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CHARACTERISTICS OF MICRO AND NANO MANUFACTURING METHODS USED IN MECHANICAL ENGINEERING

G.L. Mitu[1], AL. Bejinaru Mihoc[1]
Transilvania University of Brasov, Braşov, ROMANIA, leonard.mitu@unitbv.ro, alexandru.bejinaru@gmail

Abstract: *The term microfabrication is used to make components, devices or equipment that have at least a dimensional characteristic of the micron range (1µm - 999 µm). Similarly, nanomanufacturing refers to the manufacture of products or components in which some of the dimensions are in the nanometer range (1 nm -100 nm). The two terms refer to very wide ranges of micro and nano produced in terms of shapes, materials, etc., therefore it is necessary to analyze the characteristics of micro and nanofabrication methods.*
Keywords: *micro manufacturing, nano manufacturing, micro systems technologies (MST), micro engineering technologies (MET),*

1. INTRODUCTION

The term microfabrication refers to the production of components or devices that have at least one of the dimensions or dimensional characteristics in the range of microns (1µm - 999 µm). In a similar way, nanomanufacturing refers to the production of products or components that have dimensions in the range of nanometers (1 nm -100 nm) [10], [4], [2].
At the industrial level, micro and / or nanofabrication realizes in large series productions / and mass micro and nano components or devices in rigorous conditions of precision (very tight tolerances for dimensional and surface characteristics) quality, productivity etc. As a result of the effect of the miniaturization of micro and nano products, the complexity of the applied micro and nano production systems greatly increases - which usually reduces the reliability of the whole system [8].
The current European market for micro / nanoproducts highlights medical technology and electronic engineering as major targets (Fig.1) but to a significant extent also microsystem technology. Systemic studies on the development of production capacities in the field of micro and nano-manufacturing programs have highlighted the main characteristics of micro and nano technologies used industrially [5]: a. widespread use of the development of nanoscience's and micro / nanotechnology; b. micro / nano technologies have a disruptive character on

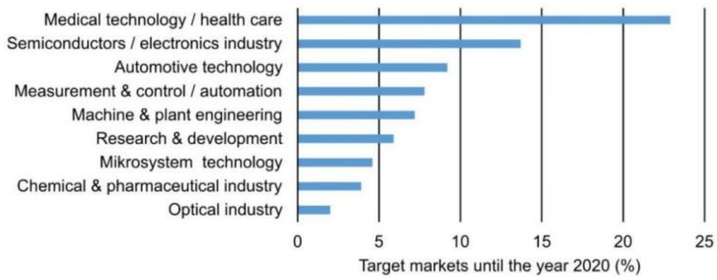

Figure 1: Target markets of European micro-technology industries and research institutions, according to [8]

existing manufacturing paradigms, determined by technological information, primarily through the relationships micro and nanomaterials - material processing - performance (Fig.2); c. revolutionizing and transforming manufacturing systems in the micro and nano fields; d. strategic impact on industrial competitiveness in manufacturing.

2. CHARACTERISTICS REGARDING MICRO AND NANOFABRICATION METHODS

In terms of material processing characteristics, micro / nanomanufacturing techniques can be classified according to the following main criteria.(Fig.3):

- depending on the specifics of the processing energy ;
- after the nano and micro structure of the processed material;

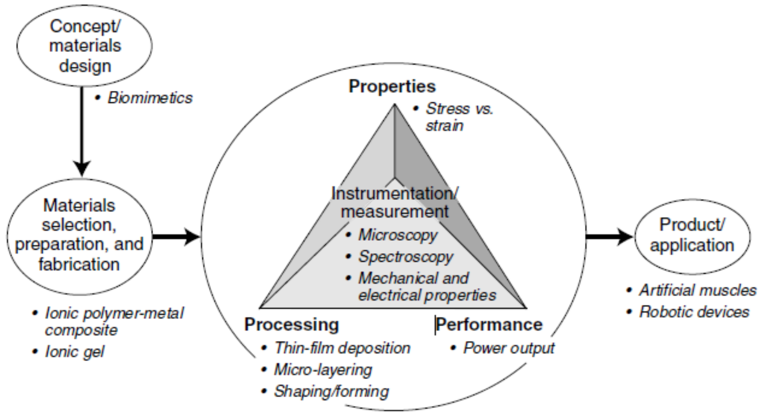

Figure 2: Interferences in material-material processing relationships - micro and nano-manufacturing , according to [1]

- according to the nature of processing: mechanical, thermal, chemical, etc.;
- after the processed material: a silicon and silicon-based materials; b. materials other than silicon
- depending on the type of micro / nano product

According to the last criterion, the micro and nanomanufacturing methods are grouped, in the literature in the field, into two main groups (Fig.4):

○ the group of technologies for the manufacture of MEMS microsystems, MOEMS, etc. They are included in the general concept of „Micro System Technology" (MST);

○ the group „micro machining" technologies, which are not based on lithography: They are specific to the field of micro-engineering in which mechanical microcomponents, micromatrites, micro and nanostructured surfaces, etc. They are defined as „Micro Engineering Technologies"(MET).

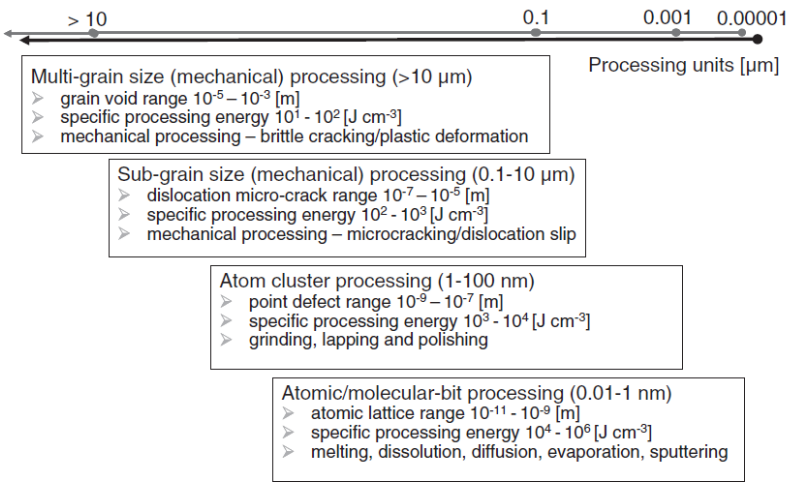

Figure 3: Processing windows for performing material removal at different scales and processing units, after [5]

The technologies for the manufacture of microsystems have generally been evaluated from microelectronics. They are mostly planar technologies and comprise the following main microfabrication techniques [3], [6], : film deposition, pattern transfer, (partial) layer removal and silicone micro machining. The technologies in this group respect the technological hierarchy in microsystem technology [2]: functional or form element; components; microsystem.

The technologies from the "Micro System Technology" group include micro / nano mechanical machining, LASER microprocessing, microreplication techniques, etc. [7]. This group also includes the techniques of subtractive processes, additive processes, etc. (Tab.1)
Each of the two groups of technologies has its own characteristics and performances (Tab.2) and uses different sets of manufacturing technologies (techniques) but also some variants of common technologies (techniques). [3], [12];

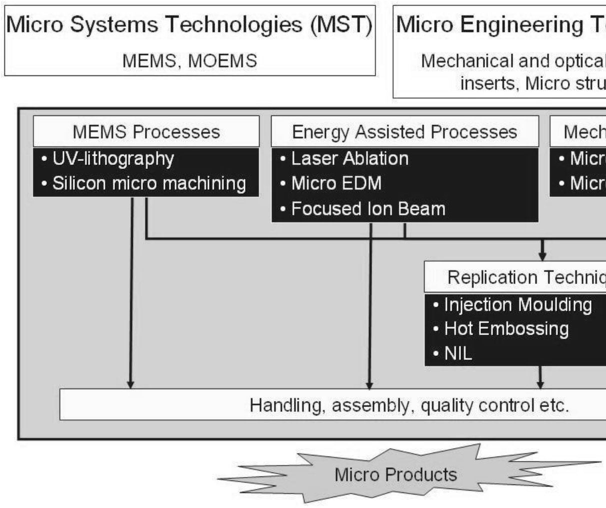

Figure 4: Process technologies for micro manufacturing, after [4]

However, the two technological principles of manufacturing must be kept in mind.

Table 1. Typical methods/processes in micro-manufacturing, after [13], [9]

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 (inkjet, 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.

Table 2. Comparisons between MEMS-based process and micro machining, after [11]

Characteristics	MEMS – based process	Micro mechanical machining
Workpiece materials	Silicon, some metals	Metals, alloys, polymers, composite, technical ceramics
Component geometry	Planer or 2.5D	Complex 3D
Relative accuracy	$10^{-1} – 10^{-3}$	$10^{-3} – 10^{-5}$
Machine size	Macro	Macro or micro
Production volume	High	High or low
Production rate	High	Low
Applications	MEMS, microelectronics, some planner micro parts	Various applications requiring 3D micro components
Total investment	High	Intermediate or low

At present, the current trends in the micro and nano-manufacturing are pursuing the following main capabilities [4]: new ways of processing micro- and nano-materials; convergence of micro and nanotechnologies achieved in two main ways, namely integration of MET and MEMS technologies and bottom up and top down synthesis.

3. CONCLUSION

Micro and/ or nanofabrication consists in industrial manufacturing, in large series productions / and mass of micro and nano components, devices or equipment in rigorous precision conditions (very tight tolerances for dimensional and surface characteristics), quality, productivity, protection of environment etc.

Compared to conventional manufacturing, micro and nanofabrication is different in many features consisting of: specific properties of micro and nanoproducts due to the effects of miniaturization, the conditions in which the precision requirements are achieved, quality, productivity, working environment, handling conditions, etc. are met, new concepts regarding manufacturing tasks, techniques and technologies, especially emerging ones, manufacturing functions, etc. In these conditions, each analysis on ways of accomplishing the micro and nano fabrication techniques allows accurate assessment of their selection in production.

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