1. - Publishable summary – 2012/12/18

The ultimate goal of the APPLE project is ***to develop the next generation of sustainable paper-based products*** with specific autonomous functionalities aiming at interacting with their users and/or reporting changes in their environment. A major focus is placed on ***the development of flexible manufacturing concepts based on printing technology*** to produce large area hybrid organic/inorganic papers with improved performance at competitive cost.

To this aim, the APPLE project is focused on 1) the integration of recent advances in functional materials (paper, fibres, inks) and functional components (battery, sensors, display, memory) and their production process upscale and 2) the development of innovative, flexible and cost-effective manufacturing processes based on printing and embedding techniques for the integration of all these functional components on the paper substrate.

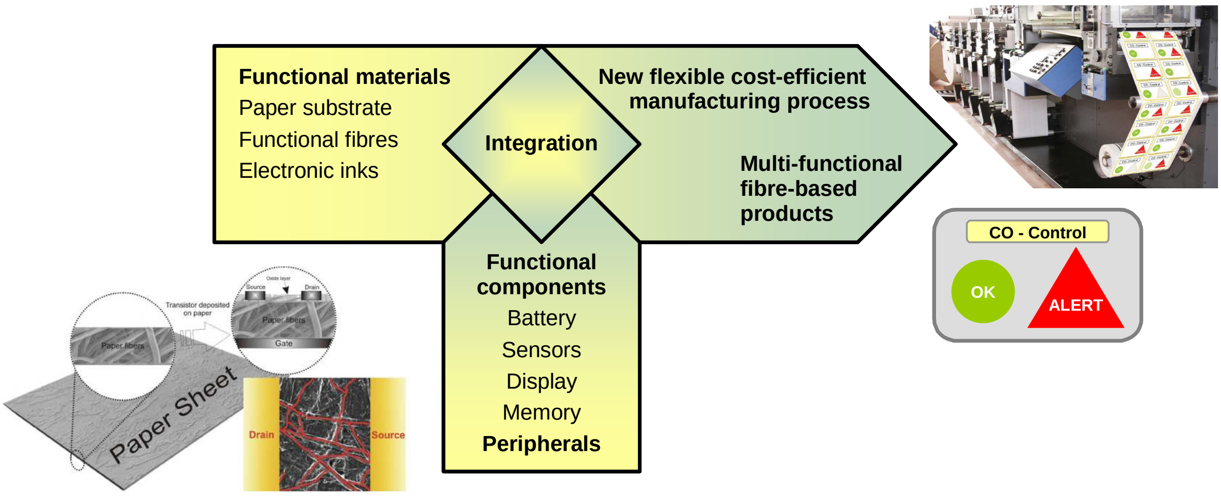

Figure: Concept of the APPLE project

APPLE project requires a multidisciplinary approach, involving 12 research and industry partners with different backgrounds, going from materials science and engineering, to chemistry, physics, electronics and micro/nano-technologies.

Table: Partners involved in APPLE

5 SMEs	IN-CORE Systèmes; LabelTech; polypore; RG Plastiques Groupe G-Pack
2 Industries	Felix Schoeller; VARTA The Battery Experts
4 Institutes 1 University	ctp centre technique du papier; cea; TNO; VTT; UNINOVA CEMOP; FCT Faculdade de Ciências e Tecnologia Universidade Nova de Lisboa

The 4 main technical objectives within the period focus the development of the demonstrator 1 of A3Ple project, an environment and safety label. This leads to:

- Develop new functional materials at industrial relevant scale (paper, fibers and inks)
- Develop printable functional components at industrial relevant scale
- Optimise design integration and develop a new manufacturing process

Work performed within the 1st period (until M18)

WP1. First versions for *(1)* End-user and technical specifications and *(2)* materials and components specifications have been completed for the three targeted demonstrators. Main focus was made on electrical and printing specifications of demonstrator 1 (Environment & safety label).

Methodologies for testing LCA, recycling, environmental and reject issues of materials, components and demonstrators have been defined. LCA was performed to compare FS paper to FR4 (Plastic for conventional electronic): CO2 impact factor is 1000 lower for paper.

WP2. Three reference papers were selected, their printability in relation to the functional and peripheral components were tested. At M18, requested properties converge into one paper reference that will be upgraded in order to increase runalibity at industrial scale. Five polymers have been selected to substitute the PE coating and tested at laboratory scale. Their biodegradability tests are on progress.
The study of the paper properties on the transistor behaviour has started; 2 kinds of papers have been found that appears rather suitable for transistor and memory components. Use of NanoFibril of Cellulose seems to be promising.
Concerning the ink development, a first grade of *1)* prime layer ink-jet ink and *2)* ink-jet conductive ink has been produced and tested at laboratory scale. A second grade of these inks is under validation for flexographic printing.

WP3

Battery structure and associated manufacturing processes have been defined. Prototypes have been realized at laboratory scale to validate both material and process. First trials have been performed at industrial scale with non functional electrolyte. This half structure should be validated before performing this risky step.
Sensors: the development of CO sensor based on CNT (Carbon NanoTube) has started on a water base ink formulation. First prototype on FS papers has already been done at lab scale with spay technique. The H_2S sensor is developed according to literature published recently (Crowley and all), moisture sensitivity has been solved bypaper choice. The design of temperature sensor has been tested at lab and industrial scale. Further investigations are still going on to improve the sensitivity.
Display: ink development is under optimisation to be compatible with industrial flexo-printing. Development was performed to adapt existing structure from classical (PVD) to printing process. First lab test are promising.

WP4

Active components.
As PVD method is optimised, paper influence on transistor behaviour is studied. Nevertheless, the classical configuration requests transistor hybridization: the devices will be produced on a foreign paper substrate that will be then placed and connected to the printed backplane.
An alternative concept of transistor has to be agreed in order to make a fully printed transistor.

Passive components.
Resistors values range has been defined and printed using flexographic water base inks, at laboratory and industrial scale.

WP5. The electrical circuit based on electrical behaviour of each printed component has been built for demo 1. Connections, resistors and component pads were printed at industrial scale. Then a hybrid circuit was made with this and Si based sensor, transistor and display. The **hybrid-Demo1** works as expected proving both printing and electrical integration efficiency!

WP6. 4 industrial printing test runs were achieved at LT factory in order to transfer the results of the previous WP. A first visual inspection system was planned, manufactured by ICS and installed at LT.

WP8. A public webpage www.A3Ple.com has been created. It was decided to present hybrid-Demo 1 at OE-A competition organized on LOPE-C 2013.