PROJECT FINAL REPORT

“Final Publishable Summary Report”

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MASMICRO

FINAL PUBLISHABLE SUMMARY REPORT

MASMICRO ("Integration of Manufacturing Systems for the Mass-Manufacture of Miniature/Micro-Products") is an EU FP6 Integrated Project. It started in July 2004, and the project was duration 51 months. The overall objective of the project is to develop an integrated solution for European miniature/micro-manufacturing industry - an integrated manufacturing facility for mass-manufacture of miniature/micro-products and a technology transfer/training package for transferring the knowledge to and for developing skills in industry. A project overview is published in the project web-site (www.masmicro.net) as well as the consortium composition (the partners involved, expertise and roles in the project). The results achieved during the first 3 years were described respectively in a series of the publications made by the project partners, some of these being listed at the project web-site. The consortium's efforts during the last period were to ensure achievements of the results that conform to the project's measurable objectives set in the beginning of the project.

Overall, following major types of the results have been achieved:

(1) A whole set of the manufacturing facilities representing an integrated manufacturing facility for mass-manufacture of miniature/micro-products – integration is effected through three strategies: (i). Integration of the developed processes into the process chains for developing demonstrators; (ii). Considerations and solutions of integrating the facilities developed into the existing systems and production lines through design of standard interfaces; and (iii). Physical integration of the facilities developed through a Manufacturing Execution System and an AGV system.

(2) 3 Desk-top Micro-Forming-Machines, together with the completion of the key technologies and devices of the machines (Micro-bulk, Micro-sheet and Micro-hydroforming Machines), as well as the industry-version machine designs;

(3) A Bench-top Micro/nano-machining machine-tool, together with the completion of the key technologies and devices of the machine, as well as the industry-version machine design;

(4) 5 sets of micro-forming-tools with new tool concepts (flexible bulk, sheet and

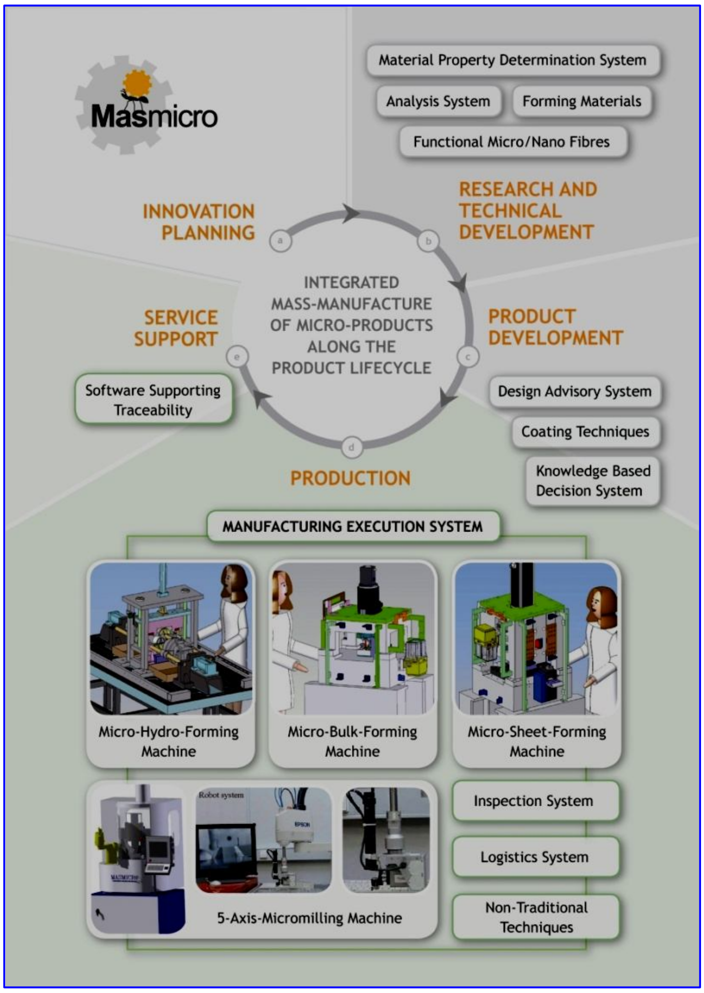

Fig. 1 Illustration of the MASMICRO lifecycle concept

hydro-forming tools, intelligent and vibration-assisted forming tools);

(5) A series of new techniques and new/improved devices of non-traditional manufacturing for mass-micro-production (Laser-equipment, Laser-forming, Photo-chemical-machining and forming, Micro-EDM), and integration of these into MASMICRO process chains;

(6) The system respectively for handling, assembly, testing and inspection (hardware and software) that severs for the Masmicro manufacturing processes and equipment;

(7) A prototype Knowledge-Based Decision-Support System (software), A prototype Design Advisory Assessment System (software) and a Micro-Mechanics Analysis System (software) for the design, analysis and planning of miniature/micro-product and/or micro-manufacturing processes;

(8) A set of novel micro/nano-materials and in-situ testing devices/procedures for micro/nano-manufacturing applications.

48 exploitable results in total have been achieved, some of these having already been introduced to industry and/or having started providing services to industry. All of the project developments together reflect a "life-cycle" concept of the development of miniature/micro-products, as indicated in Fig. 1. Industry can selectively choose one of the developed facilities for their interest. According to actual products to be manufactured, the MASMICRO consortium will be able to deliver a full, integrated system (for example, MASMICRO-Factory, as indicated in Fig. 2) that includes all of the key developments from the project, hence, an integrated solution to industry, including training programmes.

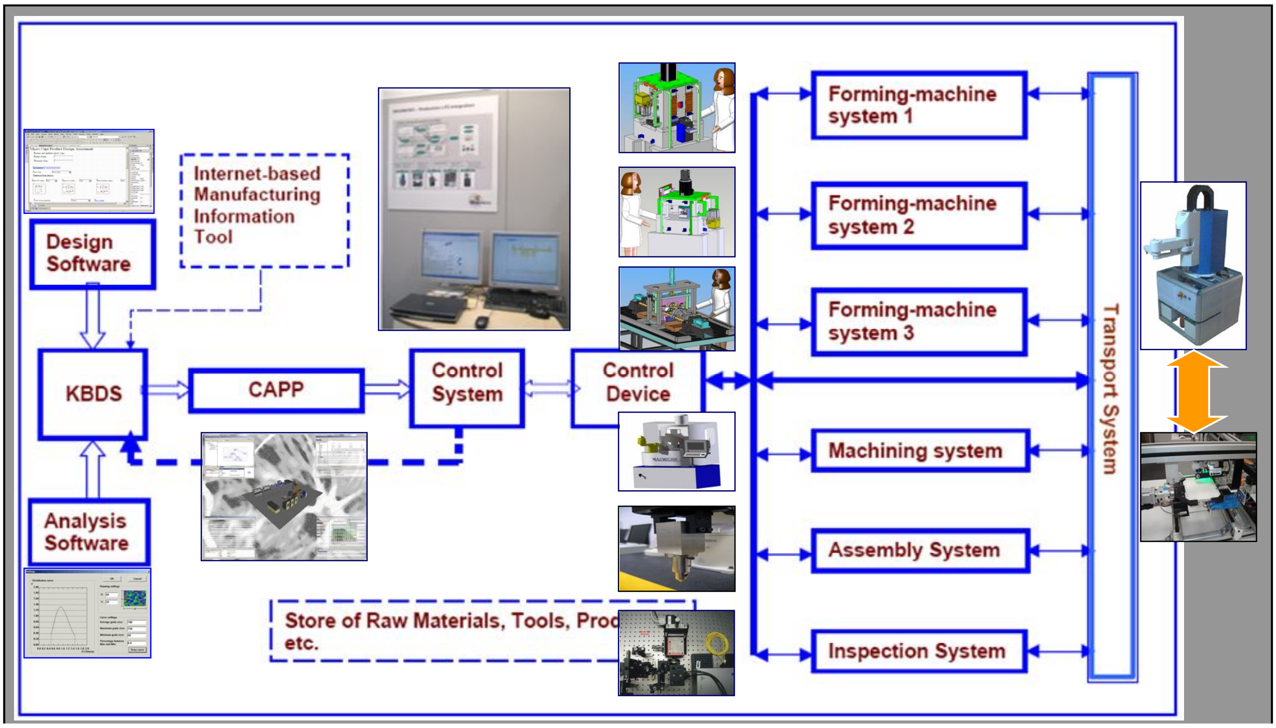

Fig. 2 Illustration of the MASMICRO Factory for Forming and Machining based Micro-Manufacturing

<u>The following are examples of the main achievements</u>:

Led by the Institute of Product Development (IPU) of Denmark, a miniature press and flexible tool system has been developed for the forming of micro-bulk-products (Fig. 3). This was the first EU attempt to mass-manufacture miniature/micro-components via micro-forming. The press is driven by a linear servo motor and is capable of fast and accurate motion. The tool-system enables eight different bulk-forming processes to be carried out by changing only small portions of tool-elements.

Precision of the tool-system is crucial due to narrow tolerances on the dimensions of the micro-components to be formed, which requires the manufacture of die-cavities within the sub-millimeters range in diameter and within a few microns in geometrical accuracy. The tool development has gained support from Pascoe Engineering, Scotland, Fraunhofer Institute Production System and Design Technology of Germany (IPK). The press and tool system have been successfully tested with the forming of two demonstration products selected by Pinol A/S of Denmark. An industry-version machine has been built at Pinol for the forming of a dental component. The targeted end-users/collaborators include Micro-manufacturing research and industrial manufacturers who wish to carry out micro-forming research and manufacture of miniature micro-metal-products for Electronics equipment, Micro-mechanical devices, Medical devices, MEMS, etc.

Fig. 3 The micro-bulk-forming machine developed

Fig. 4 The micro-sheet-forming machine system developed

A new micro-sheet-forming machine system (desk-top machine) has been developed at the University of Strathclyde, in collaboration with Pascoe Engineering of Scotland, Tekniker of Spain and other project partners. The machine is capable of a series of micro-sheet-forming processes for forming thin sheet-metal parts with thickness below 100 microns. The machine has capability of up to 800-1000 strokes per minute, force capacity of 5KN, and machine precision 2-5 microns, with modular and flexible set-up. The machine is equipped with a new, linear-motor driven, high-speed feeder, a novel part-carrying device, and force-displacement monitoring system. With the tool systems developed in collaboration with Pascoe Engineering Ltd., Gammastamp SpA of Italy, IPK of Germany, and Tekniker of Spain, different types of materials have been tested for demonstrators. The industry-version machine has been built at Tekniker, with support from Pascoe Engineering, University of Strathclyde, and CEDRAT Technologies S.A. of France. The machine will be ready for commercialisation in 2009. Targeted end-users/collaborators include micro-tubular components manufacturers and users in every sectors, and products such as MEMS, Micro-fluidic devices, micro-reactors, micro-casing, etc. The capability to produce tubular micro-components in such an innovative way may also change the way in which some micro-devices are designed, like micro-fluidic devices. The targeted end-users/collaborators include micro-manufacturing research and industrial manufacturers who wish to carry out micro-forming research and manufacture of miniature micro-sheet-metal products for Electronics equipment, Micro-mechanical devices, Medical devices, MEMS, etc.

The Institute of Production (IFP) of the University of Applied Science Cologne (ASC) leads the development of the 1st generation hydroforming machine for the forming of miniature/micro-tubular components. Hydorforming processes have been employed successfully in industry to produce mass products predominantly relating to lightweight automotive components. The mass-production of such components at present is, however, limited largely to the parts with cross-sections of above about 20mm in width. There was a lack of experience in the hydroforming of tubular, miniature/micro-parts. A machine system has been developed for forming of miniature tubes down to 0.8 mm with thickness down to 20 microns. To assist in the deformation of miniature tubes, a laser system for localized heating is incorporated into the forming process. The applications of the system will significantly extend micro-manufacturing capabilities, especially manufacture of hollow sectioned parts, such as that used in micro-housing, fluidic devices, light-weight structures in micro-mechanical devices, etc. which has not been achieved before. The approved manufacturing capabilities will also fundamentally change the way in which some micro-products/devices are currently designed.

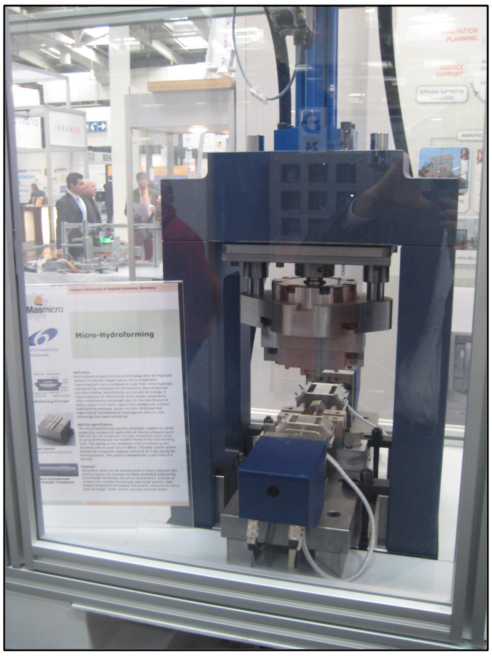

Fig. 5 The micro-hydroforming machine developed

A bench-top, multiple-axis machine tool capable of machining intricate 3D geometries in components with nano-scale tolerances has been developed, led by the Brunel University and Ultra-Precision Motion Ltd. of the UK. The associated series development includes an air bearing slideway and a rotary table with improved damping capacity (Patent Application: GB 0505798.9) and an ultra-high speed air bearing spindle (Loadpoint Ltd./Ultra-Precision Motion Ltd. of the UK), a piezo-driven fast tool servo system and Piezoelectric actuation unit for vibration assisted machining (CEDRAT Technologies S.A. of France), new micro diamond tools (Contour Fine Tooling Ltd of the UK), a robotic arm unit for micro-components/tools handling and management (Carinthian Tech Research AG of Austria) , and a tool and spindle condition monitoring system (University of Patras of Greece). The machine has already started performing commercial machining tasks for end-users. The targeted end-users/collaborators include Micro mould, micro fluidics manufacturers; optical, electronic and medical components manufacturers. Micro-manufacturing research institutes and industrial manufacturers who wish to carry out micromachining research or manufacture of 3D miniature components with high accuracy and mirror surface finishes on a range of engineering materials.

Fig. 6 The micro/nano-cutting machine tool developed

MASMICRO Manufacturing Execution System (MES) is developed by Fraunhofer Institute IPA, Germany, to facilitate the integration of the manufacturing facilities developed within

MASMICRO. It is consequently built upon the concept of a service oriented architecture and implements a number of additional measures to improve the agility of this class of systems, such as the integrated configuration management system covering all artifacts that determine the system's behaviour and the integration of real-time simulations to evaluate the configuration setup. In order to reduce the license costs for layered products, it makes heavy use of proven internet concepts and technologies and thereby reaches a high level of scalability. Altogether, the system facilitates the reduction of time and budget required to adjust an MES to the requirements of a specific production environment. The targeted end-users/collaborators include the system targeting towards highly automated production environments in the field of Micro- and Nanomanufacturing (e.g. flexible precision assembly lines, PV industry, micro-manufacturing platforms, etc.).

The mobile robot with a manipulator for micro-manufacturing system applications is another development by Robotnik of Spain for facilitating the systems integration. The system consists of a mobile platform and a robot arm. The platform can be controlled remotely via joystick or can work autonomously via laser sensor and beacons. It has also a laser range finder for obstacle avoidance. The robot arm is a 4 DOF Scara robot with a portable weight of up to 5 Kg and an accuracy of 0.01 mm. This robot arm can be upgraded with a camera to perform difficult tasks or improve the final accuracy. The whole system is powered by two 50 Ah batteries, and its final velocity is software restricted to 1 m/s. The targeted end-users/collaborators include the system developers needing to transport trays of micro-components, but it is also suitable for performing many different transport tasks, with the only requirement of the final payload (5 Kg). Any user of autonomous precise transport task can be a potential user of this system.

The customized laser system for micro-material processing is another commercially-ready result from MASMICRO (by Latronics of Germany). Software controlled modular laser system based on a 50 Watt CW-Ytterbium fiber-laser. Material processing like laser assisted Micro-forming (cf. facility 1) and further application of 3D-micro-material processing are performed with a spatial resolution of 10 µm. Furthermore, additional axes of rotation and translation can be implemented and are synchronized with the ‘master software’. In order to avoid thermal drift of the scanner an optical auto-calibration can be started at fixed time periods in order to achieve very accurate long term stability and reproducibility of the positioning of the focal point. These properties make the system suitable for accurate ‘non-stop’ processing of micro-components in an industrial production line. The targeted end-users/collaborators include industrial manufacturers from the automotive- , electro-mechanical and semiconductor-industry, universities, research institutes, etc.

Fast tool servo SPT400MML (developed by Cedrat Technologies SA of France) is also ready for commercialization. It uses the patented Amplified Piezo Actuator from CEDRAT to get a fast motion of a diamond tool to machine free forms. It includes an eddy current proximity sensor to increase the accuracy of the actuator. It is driven by a standard LA75C drive and is controlled with the real time UC75 platform. The closed loop is performed at high sampling rate and realizes the following tasks: closed loop between the SPT and the proximity sensor, and monitoring of the different variables of the SPT. The SPT400MML is compatible with specific diamond tools from Contour Fine Tooling Ltd. with light shank of 6.35mm square cross section. The preliminaries performances are: Stroke up to 400µm, bandwidth up to 450Hz with a first resonant frequency above 600Hz, force capability up to 10N. The targeted end-users/collaborators include industrial manufacturers in Machining of oval pistons, moulds, non circular optics, non spherical lens, and assistance in machining of hard materials in general.

An inter-machine material handling system for handling micro-parts and for manufacturing integration is developed by Polytechnic University of Valencia of Spain, for which a conveyor belt system able to fit into a linear pick-and-place micro-manufacturing plant, was developed. The system is composed of a central controller and several modules. Each module contains a programmable logic controller (PLC), some cassettes, conveyor segments, transfer units and handling devices. The micro-part sorting machine is another main part of this handling system. The machine is able to arrange the micro-parts into the cells of the standard carrier. An empty carrier is fixed on an X-Y table. It moves the carrier under a micro-part feeder subsystem to ensure to accurately position the carrier/cells. To control the micro-parts flow, the feeding system is incorporated with a vibration principle and a vision feedback mechanism. The targeted end-users/collaborators include micro-components manufacturers and users. The feeding capability developed is also useful for micro-parts inspection and assembly.

An inspection system has been developed for micro-scale inspection of rotary micro-parts by Carinthian Tech Research AG of Austria. With the system geometric and surface features can be evaluated with a resolution of 5 µm. The parts are rotated under a line-scan camera. The acquired images are analysed with specific pattern recognition algorithms. The previously trained geometric features are compared with allowable geometric tolerances. The user receives a detailed file of inspected data and feature errors if occurred. The targeted end-users/collaborators include manufacturers of micro-rotational-parts and manufacturing equipment developers, e.g. for medical implants – Stents.

Another inspection system is the “Optical Coherence Tomography (OCT) system”, developed by Upper Austrian Research GmbH. It is developed as a contactless and non-destructive investigation tool of structures at the micron scales. 3D data from the interior of materials and micro-products can be acquired, as well as surface topographies. The acquisition time for an image with the size of one megapixel is only 36 ms. The system can be used as a module for the stent inspection system, in order to measure the thickness of coating layers on medical stents, or be operated as stand-alone system for microstructure investigations. The targeted end-users/collaborators include all end-users interested in the internal structure (also layer thickness) and surface profile of their materials and products.

A series of In-situ micro-material testing procedures and nano-manipulation set-ups to nano-accuracy for the testing micro/nano-materials within SEM have been developed at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) and has served for the project research, which has increased the capability and flexibility of the testing of miniature/micro/nano materials with SEM. The development has given the project an enabling technology and device to test the materials at smaller scales with high accuracy which had not been achieved before. One of the advantages is the capability to capture micro/nano-materials fracture and collapse (subject to the upsetting/compression) development processes during “In-situ Manufacturing”.

Other developments which can be immediately taken up by end-users include: micro- and nano-materials developed by BPE International and Swedish Institute for Fibre and Polymer Research respectively; Surface coating techniques for micro-tools developed by Centro de Ingenieria Avanzada de Superficies; Laser-assisted micro-stamping and roll-to-roll micro-hot-embossing technique and tool designs developed respectively by Fraunhofer Institute Laser Technology; New micro-EDM techniques developed by Fraunhofer Institute Production System and Design Technology; Micro- and precision-machinery testing algorithm and software system by MASMEC s.r.l. etc.

In summary, the MASMICRO consortium has achieved its objectives set in the beginning of the project.

There have been 3 spin-offs created, 3 patents awarded, 5 patent and 1 trade-mark applications made, and 3 patent applications planned. MASMICRO has made significant impact at the EU level and internationally, through a series of activities of dissemination and exploitation, including: more than 130 publications, involvement of more than 20 exhibitions, 19 press releases, and 12 media briefing; presentation at more than 72 conferences/ workshops; and many posters, web-sites, flyers, booklets, directly mailing, etc. The MASMICRO consortium had very successful demonstration days at the Hanover Fair, April 2008, during which major project results were on show. Some potentially interested organisations or individuals had met the project's partners at this event to discuss possible collaboration in exploiting project results and formulating ideas for establishing new projects and/or new business. Some of the project results have already been introduced to production/business by industrial partners. Negotiations on further exploitation/commercialisation with external collaborators on several results have started. Several new projects which involve the MASMICRO partners as the key participants have also been awarded.

Fig. 7 MASMICRO at Hannover Messe, April 2008

A registration form for individuals and/or organisations interested in the project results or collaborations with the consortium is provided at the project web-site (http://www.masmicro.net). The consortium has produced a booklet which lists major manufacturing facilities developed. For obtaining the booklet, please contact the project co-ordinator.

Contacts: contacts of all partners are available from the project web-site, in "Partners Profiles". For general enquiry on the exploitation and collaboration contact:

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