

Natural and Forced Convective Heat Transfer Analysis of Nanostructured Surface

A. Khabari, M. Zenouzi, T. O'Connor and A. Rodas

Abstract—As the number of transistors increases for desperately needed faster processing in integrated circuits, the need to remove heat effectively in small devices is crucial as the physical sizes of electronic devices shrink. This work uses nanoparticle depositions on heat sinks and investigates the heat transfer and device temperature for both natural and forced convections. The results show that there is a detectable variance in heat transfer (about 6%) causing device temperature drop between conventional heat sink and nanostructured surface heat sink with the same physical size using natural convection. As the free air velocity (forced convection) increases, the difference becomes negligible.

Index Terms — Convective Heat Transfer, Heat Sink, Nanoparticles, Nanostructured Surface.

I. INTRODUCTION

EXTENSIVE research has been done on convective heat transfer in nanofluids in last few years [1-4]. However, little work has been done to improve heat transfer of passive heat exchangers (heat sinks) without increasing their physical sizes using nanoparticles. The conventional method of improving the heat transfer is to increase the surface area or by improving the heat transfer coefficient. However, in this work, instead of increasing the physical size, the surface area was increased at molecular levels by depositing copper nanoparticles on the heat sink surface. Nanoparticles are known to have a very high surface area. Research on nanoscale heat and for energy conversion has also shown promising results [5-6]. In this work Nanoparticles are generated in a differential pressure vacuum system. As shown in Figure 1, the nanoparticles are generated in a nucleation chamber by means of aggregation using a three-inch sputtering source at one-Torr of pressure. The nucleation chamber is cooled by applying Liquid Nitrogen into a jacket around the chamber. The nanoparticles are ejected from a converging-diverging nozzle to form a beam of nanoparticles. The beam enters the gas-separation chamber with a pressure of 1 mTorr. Due to their enormous kinetic energy, nanoparticles follow a straight line and enter the deposition chamber through a 0.5cm orifice as other gas molecules and atoms such as Argon used for sputtering are pumped out by a cryopump. This nanoparticle beam is used to target a heat sink in the deposition chamber with a pressure of 10^{-6} Torr. This process is explained in detail in other publications [7-8].

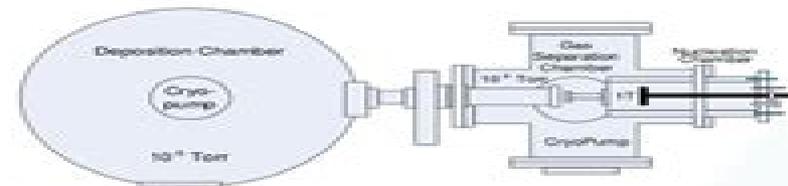


Fig 1: Nanoparticle Deposition System

II. EXPERIMENTAL

The black anodized (aluminum oxide) top surface of the heat sink was removed and polished below nanometer roughness range. To confirm the surface roughness of polished heat sink, the surface of the heat sink was analyzed using an Atomic Force Microscope -AFM (Figure 2). The surface roughness of the polished heat sink is well below nanometer range. Different spots of the polished heat sink were scanned and all confirmed that the surface roughness is below a nanometer range. Copper nanoparticles were deposited on the polished surface. After deposition, the surface of the heat sink was analyzed by an AFM again to find how the heat sink surface was altered after nanoparticle deposition. Figure 3 shows the mean roughness range is about 50 nanometer with a considerable increase in the surface area.

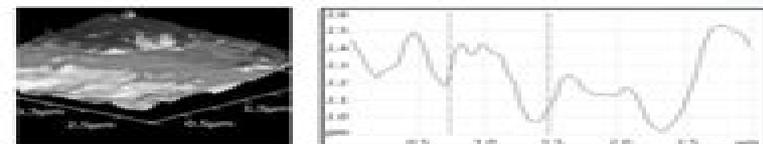


Fig 2: AFM Image of Polished Heat Sink

Figure 4 shows the photo of the heat sink. All dimensions are given in millimeters. The nanoparticles were deposited onto the top surface of the heat sink, and a transistor was mounted on it.

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