INdustrial **S**cale **P**roduction of **I**nnovative nanomate**R**ials for print**E**d **D**evices

INSPIRED – Scaling Up Nano For The Right Reasons

23. November 2016; BASMATI Workshop, Barcelona

www.nano-inspired.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646155.

© INSPIRED PROJECT 2015

Overview

- Motivation
- Markets
- Strategy
- Pilot lines
- Project Status
- Business model

© INSPIRED PROJECT 2015

INSPIRED

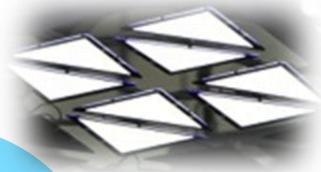
Project at a glance

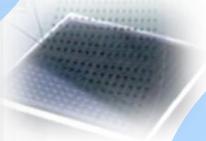
- **Project Number:** 646155
- **Project Acronym:** INSPIRED
- **Project Title:** INdustrial Scale Production of
- Innovative nanomateRials for printEd Devices
- **Starting Date:** 01/01/2015
- **Duration in months:** 48
- **Call (part) identifier:** H2020-NMP-PILOTS-2014
- **Topic:** NMP-05-2014 Industrial-scale production of nanomaterials for printing applications
- **Project volume**: € 8.005.838.-
- **Max. EU contribution:** € 6.414.872.-

© INSPIRED PROJECT 2015

INSPIRED

Novel Applications





Logic & Memory

Transistors
Smart tags

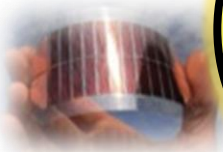
Smart fabrics

OLED Lighting

Sensors & Smart Labels

Printed, Organic and Flexible Electronics

Displays OLEDs, ECs



Solar Cells

Batteries, Actuators, Energy Harvesters

Signage Bill-boards Posters

INSPIRED

© INSPIRED PROJECT 2015

Printed, Organic & Flexible Electronics - Scale

IDTechEx: “Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities 2015-2025”:

…total market for printed, flexible and organic electronics will grow ***from $29.80 billion in 2015 to $73.69 billion in 2025****.*

OE-A Roadmap, 6th Edition” (2015):

The market for organic and printed electronics products was ***23-24 billion US$ in the year 2014****, …*

future annual growth rates of ca. 20 % predicted in all fields

IDTechEx: “Conductive Ink Markets 2015-2025: Forecasts, Technologies, Players”:

…a large market that will generate ***$2.2 billion in 2015****…*

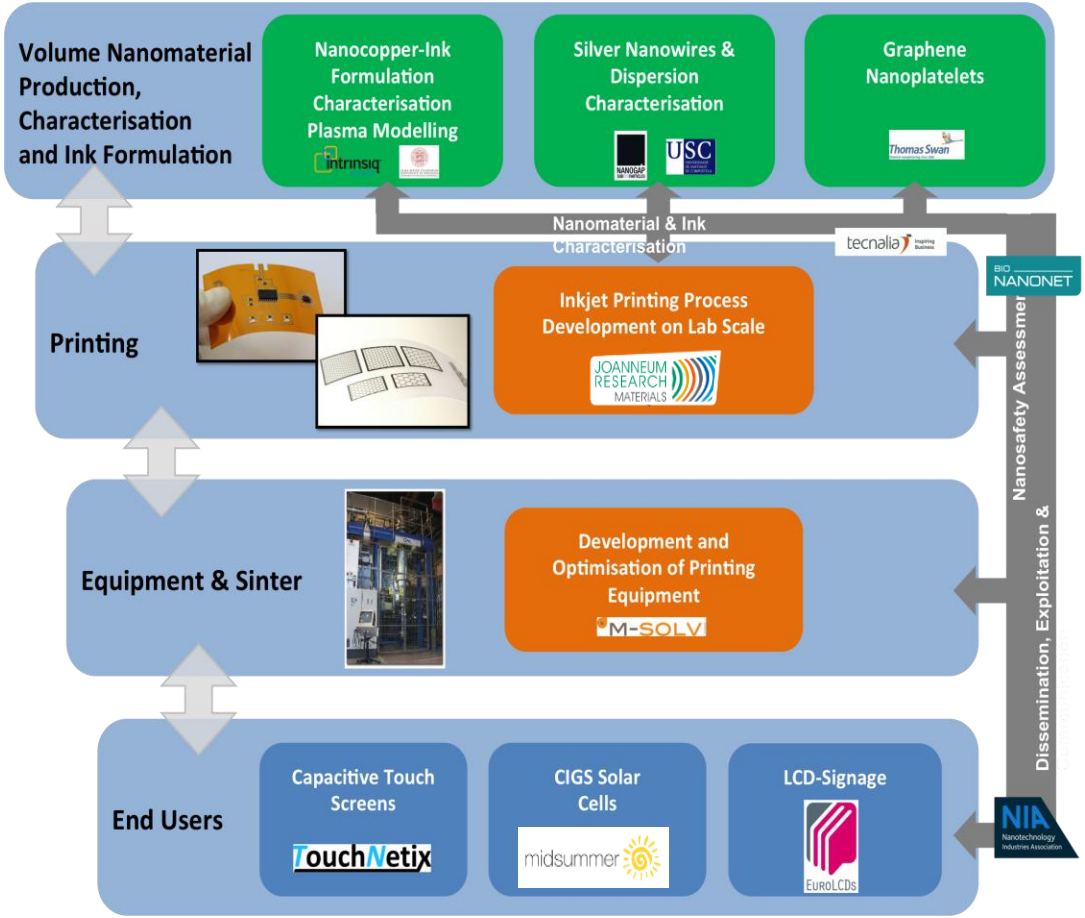
2.7% CAGR *over the coming decade, …growth will be unevenly spread with several target markets ….*

- INSPIRED targets existing PE markets directly as part of the programme
- Impacts a **massive array of other markets and technologies**

INSPIRED

Addressing the markets – issues, approach

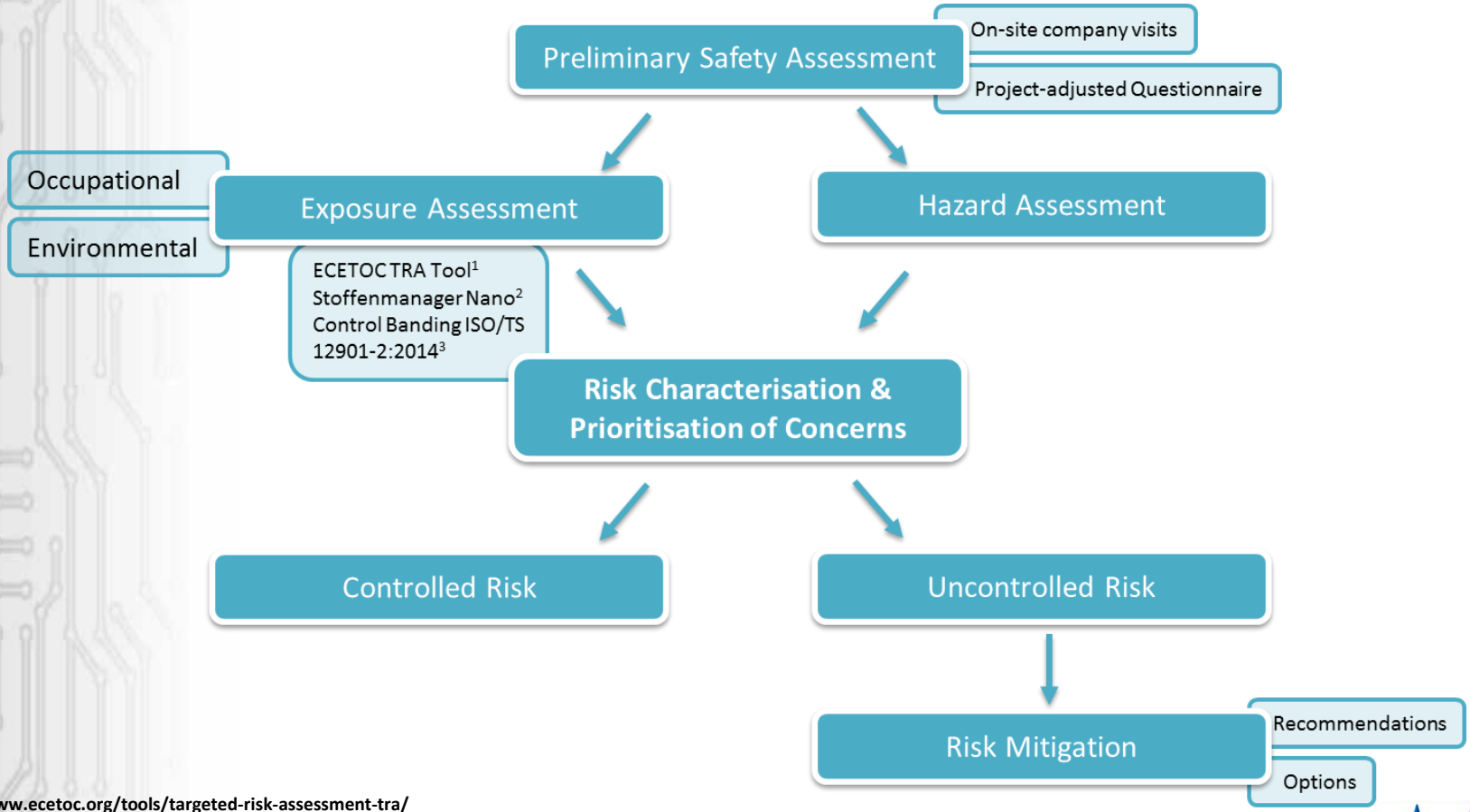
- Issues with industrial supply of nanomaterials which are
  - low cost,
  - high performance,
  - environmentally friendly
  - tailored for high throughput print systems.
- **INSPIRED** aims to address this by
  - **manufacturing technology development**
  - efficient collaboration between supply chain partners
  - Formulations tailored for end use applications
  - Low cost additive manufacturing
  - Significant IP already exists



INSPIRED

© INSPIRED PROJECT 2015

INSPIRED Nanosafety Strategy

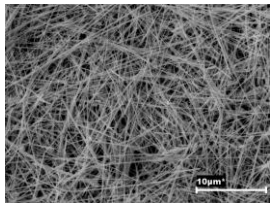


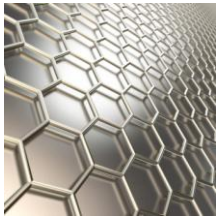
[1] http://www.ecetoc.org/tools/targeted-risk-assessment-tra/
[2] https://nano.stoffenmanager.nl/
[3] ISO/TS 12901-2:2014. "Nanotechnologies — Guidelines for occupational risk management applied to engineered nanomaterials — Part 2: The use of the Control Banding approach in occupational risk management." 2014

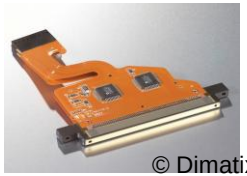
INSPIRED

Pilot Line Development

- ***Materials, their formulations and scale-up:***
  - Synthesis → Formulation
    - Nano-copper
    - Ag Nanowires
    - Graphene materials

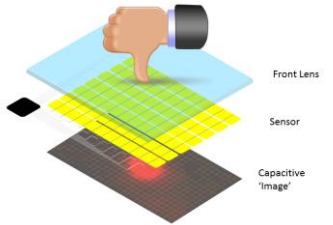




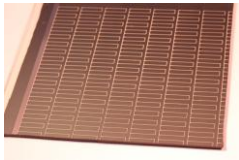


© Dimatix

- ***Processes:***
  - High-volume printing and sintering including development of pilot equipment
  - Development of simplified manufacturing process



- ***Devices (exemplar applications):***
  - Capacitive touchscreens using copper inks / AgNWs
  - LCD system using conductive inks - LC Display demonstrator
  - CIGS cells using copper inks / AgNWs/GNPs



INSPIRED

© INSPIRED PROJECT 2015

Pilot Line Development
(10 Pilot Lines; TRL 4 → TRL 6)

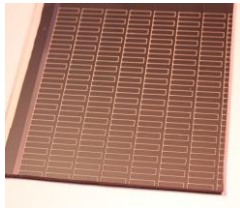
Pilot Line 1	Intrinsiq Materials	Synthesis of Nano-copper including scale-up
Pilot Line 2	NanoGap	Synthesis of Ag Nanowires including scale-up
Pilot Line 3	Thomas Swan	Synthesis of graphene materials including scale-up
Pilot Line 4	Intrinsiq materials	Formulation of nanocopper inks including scale-up
Pilot Line 5	NanoGap	Formulation of AgNWs including scale-up
Pilot Line 6	Thomas Swan	Formulation of graphene materials including scale-up
Pilot Line 7	M-Solv	High-volume printing and sintering including development of pilot equipment
Pilot Line 8	TouchNetix	Design, manufacture, characterise and validate capacitive touchscreens using copper inks
Pilot Line 9	EuroLCDs	Development of LCD system using conductive inks - LC Display demonstrator
Pilot Line 10	Nexcis / Midsummer	Development of CIGS cells using copper inks / AgNWs/GNPs

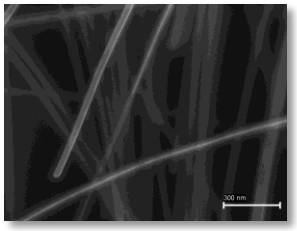
Business Cases for INSPIRED Pilot lines

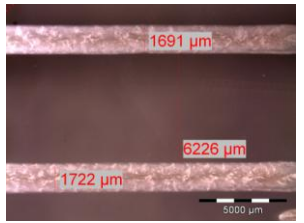
INSPIRED

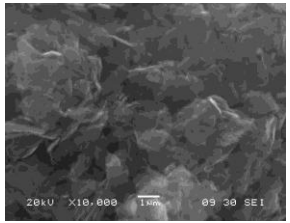
Project Status

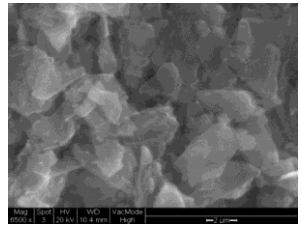
- Nano-copper: originally planned investment for the rig to upscale nano-copper came out to be too expensive → modifications of existing rig systems → purchase of recycling system → **reduced costs to a viable** (c.£350/kg) level → strong modelling support by UNIBO
- AgNW: NANOGAP on track to meet final target specification of production of 40nm NWs, which based on extrapolation of results achieved with 120 and 70nm NWs, will meet the sheet resistance and transmission targets of printed transparent conductive films; **70nm NWs developed and produced at pilot line scale**;
- Graphene Nanoplatelets: on track to meet targets for scale up to produce a product that meets required materials specifications; on track to **deliver pilot Line before M24**











© INSPIRED PROJECT 2015

Intensive Ink and Surface Characterisation

- In particular the following ink properties will be determined for a comprehensive characterisation of the inks:
  - Dynamic viscosity
  - Thixotropy
  - Surface tension
  - Solid content
  - Sedimentation behaviour and stability
  - Output – Ink Characterisation report (Month 24)
- Characterization of the different surfaces proposed in the demonstrators
  - Surface roughness
  - Surface energy
  - If necessary → surface treatments like plasma oxidation or chemical modification

INSPIRED

Features & Benefits

	Project Start		Project End	
Nanomaterial	**Scale**	**Cost**	**Scale**	**Cost**
Nano-Cu	<1 kg/day	~ 1600 €/kg	10-25 kg/day	~ 300 €/kg
Nano-Cu ink	170 litres	~ 920 €/litre	3000 litres	~ 215 €/litre
AgNW	~25 litres batch size	30-60 €/g	>250 litres batch size	25-50 €/g
GNPs	1 kg/day	<75 €/g	>25 kg/day	<1 €/g

This enables ->

Additive manufacturing
Lower investment costs
Highly flexible production technique

INSPIRED

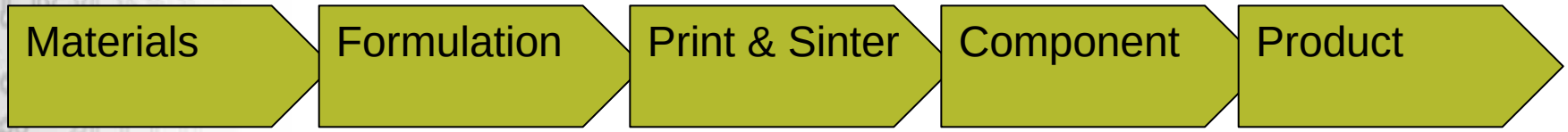
Team

Intrinsiq	**SME**- IML are the largest suppliers of nano-materials in the UK (world leaders in production of nano-Cu), producing more than 200 different nano-particles as well as expertise in nanoparticle coating technology, ink/paste formulation and development of laser sintering processes.
Nanogap	**SME** - leading manufacturers of silver nanowires and are developing alternatives to ITO materials for printed electronic applications
NTCW (till June 30th 2016), Joanneum Research (from July 1st 2016)	Leading European organisation with expertise in inkjet development to applied research projects in the field of printed and organic electronics and sensors who will lead the work on testing and benchmarking of printed Cu-conductive structures and silver nanowires
M-Solv	Are a leading manufacturer of precision laser micro machining equipment and inkjet materials deposition equipment
Thomas SWAN	**SME** - Leading manufacturer of single wall carbon nanotubes and Elicarb® graphene powder and Elicarb® graphene dispersion
Touchnetix	**SME** - Are a designer and deliverer of capacitive touch screen solutions with over 25 years' experience in development of CTS devices.
Midsummer	**SME** - Midsummer is a leading supplier of turnkey equipment for cost effective and scalable manufacturing of flexible CIGS cells and modules.
EuroLCD	Is an innovative pan-European company specialising in the development and manufacture of LCD products for both emerging 3D visualisation applications and industrial applications.
Bionanonet	Is an Austrian network which combines wide range in expertise in nanomedicine and nanotoxicology and are an active member of the EU nanosafety cluster.
NIA	Trade association which is focussed on promoting innovation and commercialisation of nanotechnology
Università di Bologna	RTO with expertise in the modelling and diagnostics to optimise plasma synthesis of nanoparticles.
Tecnalia	RTO with expertise in the materials characterisation and deposition of nanomaterials.
Universidade di Santiago de Compostella	RTO with expertise in characterisation of silver nanowires and process optimisation.

© INSPIRED PROJECT 2015

INSPIRED

Business Model

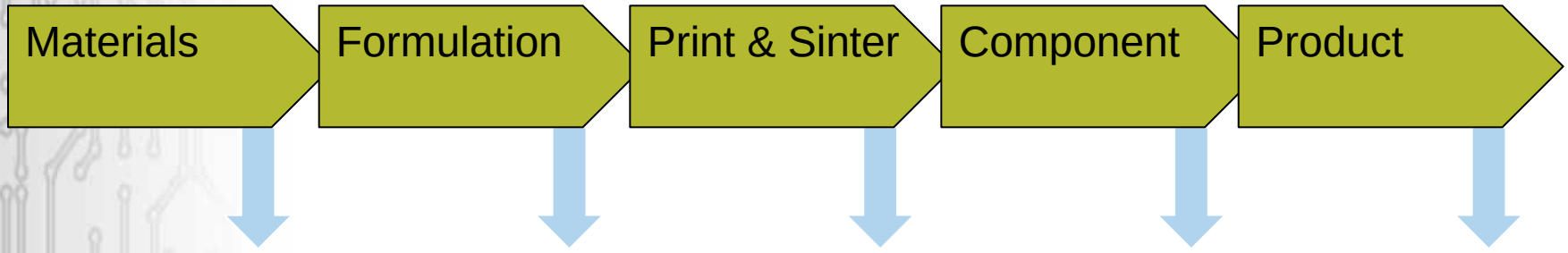


- Exit strategy – varies on Partner
  - Significant expansion possible depending on take up – possible purchase / IPO / Joint Venture
- Call for action – varies on Partner
  - Additional funding to grow the end user base - €6m
  - Scale up and integration - €10m

© INSPIRED PROJECT 2015

INSPIRED

Business Model



- Exit strategy – varies on Partner
  - Significant expansion possible depending on take up – possible purchase / IPO / Joint Venture
- Call for action – varies on Partner
  - Additional funding to grow the end user base - €6m
  - Scale up and integration - €10m

© INSPIRED PROJECT 2015

INSPIRED

INSPIRED – Scaling Up Nano For The Right Reasons

http://www.nano-inspired.eu/

Thank you!

INSPIRED coordination team:

Martina Trinkel *Joanneum Research – Project Coordinator*
martina.trinkel@joanneum.at

Andreas Rudorfer *Joanneum Research – Project Co-Coordinator*
Andreas.Rudorfer@joanneum.at

© INSPIRED PROJECT 2015