

CHAPTER 1

INTRODUCTION

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Microsystems technology is gaining more and more interest in the scientific and industrial communities. Recently published articles concerning possible future applications of micro technologies predict a big commercial impact on nearly all branches of industry.

Generally, given the multiple fields of applications of microsystems, it is quite difficult to obtain a straightforward definition of such a system. Perhaps the simplest way is to define the field with respect to the dimensions of the system components as shown in Fig. 1, where the scale of objects is represented in meters. Thus, a microsystem can be defined as a device that is characterised by a microstructure where the geometry size of at least one functional component is below 100 μm and where this component produces physical/chemical effects that cannot be achieved, without loss of performance, if the critical dimensions are significantly higher than 100 μm without loss of performance.

The main users of microsystems are industries in the field of microelectronics, chemical, pharmaceutical, and medical technology, included the automotive and aerospace companies. Typical microdevices are cardiac pacemakers, pressure sensors, accelerometers, inkjet heads, components for telecommunications and components for microelectronics. Generally, these components are characterised by reduced dimensions and increasing power generation. Therefore, the need to transfer high heat fluxes in relatively small surfaces and volumes brings new challenges in heat removal and cooling techniques.

In the present context, a new generation of micro thermal devices are developed and are gaining importance. These micro thermal devices range from compact heat exchangers for air conditioning and refrigeration systems, to cooling elements for electronic components, portable telephones and computers, and aerospace avionics. Heat removal enhancement is obtained through the increase of heat transfer coefficient and of the heat exchange surface with decreasing channel hydraulic diameter. In particular, the hydraulic diameter in these micro thermal devices ranges from 1 μm up to 2 mm, significantly smaller than macroscale channels that are on the order of 5.0 to 50 mm.

Generally, the classical thermal and fluid dynamic theories developed for “macro systems” are not applicable to fluids in microscale structures. Thermo-fluid-dynamic phenomena that are generally not noticeable in macro systems, may play a dominant role in microsystems with the consequence that a lot of open questions exist and the few experimental results available in literature reveal that there are still important differences in the conclusions. Therefore, conventional macroscale methods are generally not satisfactory for thermal design of micro thermal devices in single-phase and two-phase flows.

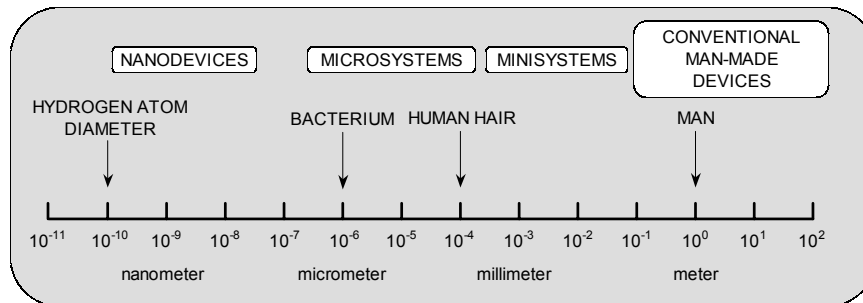


Figure 1.1 Given the multiple fields of applications of microsystems, it is quite difficult to obtain a straightforward definition. Maybe the simplest way is to define the field with respect to the dimensions of the components.

The purpose of Section 2.13 of HEDH is to provide a comprehensive overview of recent research results of fluid dynamics and heat transfer in single-phase and two-phase flow in microchannels and confined geometries. The presentation is divided into sections dedicated to different aspects of fluid flow and heat transfer in microgeometries. Thus, Section 2.13.2 reviews the results of single phase fluid flow of liquid and gases in microchannels. Disagreements reported in literature on deviations from classical theory are discussed and analysed. Section 2.13.3 is a summary of single phase convective heat transfer in laminar and turbulent flow.

Sections 2.13.4 to 2.13.6 and 2.13.8 deal with microchannel systems in which the flow is two-phase in nature. Section 2.13.4 introduces the research on boiling and evaporation in microgeometries. The topics covered include flow patterns observations, flow boiling heat transfer and the description of heat transfer model developed for microgeometries. Section 2.13.5 is dedicated to the researches on multiphase flow in microchannels. Multiphase flow regimes, flow pattern maps, and pattern transitions are presented and their deviations from those observed macro systems are discussed. Section 2.13.6 is a summary of research trends in condensation in microchannels. Flow pattern maps, heat transfer correlations are presented. Section 2.13.8 deals with micro heat pipes and their applications. The section contains a review of recent research results on micro heat pipes including pulsating heat pipes.

At the very small scale, channel dimensions approach molecular dimensions and the fluid can no longer be treated using the classical continuum mechanics approaches. In this situation modelling of the detailed molecular motions (“molecular dynamics”) becomes an important tool. Section 2.13.7 introduces molecular dynamics and its applications.