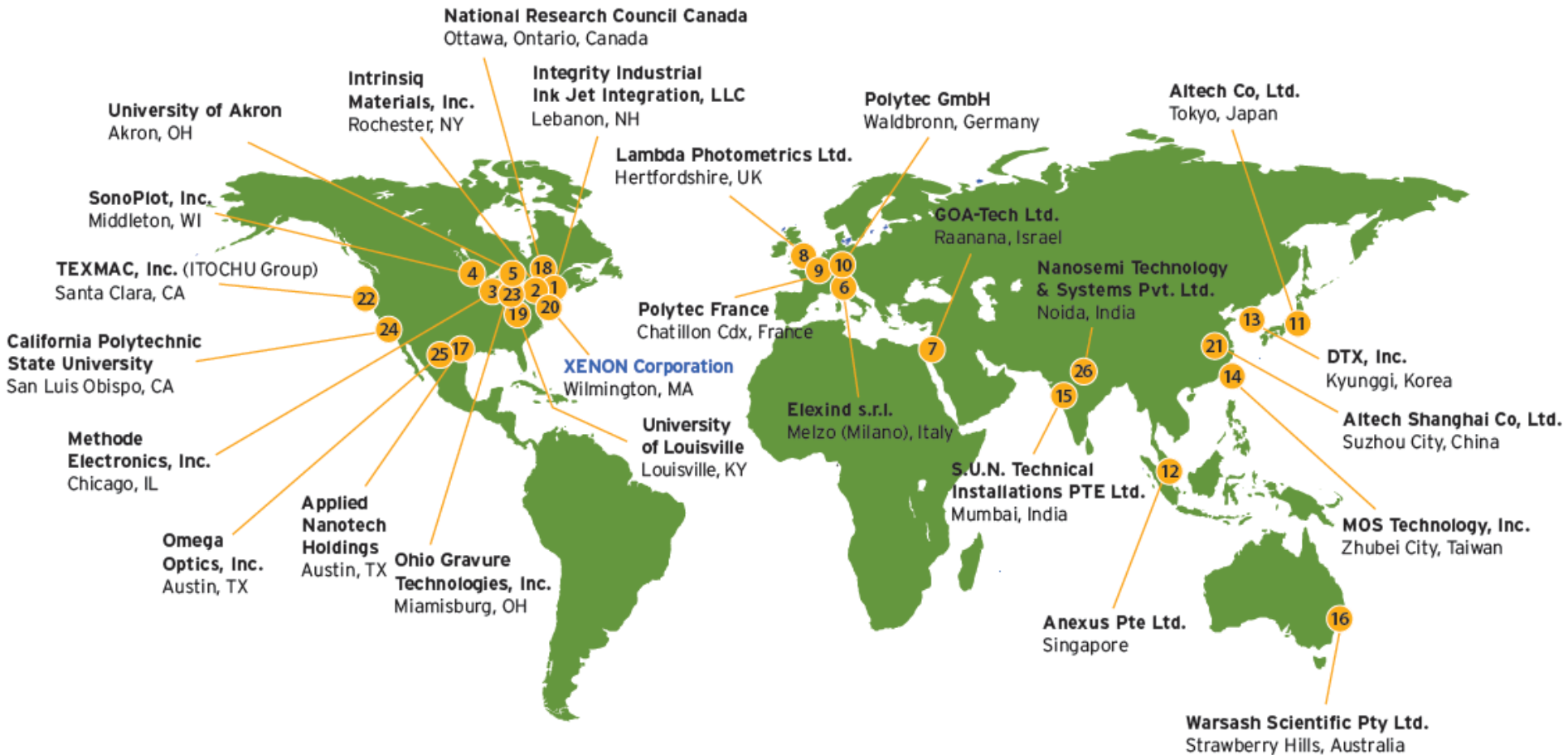
- Process speeds 5ft/min to 100s ft/min
  - Faster throughput increases efficiency and reduces costs
  - Synchronization is important
- Web based systems demand higher reliability
  - Down time and failure generates waste
- Web size can vary
- Flexibility is required
  - Different inks, different substrates, different applications
- Functional Uniformity of result is important.
  - Tolerant to ink thickness and printing process



# The Strategy for Successful Deployment

- Create R&D low cost tools that can be used for Evaluation of Ink Formulation
- Develop Application Lab support for Fast track process development
- Create Key Partnerships
  - ink developers,
  - print technology groups
  - substrate manufacturers
  - process integrators
  - Academic Institutes
  - Government Funding
- Develop Satellite sites for evaluation of technology
- Identify end to end working solutions

# Satellite Sites



# Satellite Sites

- XENON understands that successful deployment of photonic sintering requires collaboration with multiple technology groups.
- XENON has led the formation of a consortium of manufacturers, integrators and universities called Printed Electronics Test Center Network.
- This network includes seven US and eleven International sites. These sites offer Laboratory, equipment and expertise to develop printed electronic solutions. Distributors.
- Please visit [www.xenoncorp.com](http://www.xenoncorp.com) for more information.

# Moving to Roll to Roll- The Future

- Large web width sintering
- Low energy sinterable inks
- Low cost ink/Substrate solutions
- High speed printing Capability
- Dynamic Monitoring of Functionality
- Sinterable semi-conductive materials
- Novel interconnect solutions between Flexible electronics and devices

# Conclusions

- Photonic sintering:
  - Works with many conductive nanoparticles for printed electronics needs
  - Requires high energy which can be generated by a flash lamp
  - fast, compact and cost effective alternative to ovens
  - easy retrofit to existing process for roll to roll deployment
  - Needs to be flexible to work with various ink formulations
  - Should be scalable for different process speeds
  - Providing system that have meaningful controls for pulsed light opens new opportunity for dealing with the diverse range of process requirements.
- Roll to Roll offers unique challenges for pulsed light.
- XENON is developing a strategy which includes all aspects of the development

**THANK YOU!**