ABSTRACT

The thermal performance of the micro heat pipe can be significantly enhanced by integrating it with the electronic component itself, leading to *on-chip micro heat pipes*, which are compact yet efficient. The objectives of the present dissertation are the design and fabrication of on-chip micro heat pipes using microchannels etched on the unused side of the semiconductor devices, followed by their characterization and performance analysis.

Microchannels of different shapes and orientation are etched on double sided polished silicon wafer using standard lithography process (both wet etching and reactive ion etching) with masks designed specifically in AutoCAD 2007 and developed within a precision of 1 μm. Heat shock resistant Pyrex 7740 glass is used to cover the top of the micro channels with specially made ports for vacuum connection and coolant entry. The system is evacuated to a pressure of less than 6 mTorr for a period of 24 hours and then charged with a small amount (0.3 ml) of de-ionized water followed by thermal sealing to form the on-chip micro heat pipe. Additionally, the grooves and surfaces are characterized using atomic force and scanning electron microscopy.

In the microscopic analysis of spreading and cooling, a heat transfer cell is specifically designed and the shapes of the liquid menisci in the V-shaped microgrooves are accurately measured using image analyzing interferometry as functions of heat input. The relevant parameters e.g., the adsorbed film thickness, contact angle and curvature at the thicker end of the meniscus are accurately measured and used to explain the physics of the process. The temperature profiles are measured for the microgrooved and non-grooved silicon substrates under identical conditions of heat input and inclination. The axially averaged values of a dimensionless temperature are used to quantify the enhanced cooling and temperature homogenization potentials of microgrooved surfaces.

The performance and the cooling potential of the on-chip micro heat pipes are quantified by accurately measuring the temperature distributions along the channel length. The capillary suction capability of the fabricated micro heat pipe is evaluated by a mathematical model taking into account the capillary pressure driven flow in an evaporating curved microfilm as functions of temperature profile, groove geometry, thermo-physical properties, and contact angle. The numerical solutions of the governing equations provide additional insights into the complex process of flow and enhanced heat transfer in a micro heat pipe. The results establish that the fabricated on-chip micro heat pipes are efficient heat spreaders and are operating within the capillary limit without the occurrence of dry-out. The average effective thermal conductivity is calculated to be 7624 W/m.K for the present range of heat input

Keyword: Microfabrication, Microchannel, Film thickness, Spreading, Contact angle, Phase change, Cooling, Micro heat pipe, Microfluidics