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EXTENDED ABSTRACT

This paper targets the nascent area of nanotechnology electronics called "spintronics" as a future solution for decreasing the size of microchips and increasing their power in computational performance. The problem is that thermomagnetic radiation is causing current microchips to melt under heat. As a result, an entirely new way of designing microchips must be established.

The aim of this research is to align several emerging technologies into a metaconvergent context in order to explain the bulk social phenomena that are occurring throughout the world due to advances in communication engineering. The focus of the study is not on the technology, but instead on the social impacts brought about by the advances in communication systems derived from nanotechnology.

The reader/audience will become more aware of the internal structures of their computers and mobile devices, while understanding that the next generation of computational systems emerging over the next decade are going to be extremely more robust with a reduced physical footprint. The reader/audience will be able to selectively choose to be more involved with technology (as an innovator) or decrease their participation in a technological society (as a Luddite).

For roughly 50 years, silicon-based metal-oxide field effect transistor (MOSFET) microchips have been the cornerstone of the computing industry. It is important to revisit Intel-founder Gordon Moore's celebrated argument dubbed "Moore's Law": the number of transistors on a microchip will double every 18 months (Brock & Moore, 2006). Indeed, when Moore first predicted this in 1965, his trend-line evidence was sound and has held firm until roughly 2015.

What Moore could not have foreseen in his crystal ball was that the electromagnetic radiation produced, because the transistor circuitry itself was so tightly packed on the wafer, would begin melting the crammed transistors on design chips. *ScienceDaily* of May 16, 2001 signposted the forthcoming barrier, accordingly:

> *"For decades, the semiconductor industry has been able to continue increasing the amount of circuitry, or computing power, on a chip while reducing its size, enabling smaller, faster and better electronic products. However, researchers have long known that the industry will eventually hit a 'wall' that will prevent semiconductor designers from achieving additional size reduction"* (Pacific Northwest National Laboratory, 2001, para. 3).

For this reason, many chip makers are switching from their standard means of making chips, known as deep-ultraviolet lithography (DUVL), to a new method called

extreme-ultraviolet lithography (EUVL). This sophisticates compression techniques significantly. Yet, whether chipmakers focus upon DUVL or EUVL processes of reducing the numbers of transistors on a wafer surface, the general consensus remains that another means of rethinking the transistor itself must emerge for chips to continue their path toward the fast and furious (Adams & Smith, 2015). Let us now turn to the various solutions on the table to keep microchip advances heading forward.

One of the problems that has crippled the semiconductor industry is that of its two-dimensional thinking. Ever since microprocessors first rolled off the production lines with the Intel 8080 series, engineers have considered microchips to be something of a “flatland.” In 2000, several engineers at Matrix Semiconductor proposed the idea of designing and building chips with multiple layers. Still, the basis of Moore’s Law is forecasted to become “Moore’s Hope” sometime before 2020, even with these layered housings. Why? Well, once transistors get miniature enough, they begin picking up “interference” from other neighboring transistors. And further, whether they are fluid-cooled or fan-cooled, they still melt under extreme conditions. So, stacking chips upon one another (much like a skyscraper) seems a reasonable fix to the problem — for the interim. However, this does not extend Moore’s Law whatsoever; it merely adds architectural layers to the original design. However, nanowire field-effect transistors (FET) could well extend the relentlessly exponential expectations for fulfilling the prediction.

On the other hand, computer engineers are working around the clock on a host of other solutions to try and break the lower-nanoscale level of microprocessors once and for all. The inventory of solutions emerging to push silicon smaller and faster is comparable to something out of a science fiction novel. However, you can rest assured that these plans are on the drawing boards of several noteworthy companies like IBM, Intel, Qinetic, Philips, Hewlett-Packard, AMD, and the like: (1) spintronics, (2) phase change, (3) nanowires and nanotubes, (4) crossbar latches, (5) resistance switching, (6) III-V compound lithography, (7) optoelectronics, (8) human DNA-based chips, (9) immersion lithography, and (10) imprint lithography (Adams & Smith, 2015). There are other solutions possible; although, these are the known leading developments coming out of the major research and development laboratories. And each solution is definitively exciting, pointing to a new era of microprocessor science.

To this point, we have been discussing the known and dabbling in some of the possible tomorrows of microprocessor development forecasted in the next decade. However, the top players in microprocessor research and development are investing a significant amount of capital, energy, and time in a new idea that would, by any reasonable measure, completely shatter the miniaturization “wall” being encountered by chip engineers. This idea relies heavily upon something called nanotubes (or nanowires) and a fresh approach to electronics altogether called: spintronics.

Recall that the miniaturization of transistors is critical for computer design engineers. Nanoscientists have already developed semiconductor electronic devices well beyond the sub-30 nanometer stage, and they want the devices to be durable and fast. Also recall that once engineers go below the sub-100 nanometer range, an entirely new type of physics comes into play — quantum physics. At these sub-100 nanometer levels, gravity, force, friction, et cetera, no longer apply as they do in traditional bulk science. For that matter, the physics gets highly unpredictable. We are essentially talking about quantum computing (Adams & Smith, 2015). These developers are working with entirely new means of energy transference, mathematical adaptations to binary logic, and a battle of history that has a tendency toward traditional microchip design. There are many issues working against these designers. With that so noted, there are, however, many breakthroughs being made throughout the world in spintronics.

Spintronics is short for spin-based electronics. It is sometimes referred to by industry specialists as magnetoelectronics, and operates on the quantum level of physics where electrons spin — either “up” or “down.” The field of spintronics is still in its infancy and is a theory more than a practical operation as of yet. Nevertheless, it is the theory of harnessing the power of one single electron’s spin as a piece of computational information that has the electronics engineering field abuzz. The theory of spintronics works accordingly: the device must be able to (a) generate spin states among specific single electrons, and (b) have a detector sensitive enough to be able to register the spin state of a single specific electron.

Electronic devices of the past and present (whether vacuum-tube based or modern silicon-transistor based) ignore the spinning state of the trillions of electrons moving through their circuitry. They are not engineered to appreciate spin. Instead, these transistors deal in “bulk” electrical charges where thousands of electrons define the open or closed properties of a circuit gate inside a chip. Spintronics, once it moves from the theoretical drawing boards into practical applications, will alter this by focusing information processing not on thousands of electrons tripping a circuit, but instead by placing data reliability on one single electron — where its “spin” defines the meaning of the binary data. Try to think of it in another sense: rather than relying upon the thousands of electrons in today’s traditional silicon transistor gates defining a bit of data (e.g., a 0 or a 1), we could be relying on one single electron and its “up” or “down” spin state. This is the “Holy Grail” of microprocessor engineering; being able to reduce circuits to one single electron of energy has been the dream of engineers for decades.

The leaders in spin research and development — to the present — have been the hard-drive manufacturers such as Seagate and Maxtor. Why, you may ask? Well, their memory storage technologies rely heavily on something called giant magnetoresistance (GMR) rather than microtransistor circuitry compression. Ever since the first computer hard-drives were introduced, hard-drives have saved data on magnetic discs using the spin state of energy. In fact, the technology developed specifically for making smaller, powerful laptop computer hard-drives has been especially helpful in understanding magnetic spin. As a result of these and other developments, spintronics is already starting to find its way into RAM chips in the form of something called MRAM (magnetoresistive random access memory). In contrast to traditional RAM chips, data are stored in MRAM by magnetic storage elements and not electric charge (Adams & Smith, 2015). While MRAM is not the popular choice of RAM by many of today’s leading computer makers, it offers several noteworthy advantages that will, in time, lead to its market dominance.

The claim that spintronics-based CPUs will thus become extensively miniaturized and more powerful is not only feasible but theoretically consistent. What most do not consider in this promising context, however, is that spintronics-based CPUs will rapidly evolve into all-in-one nanotech-driven, self-contained components. In other words, the present need for a dispersed system motherboard, RAM modules, and supporting graphics and audio cards in a PC will simply be eliminated. When spintronic circuit gates emerge at the 4 to 5 nm scale, computers with a smaller footprint and tremendously overwhelming power will, without a doubt, make the quantum leap from our desktops to our palmtops.

One of the most significant design problems that microchip engineers are facing in terms of controlling single electrons is that current manufacturing does not allow for such quantum-level mechanics. Inherently then, the structures that are to govern the flow of electrons through a “nanocircuit” must also be nanometer in scale. If you will, imagine a common drinking straw filled with spinning ball-bearings shooting down its shaft; this is what preliminary designs are looking like and they are implementing a technology called carbon nanotube (CNT) pipelining. Let us now take a closer look at the CNTs themselves and see how they are being applied in nanocircuits.

Carbon nanotubes (CNTs) are, by definition, allotropes of carbon. An allotrope is simply a compound formation, like diamond, graphite, or amorphous carbon. As a compound formation of carbon, CNTs are not naturally-occurring. In fact, they are grown on differing substrate surfaces in nanotech laboratories. Distinctively, they take the form of an elongated tube or cylinder and are enjoying widespread applications in nanotechnology, electronics, and optics (Adams & Smith, 2015). CNTs are even being used in current technologies as “nanowires” to speed traditional microcircuits and create better liquid crystal display (LCD) and plasma monitors.

Not surprisingly, these are not the only types of CNTs in existence. There are many shapes and configurations. The two referenced above are simply the most popular and widely used among physical scientists. What is known about the CNT structures, however, is that they are extremely small, about 50,000 times less than the width of a human hair. And, for their infinitesimal size, they are extremely strong and durable because they are a chemical bond sharing cousin to both graphite and diamond. And, as we all know from our high school chemistry class, diamond is the hardest substance known to man. Think of nanotubes and nanowires as strands of hollow diamond wire thin enough to carry single electrons.

Conclusively, the way forward from here is that nanocircuitry focuses upon the electron gate processor (EGP) where the “spin” of one single electron is measured to create binary data for the computer to process. Going from tens of thousands of electrons being measured to simply one electron will create a spike in computational outputs that will completely revolutionize modern circuitry. Accordingly, our hardware is going to become dramatically more powerful and robust within the next decade. This will, in conclusion, make our PCs and mobiles unfathomably more durable, thus creating an Internet that functions 10-20 times more quickly. The remaining question for the future is: What are we going to do with that much power at our disposal? What will tomorrow’s computing devices and equipment do to our computer-mediated existence?

Keywords: *nanotechnology, spintronics, electronics, modern circuitry, buckminsterfullerene, nanowires, carbon nanotubes, microchips.*

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Scholar, Administrator, Consultant and Fulbright Senior Specialist (2011-2014), Dr. Ty Adams was educated at The Florida State University (Ph.D. in Communication & Educational Leadership, 1995; M.S. in Communication Theory, 1992) and the University of Florida (B.A. in Communication Studies, 1990). An organizational specialist, Dr. Adams was a D'Aquin Endowed Professor of Communication at the University of Louisiana from 2006 to 2013, and was an Assistant & Associate Professor of Communication at Louisiana from 1998 to 2006. He began his career as a full-time Instructor in 1993 with the University of Arkansas at Monticello. Over the past decade, he has focused on internationalizing his professional network, thereby expanding his academic perspective.

Dr. Adams has held several distinctive appointments because of this global shift. Currently, he is Dean of Continuing Education & Lifelong Learning at University of The Bahamas. Prior to that, he was in Mexico City as a Distinguished Professor at the Monterrey Institute of Technology (2017-2018). He was also in Kuwait City at the Gulf University for Science & Technology as Professor of Mass Communication (2015-2016). Dr. Adams was also Vice Dean at The University of Business & Technology in Jeddah, Saudi Arabia (2013-2014). Adams taught in Pescara, Italy, as Da Vinci Fellow of Strategic Communication at D'Annunzio University (Fall 2012). While on appointment in Central Asia for the U.S. Department of State as a CIES Fulbright Senior Specialist, Adams was selected to be Vice President of Academic Affairs at the Kazakhstan Institute of Management, Economics, and Strategic Research (2011-2012).

From 2004 to 2010, Dr. Adams was the Graduate Studies Director at the University of Louisiana, where he mentored numerous graduate students into top global Ph.D. programmes. In 2006, he was a JSA Professor of Communication at Yale University. He was also a McGee Fellow at The University of Iowa (1998), specializing in new communication technology (NCT). During Summer 1997, he was appointed a Visiting Scholar at St. Benet's Hall at Oxford University. As well, he was a Debate Coach at The Florida State University from 1990 to 1993 and a champion Debater at the University of Florida from 1988 to 1990.

"*Be brave. Take risks. Nothing can substitute for experience*." --Paolo Cohelo