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Newsletter

POLYTUBES

Polymer micro-tubes & tubular micro-components

POLYTUBES PROJECT

The overall objective of the POLYTUBES project is to develop a process chain and corresponding micro-manufacturing platform for the manufacture of polymeric micro-tubes and tubular micro-components for medical and non-medical applications. The proposed development aims to create a new market for EU SMEs with innovative and economically competitive micro-products and micro-manufacturing facilities to meet the needs for a wide range of emerging applications. The development will also support the SMEs to increase business opportunities with new volume production capabilities in micro-manufacturing. The proposed development could place EU in a pole position in the manufacture and innovative applications of tubular micro-products.

Hot embossing of polymeric micro-tubes

Precision Engineering and Micro-Manufacturing Research Group (PEMMRG) at the University of Strathclyde, UK

The PEMMRG has been involved in EU funded research for more than 20 years, including overall co-ordination of the EU FP6 flagship project MASMICRO ("Integration of Manufacturing Systems for the Mass Manufacture of Miniature/Micro-Products"). The group researches and develops processes, tools, machinery and numerical modelling techniques for improving economic and technical performances of material conversion technologies (precision manufacture at macro-, meso-, micro- and nano-length scales). The group's roles in the POLYTUBES project include "Technical co-ordination of the project", "Development of a new medical instrument for patch-clamp" and "Development of a process and the machine for hot-embossing of polymeric micro-tubes". To-date, a mass-producible process has been qualified and a novel, miniature, desktop hot-embossing machine and forming tools have been developed.

Needs of Shaping Micro-Tubes

As the trend of miniaturisation of various products, devices and equipment continues, demands on the complex micro-components increase significantly.

The emerging needs include tubular micro-components (diameter < 1.0mm), such as that used in micro-medical-devices, micro-fluidic-devices and heat-management systems.However, shaping micro-tubes cannot be achieved simply by scaling down a large scale process and equipment to the micro-scale, due to many size-factors relating to the material, process, tool and machine to be considered. To address this issue, specific micro-shaping technologies, which are able to convert small tubes and thin sections into the required functional structures, and corresponding machine systems, which would enable a mass-production capability, will have to be developed. The hot-embossing process and the machine are one of the developments within the POLYTUBES project for the shaping of micro-tubes. Other developments include Laser-Drilling/Trimming, Blow Forming and Cross-Rolling of micro-tubes and the manufacturing platform.

The Hot Embossing Process

As a fabrication technique for creating micro-structures at the surfaces, hot-embossing often uses mould inserts for the forming/shaping of polymeric parts, which is similar to other replication techniques such as injection moulding and extrusion. Comparing to other processes, hot-embossing has merits of less system-complexity, shorter production cycle-time, lower processing temperature, etc. Nevertheless, the hot embossing process is often used for the moulding on the plain surfaces such as polymeric sheets and thin films or foils, to produce, mostly, 2.5D features. Hot-embossing of polymeric micro-tubes is to form 3D features (both outer and inner features), which requires more dedicated tool-design and process control, including considerations on the stiffness of tubular structures. Controlling of the formation of inner features is still of challenges, e.g. requiring more accurate definition of the process windows (related to the parameters such as material properties, temperature, holding time, pressure and handling of the tube/component).

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Materials

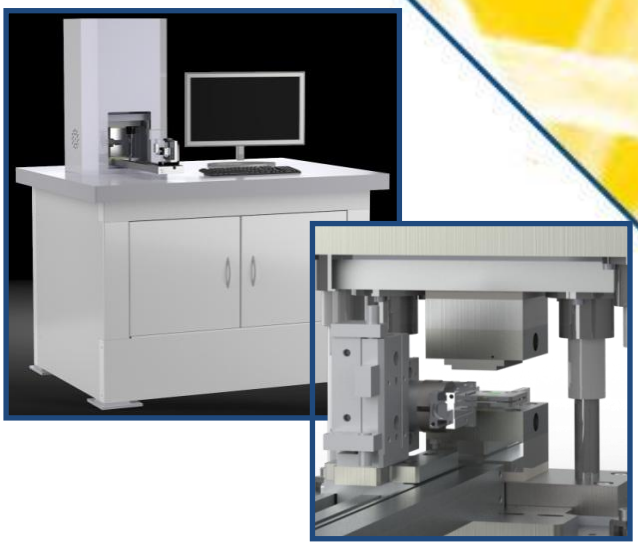
A comprehensive review on materials was conducted in order to select appropriate materials for the hot-embossing process and applications (especially applications in the patch-clamp device). A series of material tests have been carried out to determine micro-tubes' mechanical properties, which generates the data required for process design and simulations. The variables and conditions considered in these tests included: (i). type of the material; (ii). outer diameter – inner diameter ratio of the tubes; (iii). deformation rate; and (iv). working temperature.

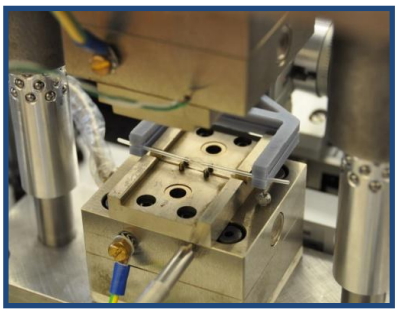
Tools

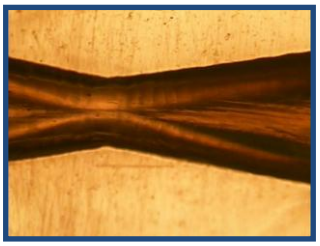
To enable high-quality hot-embossing of polymeric micro-tubes, tools are designed and constructed to enable: modular insertion of the core dies; precision guiding of the micro-tube inside the dies; heating and cooling units with a temperature control system; heat-insulation for an improved heating-efficiency; precise alignment of the upper and lower die-sets, etc. The tool design also took the requirement for automated handling into account.

The Hot-Embossing Machine

The hot-embossing machine is a miniature desktop machine which integrates a linear press, forming dies and tool components with heating and cooling units, precision guides and machine frames, and an automated micro-tube handling system. To ensure a fully automated operation, a multi-axis micro-tube handling system has been developed as an automatic raw-material feeding and component pick-up device to serve the hot-embossing machine. The machine and process parameters such as press force, travel speed and distance, temperature as well as holding time can be easily changed with a software interface developed within the project. In summary, the system has following features: integrated force, position and signal control; maximum force 3 KN; smallest force measuring 0.83 N; maximum stroke 100 mm; distance resolution: 0.049 µm; working temperature up to 500°C; 4 axis micro-tube handling unit; and a selection of the interface to PC.







Through a series of fine-tuning, the hot-embossing machine can now be fully automated and the results showed very good reliability and repeatability, hence, the process can be used for the mass-production of polymeric, tubular micro-components. The micro-tube handling system is also proved to work well and well synchronized with the press machine. Besides, very good material flow on the formed tubes was observed, especially when the working temperature is set up properly. It is showed that the shaping process and quality are influenced by the temperature, forming force and holding time significantly. More tests are being conducted to refine the process and the machine design in order to improve manufacturing efficiency and product quality. The machine is to be integrated into the manufacture platform being developed within the project. The aim is to integrate all processes/machines developed into a single platform for the manufacture of polymeric, tubular micro-components.

Other Applications

The low-cost machine system developed has potentials for a wide range of other applications, e.g. surface texturing on polymeric thin-films, glass, metals, composites, for the applications such as optical devices, micro-fluidic devices, etc.

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