European Commission

This fiche is part of the wider roadmap for cross-cutting KETs activities

'Cross-cutting KETs' activities bring together and integrate different KETs and reflect the interdisciplinary nature of technological development. They have the potential to lead to unforeseen advances and new markets, and are important contributors to new technological components or products.

The complete roadmap for cross-cutting KETs activities can be downloaded from:

http://ec.europa.eu/growth/industry/key-enabling-technologies/eu-actions/ro-ckets

Potential areas of industrial interest relevant for cross-cutting KETs in the Manufacturing and Automation domain

This innovation field is part of the wider roadmap for cross-cutting KETs activities developed within the framework of the RO-cKETs study. The roadmap for cross-cutting KETs activities identifies the potential innovation fields of industrial interest relevant for cross-cutting KETs in a broad range of industrial sectors relevant for the European economy.

The roadmap has been developed starting from actual market needs and industrial challenges in a broad range of industrial sectors relevant for the European economy. The roadmapping activity has focused on exploring potential innovation areas in terms of products, processes or services with respect to which the cross-fertilization between KETs can provide an added value, taking into account the main market drivers for each of those innovation areas as well as the societal and economic context in which they locate.

Taking the demand side as a starting point, cross-cutting KETs activities will in general include activities closer to market and applications. The study focused on identifying potential innovation areas of industrial interest implying Technology Readiness Levels of between 4 and 8.

MA.1.10: High volume manufacturing at the micro- and nano-scale

Scope:

Mass produced highly integrated functional 3D micro-products produced at high volume within a safe environment, encompassing design, tooling, assembly, joining and reliability issues, for automatic handling of parts, in-line metrology and inspection and their combination into systems.

Demand-side requirements (stemming from Societal Challenges) addressed:

Depending from the application or the type of processes used for production, manufacturing and automation can especially contribute to tackle the following societal challenges:

- Secure, clean and efficient energy
- Climate action, resource efficiency and raw materials

Demand-side requirements (stemming from market needs) addressed:

- Provide for rapid and flexible production capabilities to match supply with volatile demand of today's rapidly changing markets
- Flexibly integrate design specifications into efficient operational routines by keeping a comparable throughput time in different configurations
- Provide for fast product/service systems able to combine rapid and flexible production capabilities with enhanced product design capabilities and exploit minimal distribution lead-times to match supply with volatile demand of today's rapidly changing markets
- Provide for the production of high-quality products
- Provide for the production of durable products
- Provide for alternative manufacturing approaches coping with the need of utilizing new and advanced materials in products, adding functionalities to products, dealing with complex structures and shapes

Specific technical / industrial challenges (mainly resulting from gaps in technological capacities):

- Development of manufacturing methods based on new materials processing to move from batch to continuous formulation and to manufacture highly miniaturized components
- Development of 3D micro-components using a wide range of materials (metallic alloys, composites, polymers, ceramic) and on large volumes
- Development of conventional (forming, machining, replicating) and new manufacturing processes and related equipment - at the micro and nano-scale, encompassing design, tooling, assembly, joining and reliability issues
- Large volume patterning at nanoscale (photolithography) and new materials and greater use of space on CMOS
- Development of methods for automatic handling of parts, in line metrology and inspection to manufacture at scale with high reliability

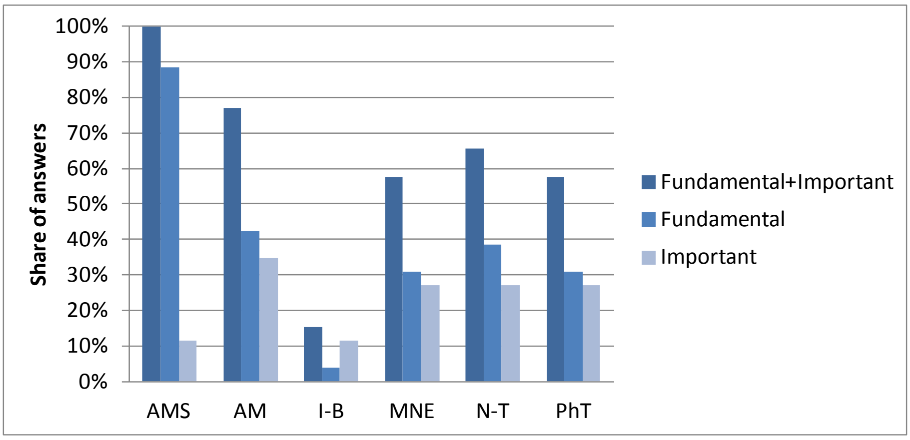
Contribution by cross-cutting Key Enabling Technologies:

In respect to this Innovation Field, the integration of KETs could contribute to the development of advanced approaches, encompassing design, tooling, assembly, joining and reliability issues, for the mass production of highly integrated functional 3D micro-products, including for automatic handling, metrology and inspection of parts. The integration of KETs could particularly contribute to the development of high volume manufacturing methods based on new materials and production processes, such as tooling and patterning of highly miniaturized 3D components.

To this aim, the combination of KETs experts' opinions collected through the dedicated survey (whose result is depicted in the below bar chart), the examination of KETs-related patenting activity in respect to this Innovation Field, and desk research activities, have allowed identifying a rather strong interaction of KETs with respect to this Innovation Field, with either fundamental or important contribution mainly by the following KETs:

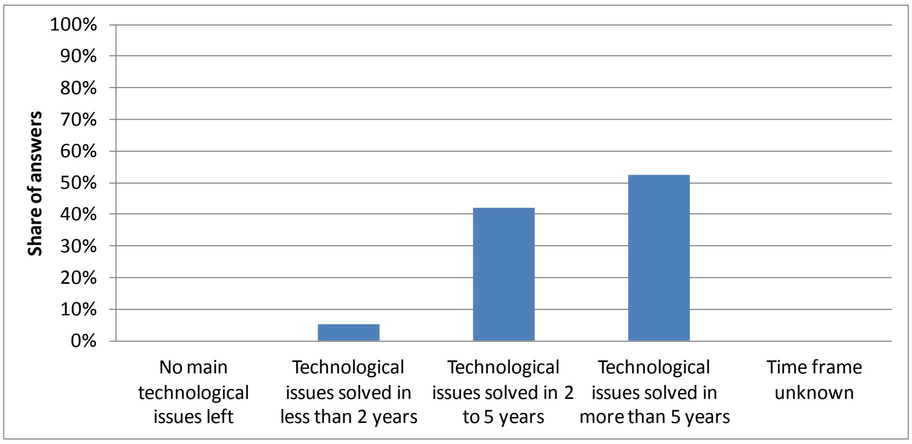
- Advanced Manufacturing Systems (AMS)

- Advanced Materials (AM)
- Micro- and Nano-Electronics (MNE)
- Nanotechnologies (N-T)
- Photonics (PhT)



Timing for implementation:

According to the majority of KETs experts' opinions (whose result is depicted in the below bar chart), desk research, and in line with the KETs-related patenting activity in this field, it is considered that the main technological issues holding back the achievement of cross-cutting KETs based products related to this Innovation Field could be solved in a time frame of more than 5 years, yet significant consensus by experts indicates also shorter periods being necessary:



Hence, depending on the specific technical and/or industrial challenges holding back the achievement of cross-cutting KETs based products related to this Innovation Field, the provision of support in the short to medium term should be taken into consideration within this framework.

Additional information according to results of assessment:

➢ ***Impact assessment:***

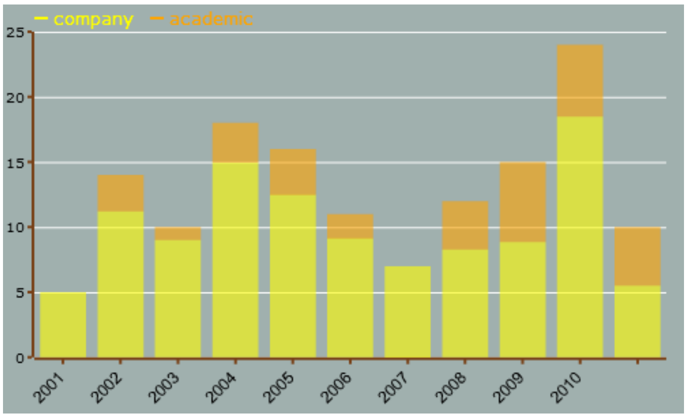
- Due to the commoditization of some MEMS devices, especially in the consumer electronics segment, MEMS manufacture has driven the development of mass scale production of highly integrated functional 3D micro-products.
- The critical physical dimensions of MEMS can range from several millimetres down to well below one micron. Moreover, MEMS can vary from relatively simple structures with no moving elements to extremely complex electromechanical systems with multiple moving elements.
- Among these Micro-Electro-Mechanical Systems, an extremely large number of micro-sensors have been developed for almost every possible sensing modality, including temperature, pressure, inertial forces, chemical species, magnetic fields, radiation, etc. More recently, a number of micro-actuators

including: micro-valves for control of gas and liquid flows; optical switches and mirrors to redirect or modulate light beams; independently controlled micro-mirror arrays for displays, micro-resonators for a number of different applications, micro-pumps to develop positive fluid pressures, micro-flaps to modulate airstreams on airfoils, as well as many other devices have been developed and demonstrated.

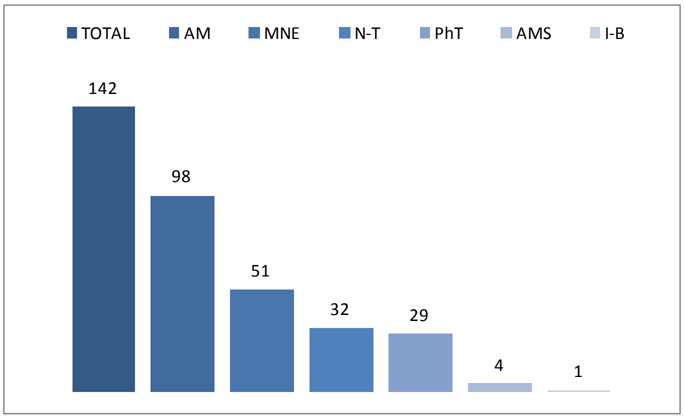
- As a result, MEMS find a very vast variety of applications in an even wider variety of products. To achieve this, their method of production leverages similar fabrication techniques used in the integrated circuit industry (such as oxidation, diffusion, ion implantation, Low-Pressure Chemical Vapour Deposition (LPCVD), sputtering, etc.), combining these capabilities with highly specialized micro-processes – which can translate into mass production and relatively low per-device production costs.
- Not surprisingly, silicon-based discrete micro-sensors were quickly commercially exploited and the markets for these devices continue to grow at a very rapid rate.
- MEMS fabrication uses many of the same techniques that are used in the integrated circuit domain such as oxidation, diffusion, ion implantation, Low-Pressure Chemical Vapour Deposition (LPCVD), sputtering, etc., and combines these capabilities with highly specialized micromachining processes.
- Source: www.mems-exchange.org

➢ ***Results of patents scenario analysis:***

- 142 exclusively KETs-related patents identified in the period 2001-2011 for the specific Innovation Field
- Oscillating trend curve (number of patents per year)
- Highest share of industrial applicants:



- Patents by KET(s):

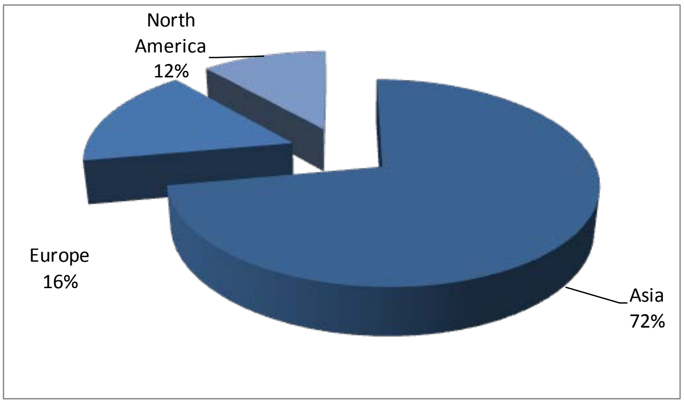


- Patents by KET(s) and relevant combinations of KETs:

KET(s)	*Number of patents*
AM	98
AM / MNE	20
AM / MNE / N-T	3
AM / MNE / PhT	12

KET(s)	Number of patents
AM / N-T	21
AM / PhT	16
AMS	4
AMS / AM	3
AMS / AM / N-T	1
AMS / MNE	1
AMS / N-T	1
IBT	1
MNE	51
MNE / N-T	6
MNE / PhT	21
N-T	32
PhT	29

- Patent distribution by (Applicant) organization geographical zone:



- Patent distribution by geographical zone of priority protection: