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Intelligent Microsystems: Keys to the Next Silicon Revolution

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Abstract

Paul McWhorter, Deputy Director for of the Microsystems Center at Sandia National Laboratories, discusses the potential of surface micromachining. A vision of the possibilities of intelligent microsystems for the future is presented along with descriptions of several possible applications. Applications that are just around the corner and some that maybe quite a ways down the road but have a clear development path to their realization. Microsystems will drive the next silicon revolution.

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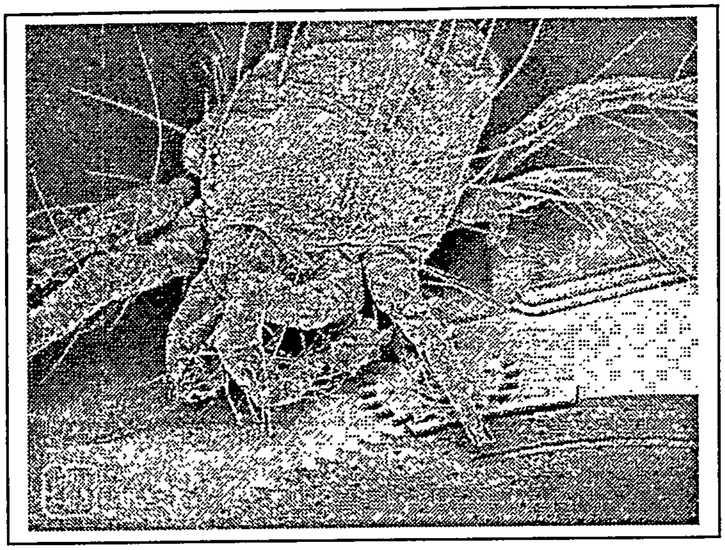

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It is hard to imagine any field of science or technology that has made a more dramatic impact on the last half of this century than microelectronics. The hallmark of the microelectronics industry has been to each year produce chips that are smaller, faster, cheaper and better. This has not been a small growth spurt, but has been maintained for some three decades now. Microelectronics have touched virtually all aspects of our lives; the way we communicate, the way we are entertained, and the way we defend ourselves have all been fundamentally changed. The impact of microelectronics amounts to nothing less than a Silicon Revolution. The world is profoundly different as a result of this revolution.

While the Silicon Revolution has changed the world, it has vectored ahead based on a surprisingly simple metric. The metric that has guided the Silicon Revolution is to continue to advance the manufacturing techniques to enable the fabrication of transistors with smaller feature sizes. The transistor is the basic building block of the integrated circuit. As transistors become smaller, they can operate more quickly, and more of them can be packed onto a single piece of silicon. This enables chips that can store and process more information. This advancement is commonly referred to as "Moore's Law", which states that the number of transistors which can be realized on a silicon chip doubles every 18 months. There is no doubt that the impact of microelectronics will continue to grow.

At Sandia National Laboratories we believe, however, that we stand on the verge of a Second Silicon Revolution. The metric of the Second Silicon Revolution will be different and more important than simply continuing to pack more transistors onto the silicon chip. The metric of the Second Silicon Revolution will be the integration of new structures, such as microscopic machines, on the Silicon, alongside the transistors, creating a whole new generation of integrated circuit; chips that will not only be able to think, but will be able to sense, act and communicate as well. This new capability will enable chips that not only know where they are, but know what is going on around them. We believe that the impact of this new capability will have as profound of an effect on the next thirty years as traditional microelectronics have had on the last thirty years. These new integrated microsystems will become ubiquitous; they will become part of virtually every commercial product that you buy. These devices will change the nature of consumer products. A fundamental change that will be enabled by microsystems is that consumer products of the future will be interactive. Take, for example, a child's doll.

Today a doll is a rather inanimate object. In the future, a doll might have a microsystems based thermal sensor in the hand. When a child holds the dolls hand, it could respond back in a positive manner. The doll could be instrumented with inertial measurement chips, and know that it has been picked up, turned upside down, dropped, hugged or even spoken to, and respond in a suitable manner. The doll would go from being an inanimate object to something that actually interacts in a lifelike way with the child. The doll would become aware of its environment and respond accordingly. Similarly, microsystems will enable consumer products of the future to become aware of their surroundings and much more interactive with the user. Imagine golf clubs that automatically diagnose your swing and offer advice; imagine running shoes that keep track of distance, pace and your vital signs, and coach you during a workout; imagine products that learn your preferences and adapt to provide you with what you want, the way you want it.

The Second Silicon Revolution is underway, and breakthroughs in this field are being achieved every day. In order to fully realize the potential of the technology, it is important to understand certain fundamentals. The most important fundamental is that the Second Silicon Revolution is about ***cost*** not ***size***. There is no doubt that recent advances in micromachining have captured the imagination of the world. Fully functioning machines with features smaller than a human red blood cell are truly captivating. While captivating, the truth is that the world will not necessarily be changed by ***small*** mechanical devices; it will be changed by the ability to achieve complex electro-mechanical functions at very ***low cost***. By way of analogy, consider the modern Pentium microprocessor. It no doubt has had enormous impact on the world. Now imagine that the Pentium chip were 1000 times the size that it is today (ten times wider, ten times taller, ten times longer). If other things were the same, the truth is that the impact of the Pentium would hardly be affected if it were this much larger. Certainly the size of your overall desktop computer system and most laptop systems would not be affected if the size of the chip were 1000 times bigger. Now imagine that the *price* of the Pentium is increased 1000 fold. It would not be affordable and its impact would become negligible. So, the impact of microtechnology comes primarily from *cost*, not *size*. Microsystems achieve low production costs by exploiting the batch fabrication techniques pioneered by the microelectronics industry.

The low cost of microsystems will enable incorporation of new features into products without significantly affecting the cost. Already, integrated microsystems are finding their way into successful commercial products. Ink jet printers, computer-input devices, airbag deployment systems in cars, and digital projectors are examples of systems taking advantage of microsystems today. In the near future, low cost microsystems based optical switches will become an important part of the global telecommunications infrastructure, and microsystems will begin to make significant impact on healthcare. The technology is advancing at a significant rate, and new applications are being found each day.