MONA - Merging Optics and Nanotechnologies: The Nanophotonics Technology Roadmap

Laurent Fulbert (1), Roel Baets (2), André Scavennec (3), Ulrich Fotheringham (4), Rainer Beccard (5) Krassimir Krastev (6), Dirk Holtsmanspötter (7), Eric Mounier (8), Bertrand Noharet (9), Thomas Pearsall (10) and Suvi Haukka (11)

1) CEA-LETI Minatec France, Laurent.fulbert@cea.fr 2) IMEC, Belgium, Roel.Baets@intec.UGent.be 3) Alcatel-Thales 3-5 Lab, France, andre.scavennec@alcatel.fr 4) Schott, Germany ulrich.fotheringham@schott.com 5)Aixtron, Germany R.Beccard@aixtron.com 6) Optics Valley, France k.krastev@opticsvalley.org 7) VDI-TZ, Germany holtmannspoetter@vdi.de 8) YOLE Développement, France mounier@yole.fr 9) Acreo, Sweden Bertrand.Noharet@acreo.se 10) EPIC France pearsall@epic-assoc.com 11) ASM, Netherlands suvi.haukka@asm.com

Abstract: *The MONA project has three principal objectives:*

- *Create a common site for the exchange of information concerning research, networks of excellence, and integrated projects in photonics and nanotechnologies.*
- *Promote the timely exchange of scientific results, market development, and technology needs through MONA-developed workshops.*
- *Develop a European roadmap for photonics and nanotechnologies.*

MONA, both through its expected outcomes and the collective process implemented, will help the future European research be more competitive through the development of the Nanophotonics Technology Roadmap. The MONA Roadmap will provide an essential decision-supporting instrument for the Community at a broad and international level. The results will directly feed into the European Technology Platform Photonics21.

Introduction

The goal of the MONA project (Merging Optics and Nanotechnologies) is to leverage synergies in photonics and nanotechnologies, seeking to increase the impact and efficiency of investment on European research.

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- Promote the timely exchange of scientific results, market development, and technology needs through MONA-developed workshops.
- Develop a European roadmap for photonics and nanotechnologies.

MONA will foster collaborations between photonics and nanotechnologies stakeholders and will help preparing future research activities. A major outcome of MONA will be a consolidated scenario (time horizon 5-10 years), setting out development and technology road maps.

The MONA project contributes directly to the development of synergies between photonics/nanophotonics and nanomaterials/nanotechnologies. The challenge of mastering nano-electronics and nano-photonics science and technologies at an industrial scale (i.e. aiming at low cost mass production capability) is of utmost strategic importance for the competitiveness of the European industry in a global context. Through the cooperative work between equipment manufacturers, nanotechnologies and photonics experts, MONA will help to identify and address the most critical manufacturing issues. This will ensure the building of a strategic comprehensive approach for the key technologies in order to profit from this highly important area for the European Union

Development of a roadmap: starting point

During the first part of the project, a frame of reference summarizing the state of the art in the fields of nanostructuring technologies and nanophotonics has been established. Each of these two fields have been analysed with respect to:

- Materials and technologies
- Equipment and processes.

The main result is a report that analyses and assesses the various technologies with respect to their potential for volume production. In particular, the compatibility with CMOS processes will be investigated.

The main topics addressed in the report are:

- Current Production Technologies in Photonics
- Nanostructuring Technologies
  - Top-Down Technologies
  - Bottom-Up Technologies
- Photonics
  - New Approaches in Nanophotonics
  - Nanotechnology in Photonic Devices
- Equipment
- Projects and Networks of Relevance

The MONA consortium adopted the following definition for Nanophotonics: Optics and Nanotechnologies merge, where lateral structures, layers, molecular units, inner boundary layers and surfaces with

critical dimensions or production tolerances that extend from about 100 nanometers down to atomic orders of magnitude are produced, studied and utilized for the generation, transmission, manipulation, detection, and utilization of light.
In addition to this definition, the MONA consortium decided to study in the roadmap only 2D and 3D structures. 1D structures such as Quantum Wells for instance are already well known and used and have not been investigated in depth.

Development of a roadmap: methodology

For the Mona roadmap, we have considered both **a market-pull perspective and a technology-push approach** (see *Fig 1*)**:** In one hand, we have considered the applications with potential market volume. Then we have identified what photonic products will be used and where nanotechnologies can be used to improve performances, add new functionalities and/or reduce costs. However, for technologies such as nanophotonics which can be considered as "disruptive" technologies (in the sense that it is still difficult to imagine markets for functions and materials which have not yet an industrial reality), one can miss out interesting technologies. Then we have considered a technological approach as well.

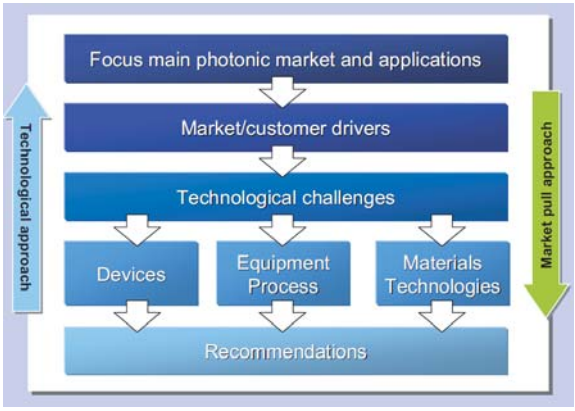

Fig 1*: the Mona methodology*

Based on the first MONA workshop, on the work done the frame of reference, as well as on different market studies, the consortium members has made a selection of the most promising applications area of Nanophotonics devices. These applications areas are:

- Optical Interconnects
- Datacoms/Telecoms
- Lighting
- Data storage
- Imaging
- Sensors
- Displays
- Photovoltaics
- Instrumentation/metrology

As already mentioned, we have also followed a bottom-up methodological approach that leads us to identify the following families of nanostructures/nanomaterials:

- Semiconductor quantum dots&wires in silicon including colloidal nanostructures
- Semiconductor quantum dots&wires in III-V including colloidal nanostructures
- Semiconductor quantum dots&wires in II-VI including colloidal nanostructures
- Plasmonics/metallic nanostructures including colloidal nanostructures (metal)
- Photonic Crystals/High index contrast nanostructures in silicon
- Photonic Crystals/High index contrast nanostructures in III-V
- Photonic Crystals/High index contrast nanostructures in other materials
- Organic nanostructures
- Carbon Nanotubes (CNT)
- Integration of nanophotonic materials/structures with electronic ICs/Silicon Photonics
- Nanoparticles in glass or polymer
- Left-handed metamaterials

A separate roadmap has then been established for each class of material that could be used for each application identified. A final set of more than 50 roadmaps have been created. Each of these roadmaps drafts describes the nano technology, the application, the manufacturing process and required processes/equipments, as well as the timeline of technological development.
As far as equipment are concerned, the major equipment and processes classes have been identified and some issues have been raised. For example, high resolution / high throughput lithography is still a challenge, or metrology for in-situ process control is identified as one of the major key issues for transfer to industrial scale
A final consolidation and synthesis will be made in 2007 to obtain a comprehensive document that could be used by the whole photonics and nanophotonics community.

Development of a roadmap: assessment and feedback

For successful roadmapping, the process is as important as the technical quality. That means that the two following points are essential:

- Real involvement of the right players in set-up and propagation of the roadmap
- Endorsement of its strategic relevance by the wider photonics community including industry

The MONA consortium has organised three different workshops to implement the roadmapping process. As an example, the second workshop gathered more than 100 experts from 13 European countries, including more than 40% of industrial participants. During

this event, the draft versions of the roadmaps have been discussed and improved.
The third workshop has been organized during one of the major international conference in photonics in the US. This workshop has included comparison of roadmapping activities in Japan, Korea, Taiwan, US and Europe.
A continuous updating of the documents is expected during the first half of 2007. Feedback from the wider nanophotonics community as well as industrial players will be encouraged.

Dissemination and intention for use
Dissemination of the results and communication with other nanotechnologies and photonics activities are key objectives of MONA. The following actions have already been made:

- Launch of the MONA web site http://www.ist-mona.org.
- Press release on the launch of MONA disseminated to general public and branch press in Europe and US.
- Organization of a symposium collocated with the second workshop with more than 100 particpants
- Publication and dissemination of the electronics newsletter.
- Edition and dissemination of a CD-ROM on the Frame of Reference. This CD-ROM was distributed at conference exhibitions. The report could also be downloaded on the MONA website.
- Exhibition in conferences
- Exchange mission to several Asian countries with extensive two-way exchanges of information on nanotechnologies and photonics activities in European and in Asia. CD-ROMs have been edited and disseminated afterwards.
- Links have been established with other European projects related to nanophotonics/nanotechnologies. It has been decided to line up the activities and make a combined effort in order not to duplicate efforts and come up with the best possible outcome.

It is intended to broadly disseminate the results of MONA to the industrial, R&D and education communities through conferences and the media.
The project MONA is strongly contributing to the European Technology Platform Photonics21. One of the objectives of the platform is to pave the way for Europe's scientific, technological and economic leadership in Photonics and, in the long run, to make Europe the number one knowledge-based economic area in the world.
The MONA consortium will participate to the roadmapping activities of the platform and thus is expected to shape nanophotonics in European and national research programmes.

Conclusion
MONA will produce tangible results for the benefit of the European Community. The main end results will be roadmaps of technologies / processes / applications / research.
The real involvement of the right players in set-up and propagation of the roadmap, as well as the endorsement of its strategic relevance by the wider photonics community are essential. The outcomes of MONA should be used to shape the future national and European research programmes in the field of nanophotonics.

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