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Dear Mr. Defehr,

Moore's Law is coming to an end due to the physical size of the silicon atom, which will limit the size of transistors in semiconductor chips. Without the ability to make smaller, more efficient transistors, computers cannot be made faster while maintaining the same form factors as we know today. Unless research is done to find other suitable semiconductors for making smaller transistors , we will hit a wall in computing where we are limited by processing speed of our computers. Right now, carbon nanotubes may seem as a promising material for building semiconductor chips, given that a team of researchers at the University of Wisconsin-Madison recently built a carbon nanotube transistor which outperformed silicon. Currently, carbon nanotubes are not feasable for use in integrated circuits. For the most part, carbon nanotubes grown from solids other than carbon (especially semiconductors) are too fragile for practical use, and the gate voltages are rather high, which results in higher power consumption. On the other hand, gallium nitride (GaN), which is already known for its fantastic semiconductor properties shows a lot of promise, given that it is already used in many industrial and military applications. Datacenters are reducing their power consumption today by powering their servers using power supplies with GaN to convert voltages more efficiently, and Raytheon (a defense contractor company) makes radar systems which use GaN to amplify radar radio frequencies. In addition to being smaller and more power efficient, GaN chips are also much faster compared to their silicon-based counterparts. Autonomous vehicles use LiDAR technology to fire beams of light in order to map the area around themselves. Underlying this technology are GaN chips, because GaN allows the laser beams to be fired at faster speeds than a silicon chip could process. This allows for higher resolution 3-D maps to be made, which has improved the quality and reliability of autonomous vehicles. Given that GaN is already useful in all these applications today, a computer chip made from GaN would revolutionize the computing industry, bringing new speed improvements to our daily computing needs. The main reason we have not yet moved on from using silicon processors in computers today is because of the economies of scale of silicon chips. It is very cheap to produce silicon chips, since obtaining silicon is easy, and companies like GlobalFoundries and Intel have been producing and improving the manufacturing process of these chips for over 50 years. GaN is still relatively new, which means that improvements definitely can be made with regards to finding a cost-effective manufacturing process that would enable the mass production of GaN based processor chips.

Yuji Zhao, an expert in electrical and computer engineering from Arizona State University notes that GaN chip design and fabrication requires special growth techniques which are different compared to how silicon chips are manufactured today. Many other researchers have already investigated different techniques of growing pure GaN crystals. The crystals grown need to be pure, just like for silicon chips since we are dealing with transistors smaller than the 12 nm silicon ones being manufactured today. Since many methods are already known for growing pure GaN crystals, my research would be concerned with improving these methods and finding a cost-effective way to mass produce GaN crystals. The current practice for growing silicon crystals, which is vapour deposition does not show much promise for growing GaN crystals. However, growing crystals under high temperature and pressure seems to show promise for GaN, since most leading gallium nitride substrate manufacturers are doing this now. A company in Warsaw named Ammono, which is regarded for its high quality GaN crystals is currently able to grow GaN crystals measuring about 51 mm in diameter. Similar to how quartz crystals can be grown in a high pressure chamber with supercritical water, GaN crystals can be grown using high pressure and heat with supercritical ammonia. This process is known as *ammonnothermal* growth. Without a doubt, this process can be improved upon to get higher yields. Ideally, the process of growing GaN crystals could be improved to a point where GaN crystals are grown about as large as silicon crystals in semiconductor manufacturing. Large, lab grown silicon crystals typically have a diameter of about 300mm. An advantage of GaN crystals is that if we can get a the crystal to grow as large as we can grow silicon crystals today, each wafer can be sliced thinner, because it is stronger than silicon. This would result in higher yields, and in turn lower the cost of growing the crystals. One method that could be used to improve the growth and size of the GaN crystals is to dope the crystals, similar to how silicon manufacturers dope their crystals with small amounts of boron, aluminium, and various other elements. By trying out different doping agents, and refining the ammonothermal process, progress will be made towards being able to mass produce GaN crystals in a more cost-effective fasion than they are produced today.

As a second year Computer Engineering Co-op student at the University of Alberta, it would be exciting to contribute research that would make gallium nitride based processors a reality. I believe my background in computer engineering and tendency to always be on the bleeding edge of technology make me well-suited for this type of research. So far during my degree, I have been exposed to digital logic, time signals, assembly language, C programming, and chemistry which are all essential for this type of research, which involves working on the foundations of next-gen computing devices.

Sincerely,

Arun Woosaree

Note: This page is not a part of the letter
Links visited:

- http://fortune.com/2016/06/11/raytheon-next-gen-chips/
- https://arstechnica.com/information-technology/2016/06/cheaper-better-faster-stronger-ars-meets-the-latest-military-bred-chip/
- https://www.allaboutcircuits.com/news/how-carbon-nanotubes-could-help-replace-silicon-in-chip-fabrication/
- https://www.berkeley.edu/news/media/releases/2003/04/09_tubes.shtml
- https://pdfs.semanticscholar.org/3fb6/afb5918951c44db170da745cc6aeb326da10.pdf
- http://www2.lbl.gov/Science-Articles/Archive/MSD-gallium-nitride-nanotube.html
- http://www.nbi.dk/~nygard/Integration_of_Carbon_Nanotubes_Stobbe_et_al.pdf
- https://www.sciencedaily.com/releases/2014/08/140827122509.htm
- https://www.cnet.com/news/life-after-silicon-how-the-chip-industry-will-find-a-new-future/
- http://epc-co.com/epc
- https://spectrum.ieee.org/nanoclast/semiconductors/materials/carbon-nanotube-transistors-finally-outperform-silicon
- https://news.wisc.edu/for-first-time-carbon-nanotube-transistors-outperform-silicon/
- https://www.raytheon.com/news/feature/power_patriot
- https://phys.org/news/2017-12-gallium-nitride-processornext-generation-technology-space.html
- https://www.allaboutcircuits.com/news/gan-gaining-traction-one-chip-at-a-time/
- https://venturebeat.com/2015/04/02/move-over-silicon-gallium-nitride-chips-are-taking-over/
- https://na.industrial.panasonic.com/products/semiconductors/microcontrollers
- http://www.beck-shop.de/fachbuch/leseprobe/9783642048289_Excerpt_001.pdf
- https://spectrum.ieee.org/semiconductors/materials/the-worlds-best-gallium-nitride
- http://www.dtic.mil/dtic/tr/fulltext/u2/a444058.pdf

This is an assignment for an English class. Therefore, it is not a real research proposal letter, and none of the contents of this document should be taken seriously, as I cannot guarantee the validity of the information presented. I am not an expert in the process of semiconductor crystal growth.