Hydrogen bonding enhanced thermally conductive carbon nano grease for enhanced CPU performance

C. Bailey, T. Grablander, D. Lou, G. Christensen, H. Younes, H. Hong

Novum Nano, 525 University Loop, Rapid City, SD 57701:
craig.bailey@novumnano.com
greg.christensen@novumnano.com
South Dakota Mines:
travis.grablander@mines.sdsmt.edu
ding.lou@mines.sdsmt.edu
hammad.younes@sdsmt.edu
haiping.hong@sdsmt.edu

ABSTRACT

Thermal greases are vital for electronic temperature regulation and overall performance. Improved thermally conductive greases have been made utilizing hydrogen bonding of carbon nanotubes (CNT) and hexagonal boron nitride (hBN). Nanomaterial fabricated greases have similar material characteristics including viscosity as market thermal greases but have enhanced thermal properties for heat transfer. These greases show improvements of up to 80% in thermal conductivity measurements. CPU testing resulted in 100% decrease in standard deviation of temperature from commercial grease variation.

Keywords: Carbon Nano Grease, Hydrogen Bonding, Thermal Conductivity, Boron Nitride

1 INTRODUCTION

Computer electronics need to maintain a low operating temperature. These electronics including graphics cards and central processing units (CPUs), are continuously upgraded by manufacturers to improve performance but are still limited by excessive heat generation. Heatsinks are used on top of CPUs to help mitigate this heat buildup inside the processor case. However, the surface of both the heatsink and the CPU case is not smooth, leading to air pockets forming between the two media.

Air has a very poor thermal conductivity, 0.02587 W/mK at 20°C [1]. Air pockets cause heat to stay significantly longer in the CPU case, which in normal cases causes performance drops through thermal throttling, or in rare cases, a melted CPU.

A primary solution to fill the air gaps is through the use of a thermal paste, but it can also be substituted with a thermal grease or thermal pad. Thermal pastes and greases are constantly tested and improved upon for a globally competitive market and the scientific research community. Computer applications and their associated processing demands can vary greatly. In the research and other fields, simulation is a powerful tool for testing and requires heavy usage of computation power and memory.

Esports is a constantly growing video game competition and market. Leading-edge greases and pastes allow PC enthusiasts to overclock their hardware for significantly improved performance. However, this does come with the tradeoff of potentially causing fatal crashes or overheated systems.

Many kinds of materials can be used to make a thermal paste/grease. Examples can range from liquid metal, being a very expensive yet almost perfect solution, to toothpaste. Nanomaterials such as CNTs and hBN have great potential in adding to this market with their superior thermal properties.

2 MATERIALS AND METHODS

Comprised in the grease are both multi-wall CNTs and hBN in varying proportions. Christensen et al. [2] reported that Glycerol fluid increases by > 50%, and silicon oil having an increase of 86%. For hBN, Christensen et al. [3] had shown that using hBN can enhance both thermal conductivity and lubricity of the base oils in addition to CNTs.

In our case, two types of silicone oil were used to produce our greases labeled as Phenyl Methyl Silicone (PMS) oil and Polydimethylsiloxane (PDMS). The structures of both oils contain oxygen atoms outside functional groups, which suggests that they will form hydrogen bonds with our CNTs.

Figure 1: Fabricated Grease
Although thermal conductivity performance greatly increases from the addition of functionalized nanotubes, electrical conductivity will also increase [4]. Electrically conductive material can destroy sensitive computer electronics if it leaks off of the CPU and contacts other components. Since silicone oils are dielectric in nature and hBN is an excellent electric insulator, electrical conductivity is not a major problem.

Grease fabrication is done as in [5], and the result is shown in Figure 1. Greases are milled to increase dispersion throughout the sample. A grease made with a higher concentration of CNTs will result in a sticky and flaky substance, whereas higher hBN concentrations will keep the oil as a fluid.

Computer testing is done on a test bench equipped with an EVGA X299 micro ATX motherboard, Intel Core I9 7900X CPU, cooled with a Noctua DH-15 air cooler. A piece of software that is used to stress test the computer is called Prime95. This software is primarily used to find prime numbers through FFT calculations, but PC enthusiasts use its stress test capability to determine the stability of their systems when overclocking.

We set the software to run FFTs of a selected size of 8k by 8k, the lowest size FFT for custom which stresses the CPU primarily and not the RAM. A stress test set this way loads the entirety of the CPU through floating point calculations. Since the CPU is under a 100% load throughout the stress test, a large amount of heat is generated.

To measure the processor's heat generation and speed during testing, another software called Hardware Monitor is used. This software creates a csv file measured at every half second during the test.

Using MATLAB, the data was sorted through to find maximums, minimums, standard deviations, and averages of both clock speeds and CPU core temperatures.

### 3 RESULTS AND DISCUSSION

PMS silicone oil has been found to have a thermal conductivity of 0.152. Various tested combinations of this oil and MWNT-OH and hBN have been done with results varying anywhere from 15% to 83%. The values for the Novum Cool grease in figures 2 and 3 were chosen from the best performing grease of a CNT to hBN ratio of 1:5.

Our stress tests were done at two specific frequencies, the first at normal operation 3.3 GHz and the second overclocked at 3.9 GHz. The overclock frequency is much less than the maximum because when using Kryonaut, speeds above 3.9 GHz caused drastic performance changes throughout the 1 hour testing period. 3.9 was chosen due to the stability of the processor under 100% load over the entire hour.

Figure 2 shows CPU core temperature averages with standard deviations at both operating frequencies. At the 3.3 GHz operating speed, our grease was only 3 Celsius hotter than Kryonaut. Additionally, the deviation. At 3.9 GHz, our grease was able to perform within 5% difference of the leading commercial brand and 2.65% of the other. Our computer was running 5 Celsius hotter however ran more consistently at that temperature than Kryonaut based on the standard deviation. In both cases, our greases standard deviation was consistently lower than that of Kryonaut. A more consistent temperature is expected to provide a longer device life expectancy and an increased mean time between failures.
Figure 3 shows the CPU clock speed averages with standard deviations at both operating frequencies. At 3.3 GHz, all greases ran pretty much at the same average speed but our grease had a lower standard deviation. At 3.9 GHz, we see that Kryonaut and Novum Cool ran at average the same. Our grease had lower fluctuations, as seen by the standard deviation. This, again, increases life expectancy and mean time between failures.

4 CONCLUSION

CNTs in combination with hBN have been found to increase the thermal conductivity of silicone oils significantly. The thermal stability of the tailored thermal grease shows improved stability greater than double for both temperature and clockspeed control. Fabricated samples have been shown to have similar performance and increased stability vs. commercial products. Novum Cool has been shown to produce similar clockspeeds, stay within 5 celsius, and increase stability by 100% compared with leading thermal compound Kryonaut.

REFERENCES