

SUMMARY FOR GENERAL PUBLIC

Today electronic nanosystems are commonly encountered in almost all domains of everyday life including home appliances, automotive technology, environmental pollution monitoring, medical diagnostics or cancer therapy. Because of extremely small dimensions of such structures, heat generation and transport phenomena influence their operation to a larger extent than in typical microstructures. Therefore, the analysis of thermal processes and the precise determination of temperature and its influence on thermal stresses is crucial for nanosystem designers.

For almost 200 years thermal processes occurring in solids have been commonly modelled with a differential equation which was derived based on the Fourier heat conduction law stating that the heat flux is directly proportional to the temperature gradient, hence implying that the heat propagation speed is infinite. Although this assumption contradicts basic laws of physics, it renders possible accurate computations of temperature, especially away from heat sources and for large analysis times.

Unfortunately, in the case of heat transfer mathematical modeling, similarly as in other scientific domains, the standard equations describing physical phenomena are not applicable to analyses of nanosized structures and extremely rapid processes. Thus, taking into account that state-of-the-art electronic systems are often just a few atomic layers thick and that transistors operating at gigahertz frequencies are several thousand times thinner than human hair, the application of classic heat transfer theory for modelling of thermal processes in such structures might lead to significant simulation errors.

The most appropriate approach to the modelling of thermal phenomena at nanoscale would be the application of microscopic physical models allowing the computation of temperature value at the atomic level, however due to their computational complexity and long simulation time such models can be used only for analyses of individual structures and devices. Thus, there is an urgent need to develop new mathematical models for simulation of thermal processes at nanoscale.

Thus, the main goal of this project will be to demonstrate the existence of non-Fourier heat conduction phenomena in electronic nanosystems and the development for their description of adequate mathematical models employing a differential equation based on the modified Fourier law. Owing to this approach, it will be possible to take into account the most critical microscopic phenomena. This project will result in the development of three-dimensional thermal simulators allowing accurate computations of temperature field in electronic nanosystems. Additionally, the theoretical research will allow the precise determination of links between the parameters of the hereby proposed model and the parameters of microscopic models currently used for nanoscale temperature computation.

The mathematical thermal models developed within this project will be validated experimentally by dynamic temperature measurements of dedicated Nano-Electro-Mechanical Systems (NEMS) manufactured explicitly to test heat conduction processes at nanoscale as well as electronic integrated circuits containing non-planar FinFET transistors. The experimental validation of developed models will entail temperature measurement taken with nanometer precision and nanosecond time resolution. This will be accomplished owing to special microscopic measurement techniques which are currently being developed within the EU 7 FP NANOHEAT project.

The research proposed within this project will have important impact on the design of modern electronic nanosystems where the possibility of accurate determination of their temperature is crucial for the operation of the entire system. Except for the development of novel mathematical models describing the heat diffusion processes in electronic nanostructures, the project is aimed also at the demonstration of the existence in such structures of physical phenomena which are not observed in macroscale. The proposed approach will render possible thermal simulations of complex electronic microsystems with thermal models taking into account the most important microscopic phenomena. The practical application of theoretical and experimental results will allow not only substantial reduction of simulation time but also it will increase reliability and render possible further optimization of such systems.