ICARUS SUPERMAT

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Micro-Manufacturing: Products, Research, Applications and Trends

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- ✓Background Information
- ✓Products and Market
- ✓Micro-Manufacturing Research
- ✓Significance and Issues Relating to Applications
- ✓EU Funded Initiatives on Micro-Manufacturing
- ✓Conclusions

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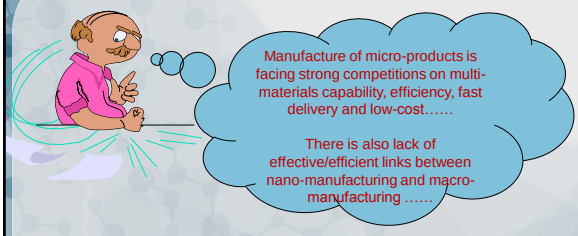

Significant effort in research in Micro-Manufacturing, starting in the late of 1990s, has been made on the development of non-silicon-based manufacturing techniques ……

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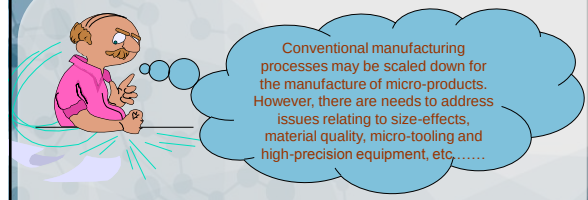
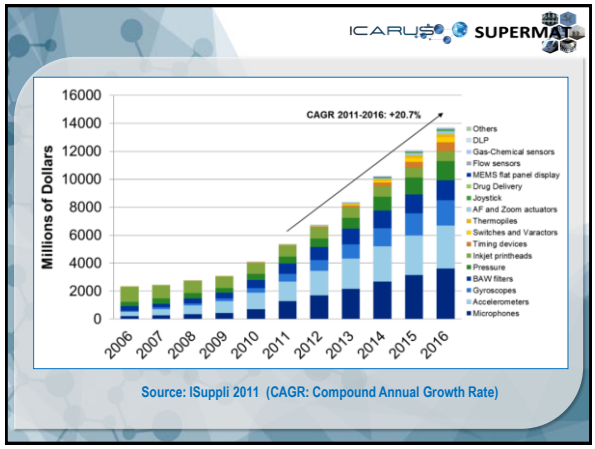


For example, conventional forming and machining technologies are of potential to be enablers for low-cost, mass production of micro-components and they also provide multi-materials manufacturing capabilities …… these could help to meet high demand for the micro-products and components.



Source: ISuppli 2011 (CAGR: Compound Annual Growth Rate)

- Globally, the predicted values on the increases of the micro- and nano-technology products vary from different sources, generally speaking, there is an average 10 to 20 % annual increase.

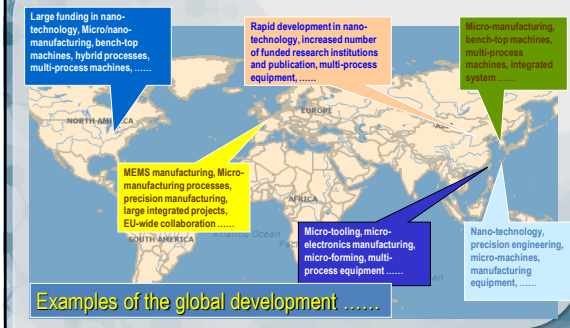
- ✓ Smartphones are the main target market for emerging MEMS devices ……
- ✓ MNMT are now widely used for developing energy efficient systems for energy production, conversion and storages ……
- ✓ More than 200 micro actuators and sensors are integrated into modern automobiles ……

Medical Device and Implants - the development that is benefited from micro- and nano-technology

Types of Applications	Products and/or Fields Benefitted from Nanotechnology
Implantable materials for orthopaedics and dentistry	Implant coatings, Surface modifications, Bone replacement materials, Tissue Engineering, etc.
Implantable materials for vascular interventions	Stent coatings, Stent coatings with drug-eluting capacity, etc.
Active implantable devices and bionics	Vision rehabilitation, Pacemakers and hearing aids, Neuro-engineered systems for motor control, Microchip-based drug delivery systems, Prosthetic knee system, etc.
Chips for molecular diagnostics	DNA microarrays, Protein microarrays, Lab-on-a-chip, Cell chips, etc.
Delivery devices / tools	Needles for administration and monitoring, Nanomaterials for brachytherapy and nanocapsules, Nanoparticles for drug delivery across blood-brain barrier, Nanotube-based delivery applications, Nanovectors for gene therapy, etc.

Nano-technology products will be used everywhere in our life in the future ……

Competitive Developments Globally



Examples of the global development ……

Scope of Micro-Manufacturing Research

- ✓ Micro precision manufacturing of macro/miniature-sized components
- ✓ Micro/nano-feature manufacturing over the large and small areas
- ✓ Manufacturing of micro-sized components
- ✓ Manufacturing with micro/nano-structured materials
- ✓ Manufacturing with controlled micro-structures

What does Micro-Manufacturing research do ?

Products, manufacturing and applications addressed……

Components/ Parts	Sample Geometry/Features	Possible Enabling Techniques	Typical Part Materials	Processing Accuracy	Typical Products / Applications
Surface 2.5D functionalised structures	Local features in hundred nano-meters to 10s microns	Hot embossing /Coining/Imprinting, Ink-jetting, Plating, Direct writing, Laser ablation, etc.	Polymers, Glass, Aluminium, Copper, Brass, Steel, etc.	Several microns to nano-meters	Micro-optical, Fluidic devices, Force transmit. surfaces, Dies/Moulds, etc.
Lead-frames	Various geometry, local features as small as tens microns, thicknesses vary, such as between 0.3 to 0.01 mm.	Micro stamping, with/without laser-assistance, Laser cutting, Photo-chemical etching, etc.	Copper and alloys, Nickel Steel, etc.	Several microns or to 10% of the sheet thickness	Electronics products
Micro-Pins	Diameters in 0.2-1 mm ranges, Can-wall thickness in 50 to 200 microns possible, and tolerances < 5 microns	Forward, and /or combined with backward extrusion, Micro-shape rolling, Micro-machining/EDM.	Various types of metals.	Several microns to sub-microns	Various applications as IC Carrier, Micro-device assembly, Electric contacts, etc.
Electro-thermal-mechanical actuator	2.5D/3D structural parts, various sectional geometries.	Chemical etching & Micro stamping, Laser cutting, Efab.	SMA and other metal materials	Several microns	Micro-actuating devices.
Micro-Cups	Micro-cups, less than 1mm in diameter, various thicknesses.	Micro-deep drawing, Micro-stamping, Micro-spinning, Micro-machining.	Molybdenum, Copper, Aluminium, Steel.	Several microns	Electron guns, pressure sensors, UV sensors, etc.
Micro-Gears	Diameters of 1 mm or less, local features in 10s microns.	Micro-forging, Micro-extrusion, Micro-stamping, LIGA, Micro-casting, PCE, Micro-EDM, Efab, etc.	Metals, Polymers	Several microns to sub-microns	Micro-mechanical devices, Watches.

Products, manufacturing and applications addressed……

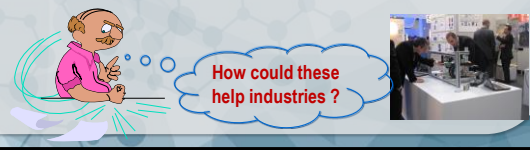
Shafts for Micro-mechanical drivers	Less than 1 mm in diameters.	Micro-extrusion, Micro-machining/EDM.	Steels and alloys	Several microns to sub-microns	Micro-driving-devices, e.g. micro-spindles.
Micro-Screws, Micro-Cans	Diameters in 0.1-0.5 mm ranges.	Micro-forging, Extrusion, Shape rolling, Micro-machining.	Various metals	Several microns to sub-microns	Micro-devices, housing and assembly, etc.
Micro-gear-shafts	Local features in 30-50 microns.	Extruded with local heating, Micro-radial extrusion, Micro-machining, EDM.	Metals	Several microns to sub-microns	Micro-mechanical driving devices, Watches
Casing/Housing of micro devices	Thin sheets, from 0.1-0.01 mm	Micro-Stamping, Dipping, Drawing, Hydro-forming.	Stainless steel, Aluminum, Copper, etc.	Several microns	Micro-mechanical, electronics, medical, optical, chemical devices, etc.
Micro-tubular components	Outer diameters less than 1mm, wall thickness larger than 20 microns.	Micro-hydro-tube-forming, Micro-rolling, Micro-bending, Laser machining, etc.	Metals	Several microns	Micro-shafts, Micro-heat-exchangers, Micro-medical devices/implants.
Micro-Moulds, Dies and Punches	Die-bore or inner pockets in less than 1mm; punch diameter from 0.05 to 1mm.	Micro-EDM, Laser-cutting, Micro-machining, Electro-forming, Sintering, etc.	Tool-steels, Glass, Powder, etc.	Several microns to sub-microns	Forming/Replicating processes e.g. injection moulding, embossing, extrusion, etc.

Over the last 20 years, various **Micro-Manufacturing Processes and Technologies** have been developed ……

Subtractive processes	Micro-Mechanical Cutting (milling, turning, grinding, polishing, etc.); Micro-EDM; Micro-ECM; Laser Beam Machining; Electro Beam Machining; Photo-chemical-machining; etc.
Additive processes	Surface coating (CVD, PVD); Direct writing (ink-jet, laser-guided); Micro-casting; Micro-injection moulding; Sintering; Photo-electro-forming; Chemical deposition; Polymer deposition; Stereolithography; etc.
Deforming processes	Micro-forming (stamping, extrusion, forging, bending, deep drawing, incremental forming, superplastic forming, hydro-forming, etc.); Hot-embossing; Micro/Nano-imprinting; etc.
Joining processes	Micro-Mechanical-Assembly; Laser-welding; Resistance, Laser, Vacuum Soldering; Bonding; Gluing; etc.
Hybrid processes	Micro-Laser-ECM; LIGA and LIGA combined with Laser-machining; Micro-EDM and Laser assembly; Shape Deposition and Laser machining; Efab; Laser-assisted-micro-forming; Micro assembly injection moulding; Combined micro-machining and casting; etc.

How do these relate to traditional industries ?

- ✓ New technological solutions for transforming the industry
- ✓ New material solutions to meet manufacturing/product challenges
- ✓ New manufacturing process concepts to help achieving breakthroughs
- ✓ New knowledge and enabling techniques for tooling
- ✓ New manufacturing machine and system concepts
- ✓ Help delivering micro-/nano-technology products



Where the value could be added to a product through micro-/nano-manufacturing?

- ✓ Improving surface quality through precision-manufacturing (e.g., nano-machining and FIB machining);
- ✓ Adding surface functionalities of the component/system surfaces through surface texturing (e.g., machining, laser, micro-EDM, micro-ECM) and/coating (e.g. multi-layered nano-coating);
- ✓ Creating new functional structures of the components/systems through micro/nano-forming/casting/sintering (e.g. hellow-sectioned, channelled, functionally graded structures);
- ✓ Converting low-value materials into high-value products such as nano-materials/composite products (e.g. micro/nano-forming, casting and sintering of high-quality components);
- ✓ Creating values by high-quality assembly from low-value components/materials (e.g. micro-injection moulding assembly, high-precision mechanical, micro-joining, self-assembly).

EU Initiatives on Micro-Manufacturing through FP6 and FP7 Programme

The Europe lead the research in micro-manufacturing, which was evident in the WTEC report which emphasized the EU efforts and their significance.

The trend was obviously enhanced since the EU FP6 NMP programme started. This was largely due to set-up of some flagship projects in this field such as MASMICRO, 4M, Launch-Micro, Production4µ, EUPASS, Hydromel, HYTI, NANOSAFE2, Manudirect, Napolyde, PRONANO, NaPa, CHARPAN, NANOIMPRINT, NanoCMM, etc

Almost of all major EU countries set up their programmes to support Micro/Nanotechnology related research and technological development, especially investment from countries like Germany, United Kingdom and France had large initiative programmes which covered almost all fields of micro- and nano-manufacturing, especially in Microsystems and Nanotechnologies.

EU Initiatives on Micro-Manufacturing through FP7 Programme

In FP7, besides the projects which had already been completed, such as POLYGLASS, MULTILAYER, NANOMICRO, MIDEMMA, FLEXPAET, INTEG-MICRO, µECM, POLYTUBES, PLAST4FUTURE, SONO"R"US, etc., within the FoF initiative ("Factory of the Future"), a group of projects were/are currently being executed in the field of micro-manufacturing, to support the effort of meeting challenges of maintaining high-quality manufacturing in Europe.

HiPr - developing a novel approach for metal 3D micro-parts production,
3D-HiPMAS - a pilot line fabrication of advanced MID-based micro assemblies;
Smartlam - layer by layer lamination of functionalised film sheets ;
Hi-Micro - tooling technologies for micro-injection (powder) moulding (µIM);
HINMICO - manufacturing high quality multi-material micro-components;
Micro-FAST - new manufacturing system for the volume production of miniaturised components with difficult-to-process materials;
FaBiMed - flexible and cost-effective tooling fabrication, precision replication and advanced inspection
MICROAB - micro-machining with abrasive waterjets.

EU Initiatives on Micro-Manufacturing through Horizon 2020 Programme

In EU Horizon 2020, some projects in the field of micro-manufacturing also have started, e.g. the R2R Biofluidics project on large scale micro-and nano-fabrication technologies for bioanalytical devices based on roll-to-roll imprinting; the TOP HIT project on transfer-print operations for heterogeneous integration; and the ADALAM project on sensor based adaptive laser micromachining using ultrashort pulse lasers for zero-failure manufacturing; Micro-Man on the footprint of manufacturing errors in micro-manufacturing .....

In EU Horizon 2020, Micro- and Nano-Manufacturing topics have been largely embedded into the NMBP (e.g. Materials and Nanotechnology, FoF and Cross-Cutting Topics, etc.), ERC funding schemes, as well as Societal Challenges Programmes, etc.)

EU MASMICRO Project

Integration of Manufacturing Systems for Mass-Manufacture of Miniature /Micro-Products

Developed an integrated solution including manufacturing facilities and knowledge transfer programmes for EU Micro-manufacturing which saw development of a series of processes, machines, tools, materials and software for micro-manufacturing

- Start date: 1st July 2004 End date: 30th Sept. 2008
- Budget: 21 496 054 Euro
- Partners: 36 Partners from 13 EU countries
- Composition: 19 IND, 11 RES and 6 HE

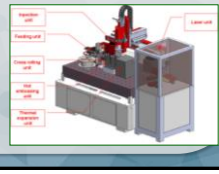
EU FP7 POLYTUBES Project

"To implement a Design for Manufacturing methodology for design and manufacture of micro-tubes and tubular micro-components for volume production;

To transfer laboratory processes and equipment to volume production of tubular micro-components;

To integrate the individual equipment into a process chain and implement it in a manufacturing platform."

- Start date: 1st Sept. 2009
- End date: 30th August 2012
- Budget: 5.05 Million Euro
- Partners: 17 Partners from 9 EU countries
- Composition: 10 IND, 3 RES and 4 HE



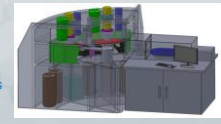
EU FP7 Micro-FAST Project

"A FAST process and production system for high-throughput, highly flexible and cost-efficient volume production of miniaturised components made of a wide range of materials"

Direct manufacturing with multi-materials, especially with difficult-to-form and difficult-to-cut materials;

Upscaling the laboratory process into production equipment ……

- Start date: 1st Sept. 2013
- End date: 28th Feb. 2017
- Budget: 7. 5 Million Euro
- Partners: 18 Partners from 9 EU countries
- Composition: 11 IND, 4 RES and 3 HE

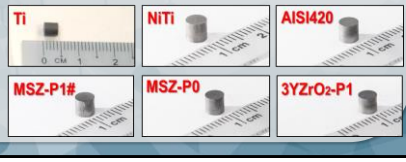


EU FP7 Micro-FAST Project

The targeted materials and applications

- ✓ Metals and Metal Alloys
- ✓ Ceramics
- ✓ Cemented carbides
- ✓ Shape memory alloys
- ✓ Piezoceramic materials
- ✓ Magnetic materials

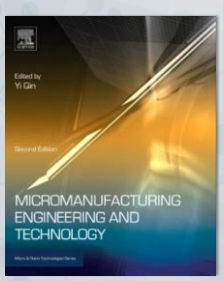
- ✓ In general, micro-parts used in several environment
- ✓ MEMS, Sensors and actuators
- ✓ Medical implants and surgical tools
- ✓ Dies/moulds, cutting tools m
- ✓ Micro-bearings
- ✓ Micro-engines, motors and robots
- ✓ Watch components ……



Conclusions

- ✓ The continuing trend of miniaturisation of products, devices and equipment has been a major driver to the development of micro- and nano-manufacturing technology.
- ✓ Compared to the development of 10 years ago, recent development has been largely applications-driven.
- ✓ RTD effort has been shifted significantly to the transforming of laboratory processes into items of production equipment; and the development has been targeting onto sector-specific applications.
- ✓ In addition to the effort in developing multi-materials processing capabilities, low-cost equipment and pilot production lines, other aspects such as advanced tools and analysis software, high-quality materials and nano-materials, automation, inline inspection, quality assurance, and standardisation, are also being addressed.
- ✓ Considering that micro-manufacturing bridges between potential, high-impact nano-science and nanotechnology and real-world, low-cost products, it will achieve further significant development over the next 10 years.

Key References .....



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