Report for the organization and results from the workshop

"4M2020 through the young eyes"

(Copenhagen, Denmark, 18 June 2014,)

Abstract

This report shows the results of a roadmapping study conducted by the 4M2020 - EU project which took place in Copenhagen, Technical University of Denmark (DTU) on 18 June 2014. During the annual DTU Summer School 2014, a one day workshop was held on the topic of "4M2020 through the young eyes". This activity is related to the objective for dissemination of the "4M2020" project ideas. The main aim of the workshop was to get the point of view of young scientists for the current state and future development of Micro- and Nano-manufacturing Technologies (MNT), as well as to find out their understanding of the industrial application of these technologies in the next 3 to 5 years. The presented results are based on the answers of fourteen participants on two questions. There was no previous frame of reference regarding the MNT; the participants had to decide, based on their understanding, which key enabling technologies (KETs) have a significant impact. They had the same freedom of decision for the application session too.

Introductions

There are a number of papers regarding the roadmapping study of MNT/processing and the related applications/products [1- 4]. The main ideas of Multi- Material Micro Manufacture (4M) are very well established. The aim of such roadmapping study is to help informEuropean research and industry about current trends and application requirements in the development of MNT for the batch-manufacture of micro/nano-components and devices. According to its original scope shown in Fig. 1, the approach adopted by the 4M Network is to link technologies, business drivers, and application requirements by establishing capabilities for Multi- Material Micro Manufacture. This generic approach is applied in the Network's roadmapping activities to examine the business and application drivers, and the corresponding trends in MNT development to meet demands for:

- Product miniaturisation through innovative integration and development of knowledge-based technologies and production concepts (especially micro and nano) for processing of advanced materials;
- Prediction of product and process performance to reduce/manage the risk during product development and production, and reduce time to market for the next generation of microsystems-based products;
- Future product platforms to meet the requirements of the next generation of microsystems-based products, and of more stringent regulations and environmental legislation;
- Production scale-up to ensure an effective and efficient transfer of product and technology ideas from laboratories to serial production.

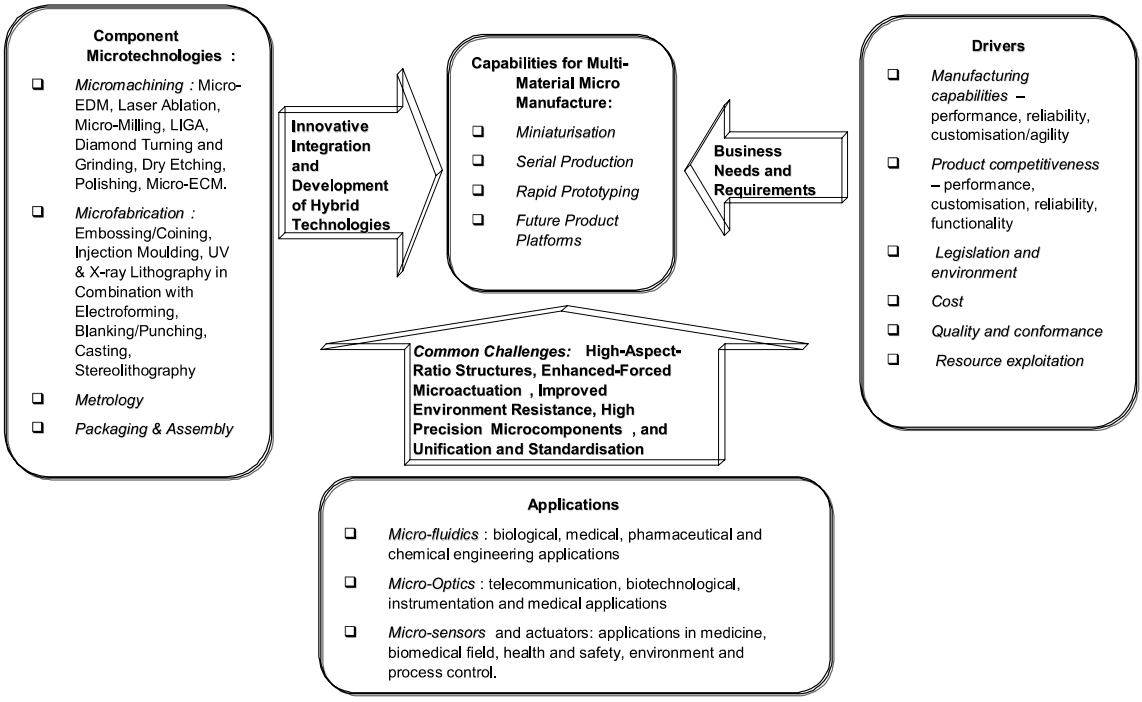

Fig. 1. 4M Scope: technologies, business drivers, and technical application requirements lead to required or provided capabilities [5]

In considering the above demands, this report discusses the key factors affecting technology and application developments and tries to answer the following four main questions:

- What are the application requirements and the corresponding trends in technology/process development?Is there a potential mismatch between future application requirements and 4M capabilities?
- What is the current level of maturity and future potential of the 4M manufacturing technology areas?
- Are there 4M manufacturing technologies requiring further investment to meet perceived future application requirements?

Methodology

The existing methodologies of roadmapping studies are based mainly on discussion and opinion of specialists in this field. The results are applied for new future programmes allowing extensional development of new product chains and solving the barrier problems in the implementation of KETs.

The current report presents the results from the roadmapping study based on opinion of young researchers in the field of MNT. Fourteen participants from four different European universities attended the workshop. The Delphi study method was used for extraction of the data obtained from the workshop "4M2020 through the young eyes", during the DTU Summer School. The results from this workshop will be compared with similar future studies based on the opinion of senior researchers and industrialists.

The first part of the workshop was a review lecture on topic "*Micro and Nano Manufacturing: Challenges and Opportunities*", given by Prof. Stefan Dimov. The main current technologies in the field of MNT and the applications in which the 4M KETs can be implemented were presented. During the lecture Prof. Dimov introduced the mismatch between the applications/products needs and technology capabilities, which is the "barrier" from industrial point of view.

The second part of the workshop was the roadmapping by using the Delphi study method.

During the introductory session Prof. Dimov talked about the meaning of "TRL", "MCRL", "drivers" in industry, "bottleneck", "barriers" and "value chain". It facilitated the participants to give their answers. After this session, the participants were divided into two groups and they were invited to answer two questions in two different sections: *Technological section* and *Application section.*

In each session the question was first "brainstormed" by the group, i.e. members of the two groups were free to call out their ideas and proposals. Handouts were provided with ideas and prompts. As a next step, the group members were asked to write down three answers, each on a sticky note, which were then placed on a "white board". The group facilitator then combined similar notes together under common headings, in agreement with and under the guidance of the group members (the answers were clustered by similarity). Once under these headings, group members were asked to allocate their "budget" of 6 stickers to what they considered the most important headings. They were asked to "spend" their budgets, partially or as a whole. The participants were allowed to "invest" into preferable for them technologies/processes, which have been placed on the board, or to keep their votes for a "better future". The participants were able to use Internet information to help them form their decision. For drivers and technical capabilities (technical requirements), each group jointly placed the identified headings along a timeline, according to when they would have impact.

Last step was to invite the participants to determine the current state of 4M KETs/processes selected by them, regarding the level scale of MCRL, and the applications/products were placed on their Readiness Levels respectively.

Results

During the *Technological section*, the participants were asked the following question:

"What are the 4M KETs/processes that are aimed at multiple applications with a high potential impact (scale up production of miniaturized parts) and can reach MCRL 5 and 6 in 5 years' horizon?"

The picture in Fig. 2 shows the results. There are two different colours of votes, linked to the two different groups. The clustering results from this section are presented in Table 1.

- "3D printing" was recognized as the high potential impact KETs by the young people which are making research in the field of MNT -18 votes.
- Second is the "Advanced materials", which could be expected as it is following the information about new sintering multicomponent material, graphene and others – 10 votes.
- Anther remarkable field is the "Ultrasonic manufacturing" – 8 votes. If this score is clustered with the 4 votes from the "Micro milling", than the result is 12.
- Micro and nano "Processing" (LPCVD; PICVD; e-beam evaporation; Lithography) – 4 votes

During the *Applications* section the participant were invited to answer the question:

"Which are the emerging miniaturized products that a enabled by the lasted advances in 4M KETs and are expected to have significant impact (reach TRL 5 and 6) in 5 years' horizon?"

The same procedure as for the "Technology" section was used for evaluation of the votes. The results from this section are shown in Fig. 3, and the clustering results are presented in Table 2. The result here is remarkable; many of the newly developing MNTs could be implemented in all of these industrial applications. In future most of the industrial products will be linked to the micro and nano technology. For example – advanced materials, highly efficient local power plants, new energy sources, etc. The participants' education and their preferable research area certainly affect this map of Applications' needs. Additionally we have to keep in mind that most of the products have to be addressed directly to the human health needs – 28 votes are scored for these products

(highlighted by yellow). That has to be like a “red light” for the industry – human health and comfort is a driver that has to be kept in mind.

The participants placed some of their answers in between the scales of Readiness Levels as seen also in Tables 1 and 2, where the mark is placed in between two neighbouring columns.

Summary

The results of the roadmapping study workshop “4M2020 through the young eyes” conducted during the annual DTU Summer school in Copenhagen, Denmark, are:

- 3D printing technology is chosen as the favourite KET.
- A favourite product does not appear in the applications. However, this section revealed that that the human health and comfort-orientated products are more important.
- The human health and comfort is the most serious driver in the future.

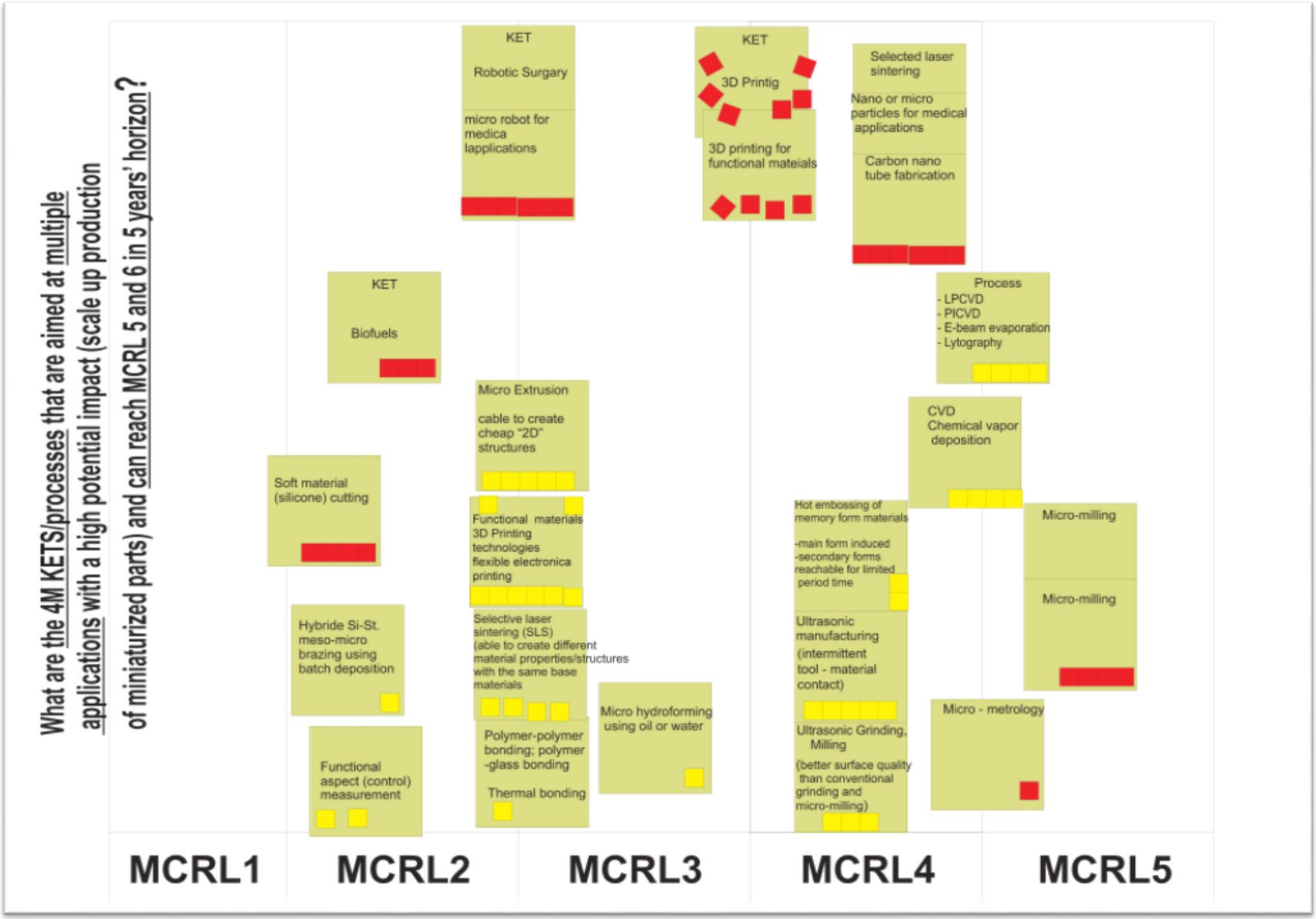

Fig. 2
The results from the "*Technology*" section.

Table 1

What are the 4M KETs/processes that are aimed at multiple applications with a high potential impact (scale up production of miniaturized parts) and can reach MCRL 5 and 6 in 5 years' horizon?

MCRL / 4M KETs	MCRL1	MCRL2	MCRL3	MCRL4	MCRL5	Vote
Micro hydroforming using oil or water			X			1
Advanced Materials (Selective laser sintering, carbon nano tube fabrication, nano particals for medical application)		X		X		10
Biofuels		X				3
Micro -milling					X	4
3D Printing technologies			X			18
Process: -Chemical vapour deposition - LPCVD - PICVD - E-beam evaporation - Lithography			X			8
Micro robot for medical applications		X				6
Ultrasonic manufacturing				X		8
Thermal bonding (polymer – polymer and polymer – glass bonding)		X				1
µ-metrology				X		1
Functional aspect (control) measurement		X				2
Hybrid Si-St. meso-micro brazing using batch deposition		X				1
Soft material (silicone) cutting	X					4
Micro Extrusion (cable to create cheap "2D" structures)		X				5
Hot embossing of memory form materials -main form induced; -secondary forms reachable for limited period time				X		2
Micro - metrology				X		1

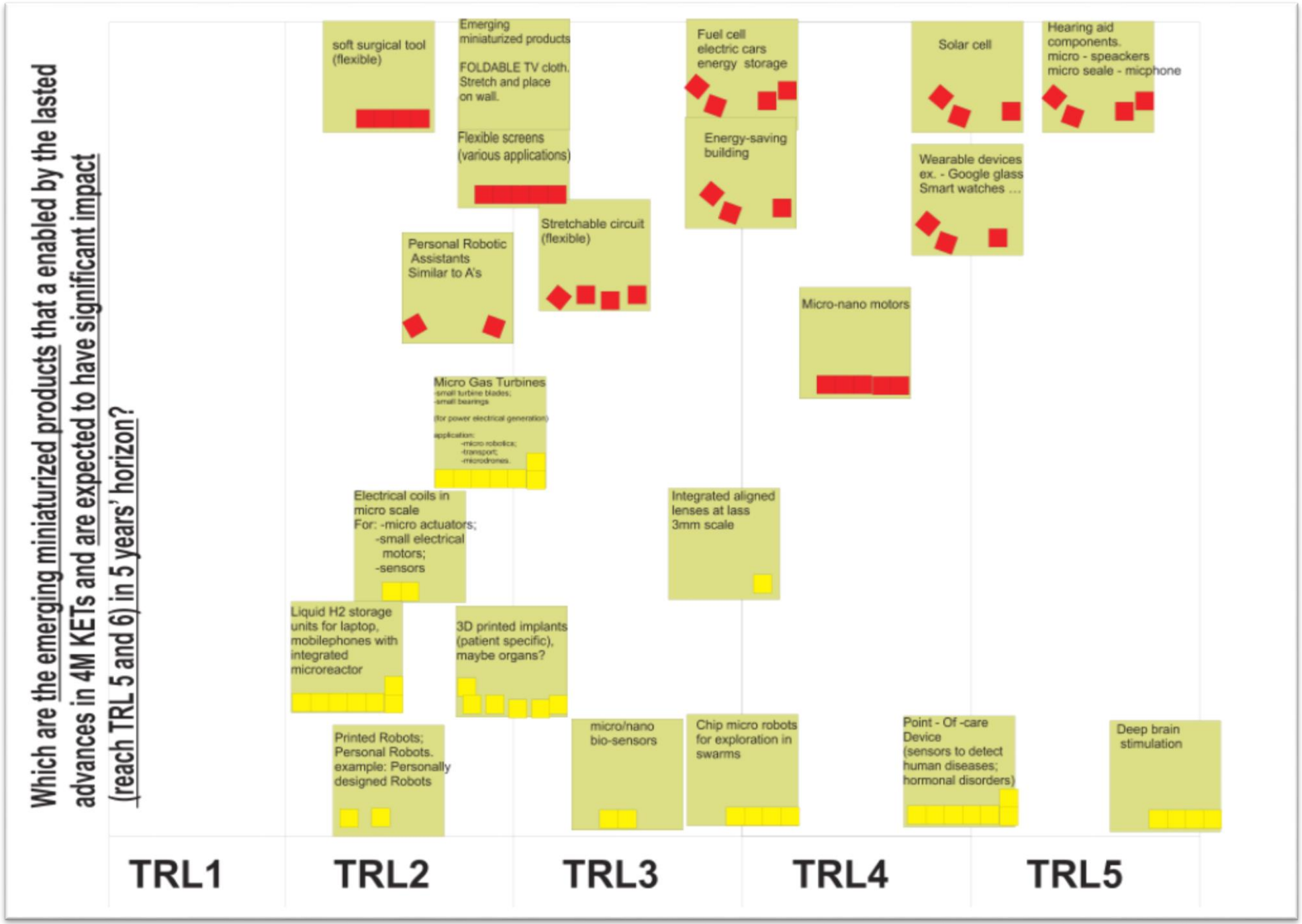

Fig. 3
The results from the "*Application*" section

Table 2

Which are the emerging miniaturized products that a enabled by the lasted advances in 4M KETs and are expected to have significant impact (reach TRL 5 and 6) in 5 years' horizon?

TRL / Applications	TRL1	TRL2	TRL3	TRL4	TRL5	Vote
Integrated aligned lenses at lass 3mm scale			X			1
soft surgical tool(flexible)		X				4
Flexible screens		X				5
Personal Robotic Assistents similar to A's		X				2
Stretchable circuit (flexible)			X			4
Fuel cell (electric cars; energy storage)			X			4
Energy-saving building			X			3
Micro-nano motors				X		5
Wearable devices				X		3
Solar cell				X		3
Hearing aid components. (micro – speakers; micro scale – micphon)					X	4
Deep brain stimulation					X	4
Point - Of -care Device (sensors to detect human diseases; hormonal disorders)				X		7
Chip micro robots for exploration in swarms			X			4
3D printed implants (patient specific), maybe organs?		X				6
Micro Gas Turbines -small turbine blades; -small bearings		X				7
Electrical coils in micro scale			X			2
Liquid H_2 storage units for laptop, mobile phones with integrated µ-reactor			X			7
Printed Robots; Personal Robots. example: Personally designed Robots			X			2

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