Micro- and Nano-Processing

(1) Aims

This roadmap picks up the processing resolution, which represents the minimum processing dimensions, as a general-purpose parameter related to the micro- and nano-processing technology important in the machine material and material processing fields. The processing resolution is an important parameter that shows the progress of the processing technology. This roadmap classifies micro- and nano-processing into two-dimensional micro- and nano-processing and three-dimensional micro- and nano-processing. It intends to clarify the chronic changes and forecast of progress of the processing resolution. It discusses about the possibility of the atom-order processing resolution, which is the limit of processing technology, the period of actualization, necessary breakthrough, and impacts of new processing technology upon the industry and society. Through these discussions, it will give quantitative targets and social and academic meaning to engineers and contribute to further progress in mechanical engineering.

(2) Social and technical needs

- Size reduction, weight reduction and performance improvement of products in use
- Development of finer and highly integrated manufacturing technology and peripheral technology pursuant to development of highly integrated electronic circuits
- Creation of new products and new industries by means of size reduction (□-TAS, micro-satellites, micro-factories, etc.)
- Minute processing and damage-less processing of functional materials

(3) Key parameters

This roadmap picks up the processing resolution as the key parameter of micro- and nano-processing and shows the chronic change of resolutions of two-dimensional and three-dimensional micro- and nano-processing. It also shows the limit of ultra-precision processing enabled by Taniguchi well known in ultra-precision processing. The processing resolution cannot exceed this processing limit.

The resolution of two-dimensional micro- and nano-processing is higher than that of three-dimensional micro- and nano-processing. It is known by intuition if we take the number of processing axes to be controlled into consideration when multiplying the dimensions. If we simply consider the current tendency, the resolution of two-dimensional micro- and nano-processing will reach the atomic order in 2025 or later, and the resolution of three-dimensional micro- and nano-processing will reach the atomic order in 2035 or later in the earliest cases.

(4) Future directions for determining key mechanisms and parameters

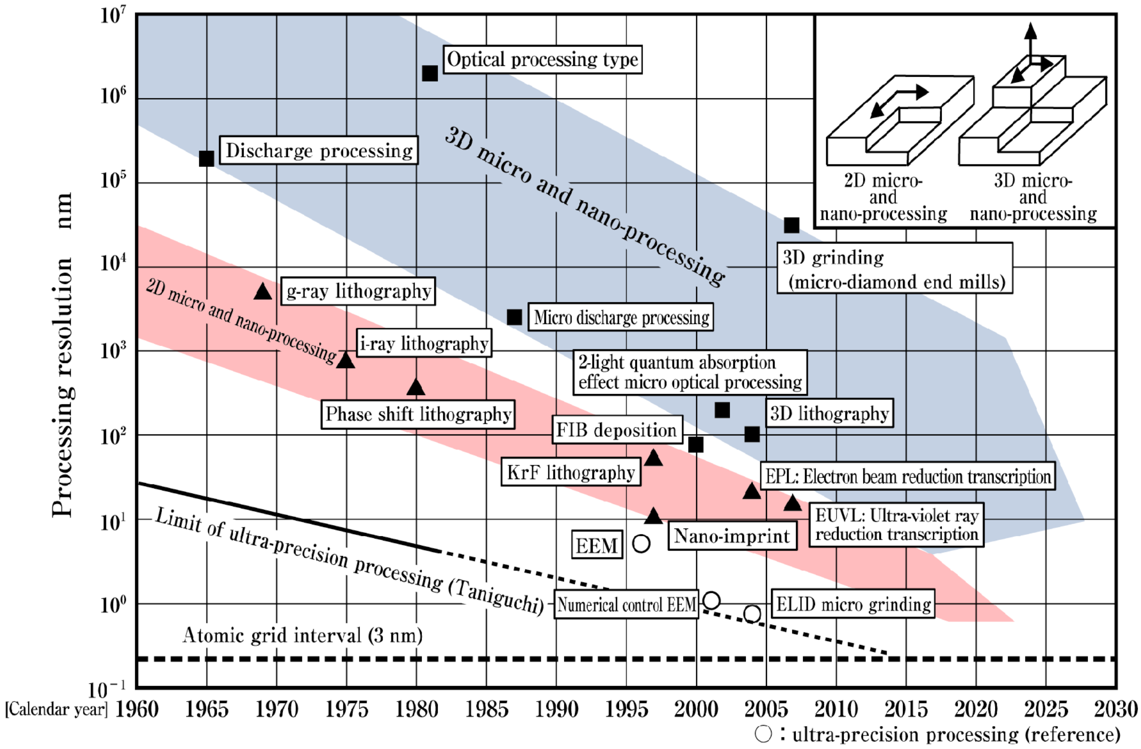
The main stream of the traditional micro- and nano-processing was removal processing or top-down processing. Another approach, i.e., bottom up processing may be needed to achieve atom-order processing. Besides, methods of using self-organization of atoms and molecules may be promising to achieve bottom up processing at practical velocity.

(5) Contribution to society

The micro- and nano-processing is closely related to products requiring high added values and functionality from metallic dies to semiconductors. If atom-order two-dimensional and three-dimensional micro- and nano-processing is put into practical use, it will enable innovation in a wide range of technologies from information equipment to environmental activities, including full color and fine electronic paper, monitors of several millimeters in thickness, terra-byte class storage memory units, very high-efficiency cars, and small fuel batteries.

Social & Technical Needs

1960～1970	・Semiconductor pressure sensors ・Presentation of top-down nano-technological concept by Feynman ・Proposal of ultra-precision processing
1970～1980	・Proposal of nano-technology by Taniguchi ・Researches of micro-mechanisms by Hayashi and others ・Researches of artificial lattice structures by Esaki
1980～1990	・Thermal type ink jet printers ・Proposal of bottom up molecular machines by Dreksler
1990～2000	・Mobile telephones ・Piezo type ink jet printers ・Mass production of DMD devices
2000～2010	・Development of intelligent cars
2010～2020	・Friction loss reduction and demands for further energy saving
2020～2030	



Technical Breakthrough

1960～1970	・Invention and practical use of ICs by means of photo-lithography
1970～1980	・Discovery of proximity field optical microscope
1980～1990	・Invention of MEMS processes ・Discovery of Fullerene ・Invention of STM
1990～2000	・Discovery of carbon nano-tubes by Iijima
2000～2010	
2010～2020	・Making 3D structures using self organization
2020～2030	

Changes in Society and Markets

1960～1970	・Large computer NEAC was released first in Japan. ・Color TV broadcasting started. ・FM radio broadcasting was started by NHK.
1970～1980	・LCD LSI calculators were released by Sharp. ・Personal computers PC-8001 were released by NEC. ・Automobile telephone services started. Word processors were released.
1980～1990	・MEMS researches boomed. STM appeared. ・LDs were released by Pioneer. ・Manufacturing of 64 KB DRAMs and satellite broadcasting started. ・Micro-machine engineer society was established. ・Personal computer communication started. Internet connection started.
1990～2000	・National micro-machine project
2000～2010	・National nano-technology strategy in the United States. ・Nano-technology market scale will reach 20 to 30 trillion yen in 2010.
2010～2020	・Very fine semiconductor processing technology featuring 1 nanometer resolution for manufacturing 0.01 micron rule LSIs will be developed. ・Technology for mass production of LSI patterns with maximum dimension of 10 nm will be put into practice.
2020～2030	・Nanometer scale 3D IC processing technology