# Enhancement of heat dissipation in an electronic chip cooling system using graphite fins

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## Abstract

As electronic devices get smaller, cooling systems with higher thermal efficiency is demanding by fast growing electronic industry. Great amount of research has been performed on the cooling systems but research on the materials of the cooling systems needs more work. Graphite with high thermal conductivity and light weight is a great candidate to be used in electronic devices. The bottleneck of using graphene in the cooling systems is the thermal transport among the interface from the substrate to the graphene fin system. In this research finite element simulation of graphite fin cooling system has been investigated to study the effect of different applied pressure on the cooling system performance. Study of this cooling system showed good improvement in comparison with common copper fin cooling systems.

## Introduction:

As the electronic devices shrink in size, cooling of the devices is more challenging and designing higher efficiency cooling systems is a must for the contemporary electronic devices(Lee and Chakrabarty; Mahabadipour and Ghaebi; Sabarou, Huang and Zhong). Various methods have been investigated by other researchers to improve cooling systems performance (Vasquez and Rastkar; Sahu, Joshi and Fedorov; Alfieri et al.; Dembla, Zhang and Bakir). Since the electronic industries (e.g. cell phone and laptop computer) demanding smaller size and lower power consumption, more fundamental research is required to improve the cooling systems from material engineering point of view alongside redesigning the available cooling systems(Gupta et al.; Sabarou and Zhong). Recently, researchers have focused on using different composite fins in electronic cooling systems to increase the heat dissipation characteristics of the cooling systems (Ellis and McDanels; Gerzeski et al.; Frazier et al.; Behfar, Ghiasvand and Yazdankhah; Putra and Septiadi; Mahabadipour and Ghaebi). The bottleneck of the graphite fin system is the thermal transport from the interface between the substrate and fins. Recently many research have been performed to improve and study the interfacial thermal transport.

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Applying pressure to the interface is one of the most common methods of improving thermal transport in chip cooling systems(Reddy et al.; Nobakht, Shahsavan and Paykani).

In this paper, we have investigated graphite find performance on a sample electronic chip cooling system to improve the heat dissipation rate of a sample cooling system. We have employed finite element simulations to perform the numerical modeling in our simulations.

## Simulation method:

We have considered a 10×20 mm graphite cooling system of an electronic chip (Figure 1) with heat flux of 250 W $cm^{-2}$ (Sahu, Joshi and Fedorov) on silicon paste. We used home developed finite element code to simulate heat transfer in the considered cooling system. The fin cooling is considered to be force convection of 3000 $Wm^{-2}$ (Alimohammadi et al.).

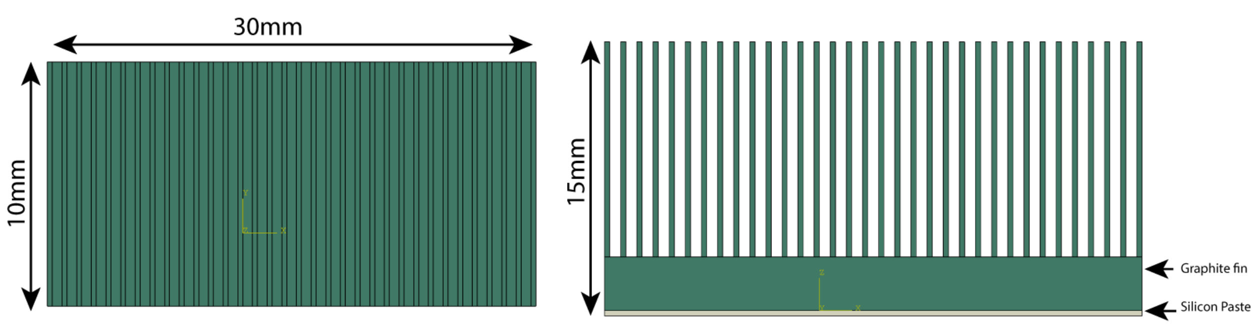


Figure1: cooling system schematic

The simulation is repeated for different interface pressure for the cooling system and interfacial thermal resistance value is considered an average value obtained from the available research in literature (Carlborg, Shiomi and Maruyama; Zhang; Ali and Seungha; Yousefzadi Nobakht and Shin *Pressure Effects on in-Plane and Cross-Plane Thermal Transport within Graphene Heterostructures;* Yousefzadi Nobakht and Shin *Control of Thermal Transport in Graphene/Si Heterostructures*). We used hexagonal mesh to improve model stability (Shaw et al.; Liu et al.; Diwan and Mahajan) the mesh was generated using G-Mesh (Geuzaine and Remacle) in a steady states simulation system. For the first few simulations we performed mesh size convergence test and after reaching a stable output for our simulation code, we used the same mesh size for all our simulations.

We used different pressures to evaluate the working temperature of the electronic chip in the different cooling system operational conditions.

The simulation model is a steady state thermal transport with constant heat flux in from the chip to the silicon layer and constant convective thermal transport from chip system to the ambient air.

**Results and discussions:**

Figure 2 shows a sample temperature profile of the simulation results. The resulted temperature is almost 17% lower than previous copper fin designs (Reddy et al.). Using graphite fins created higher efficiency fins and resulted in lower working temperature for the cooling system.

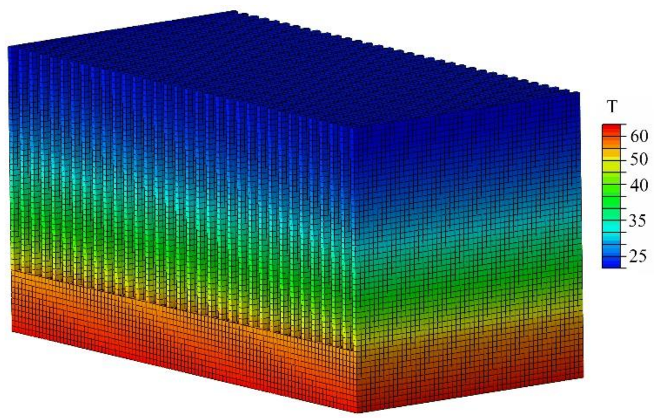


Figure2: cooling system temperature profile

The resulted working temperature for different applied pressure on the cooling system is illustrated in Figure 3. It can be seen that the efficiency of the cooling is enhancing dramatically as the applied pressure on the cooling system increases.

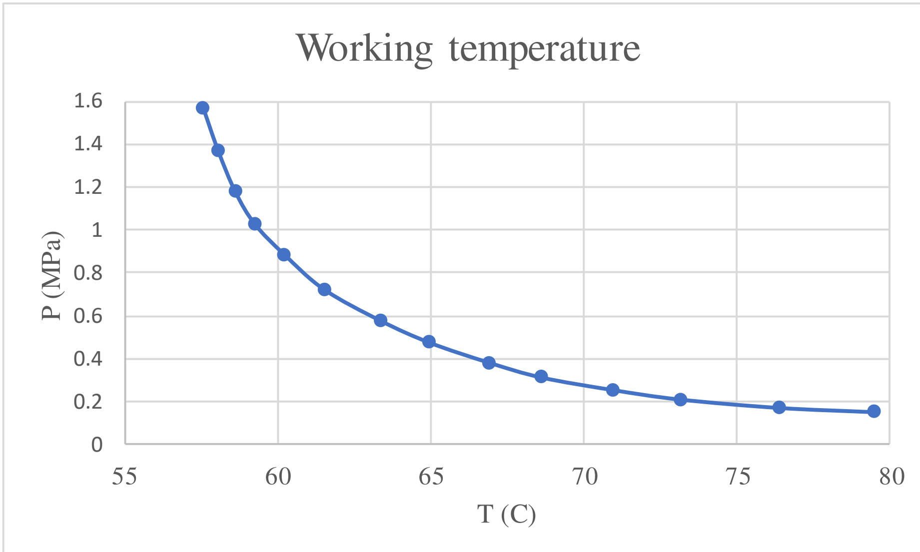


Fig 3. Working temperature of the chip with respect to different applied pressures to the cooling system interface

Figure 4 compares the graphite fins working temperature with previous research (Reddy et al.). It can be seen that the graphite fins are more effective in cooling systems.

## Conclusions:

Numerical simulation of graphite fins is investigated in this research. Different working conditions was simulated with different pressure applied to the cooling system. This research shows that using graphite fins can improve the cooling system efficiency in a dramatic way and enhance the working temperature of the electronic devices and yield in lower energy consumption and longer electronic devices life. The proposed cooling system can be used in the contemporary cooling systems in new electronic devices.

## References:


Alfieri, Fabio, et al. "Computational Modeling of Hot-Spot Identification and Control in 3-D Stacked Chips with Integrated Cooling." *Numerical Heat Transfer, Part A: Applications* 65.3 (2014): 201-15. Print.

Ali, Yousefzadi Nobakht, and Shin Seungha. "Anisotropic Control of Thermal Transport in Graphene/Si Heterostructures." *Journal of Applied Physics* 120.22 (2016): 225111. Print.

Alimohammadi, Mahdieh, et al. "Experimental Investigation of the Effects of Using Nano/Phase Change Materials (Npcm) as Coolant of Electronic Chipsets, under Free and Forced Convection." *Applied Thermal Engineering* 111 (2017): 271-79. Print.

Behfar, Mina, Ali Reza Ghiasvand, and Fatemeh Yazdankhah. "Reinforced Microextraction of Polycyclic Aromatic Hydrocarbons from Polluted Soil Samples Using an in-Needle Coated Fiber with Polypyrrole/Graphene Oxide Nanocomposite." *Journal of Separation Science* (2017). Print.

Carlborg, C. F., J. Shiomi, and S. Maruyama. "Thermal Boundary Resistance between Single-Walled Carbon Nanotubes and Surrounding Matrices." *Thermal boundary resistance between single-walled carbon nanotubes and surrounding matrices* (2008). Print.

*Fine Pitch Tsv Integration in Silicon Micropin-Fin Heat Sinks for 3d Ics*. Interconnect Technology Conference (IITC), 2012 IEEE International. 2012. IEEE. Print.

Diwan, Anukul Gautam, and Yogesh Shankar Mahajan. "Study of the Effect of Various Parameters on the Result of Stress Analysis Obtained Using Tetrahedral and Hexahedral Mesh Elements." *Journal of the Chinese Institute of Engineers* 40.2 (2017): 101-09. Print.

Ellis, David L, and David L McDanels. "Thermal Conductivity and Thermal Expansion of Graphite Fiber-Reinforced Copper Matrix Composites." *Metallurgical Transactions A* 24.1 (1993): 43-52. Print.

Frazier, Rachel M, et al. "Recent Progress in Graphene-Related Nanotechnologies." *Recent patents on nanotechnology* 3.3 (2009): 164-76. Print.

Gerzeski, Roger H, et al. "Growth of Contiguous Graphite Fins from Thermally Conductive Graphite Fibers." *Carbon* 69 (2014): 424-36. Print.

Geuzaine, Christophe, and Jean-François Remacle. "Gmsh: A 3-D Finite Element Mesh Generator with Built-in Pre-and Post-Processing Facilities." *International Journal for Numerical Methods in Engineering* 79.11 (2009): 1309-31. Print.

Gupta, Sapna, et al. "Phase Evolution and Electrochemical Performance of Iron Doped Lanthanum Strontium Chromite in Oxidizing and Reducing Atmosphere." *International Journal of Hydrogen Energy* 42.9 (2017): 6262-71. Print.

Lee, Hsien-Hsin S, and Krishnendu Chakrabarty. "Test Challenges for 3d Integrated Circuits." *IEEE Design & Test of Computers* 26.5 (2009). Print.

Liu, Celong, et al. "Distributed Poly-Square Mapping for Large-Scale Semi-Structured Quad Mesh Generation." *Computer-Aided Design* (2017). Print.

Mahabadipour, H, and H Ghaebi. "Development and Comparison of Two Expander Cycles Used in Refrigeration System of Olefin Plant Based on Exergy Analysis." *Applied Thermal Engineering* 50.1 (2013): 771-80. Print.

Nobakht, A. Y., M. Shahsavan, and A. Paykani. "Numerical Study of Diodicity Mechanism in Different Tesla-Type Microvalves." *Journal of Applied Research and Technology* 11.6 (2013): 876-85. Print.

Putra, Nandy, and Wayan Nata Septiadi. "Improvement of Heat Pipe Performance through Integration of a Coral Biomaterial Wick Structure into the Heat Pipe of a Cpu Cooling System." *Heat and Mass Transfer* 53.4 (2017): 1163-74. Print.

Reddy, Sohail R, et al. "Multi-Objective Optimization of Micro Pin-Fin Arrays for Cooling of High Heat Flux Electronics with a Hot Spot." *Heat Transfer Engineering* 38.14-15 (2017): 1235-46. Print.

Sabarou, Hooman, Dehua Huang, and Yu Zhong. "Thermodynamic Investigation on the Pmn-Pt Stoichiometry Change During Thermocycling." *Ceramics International* (2017). Print.

Sabarou, Hooman, and Yu Zhong. "Investigation on the Phase Stability of Perovskite in La-Sr-Cr-Fe-O System." *Advances in Solid Oxide Fuel Cells and Electronic Ceramics II: Ceramic Engineering and Science Proceedings Volume 37, Issue 3* (2017): 127-35. Print.

*Experimental Investigation of Hotspot Removal Using Superlattice Cooler*. Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), 2010 12th IEEE Intersociety Conference on. 2010. IEEE. Print.

Shaw, James, et al. "A Multidimensional Method-of-Lines Transport Scheme for Atmospheric Flows over Steep Terrain Using Arbitrary Meshes." *arXiv preprint arXiv:1702.00233* (2017). Print.

Vasquez, Genesis, and Siavash Rastkar. "Thermo-Fluid-Stress-Deformation Analysis of Two-Layer Microchannels for Cooling Chips with Hot Spots." Print.

*Control of Thermal Transport in Graphene/Si Heterostructures*. ASME 2017 INTERPACK® Packaging and Integration of Electronic and Photonic Microsystems. 2017. ASME. Print.

*Pressure Effects on in-Plane and Cross-Plane Thermal Transport within Graphene Heterostructures*. ASME 2016 SHTC Summer Heat Transfer Conference. 2016. Print.

Zhang, Jingchao. "Thermal Transport across Graphene and Single Layer Hexagonal Boron Nitride." *Thermal transport across graphene and single layer hexagonal boron nitride*. Print.