Trends in Microsystems for Information Technologies

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Introduction

Microsystems are key enablers for creating advanced information systems critical for both military and commercial applications. Information systems are characterized by being able to see further, with greater clarity, and with the ability to communicate critical information in a timely manner. Creation of such systems translates into achieving performance goals for components including; creating highly capable sensors; extracting useful signals from background clutter, system noise, and interfering signals; realizing assured high performance communications links; and converting complex “data” into actionable “information” in near real time.

In this talk I would like to provide an overview of DARPA’s Microsystems Technology Office’s programs supporting information system superiority in the context of our three principal technology thrusts - Electronics, Micro Electro Mechanical Systems, or MEMS, Photonics, and what we view as a principal challenge, the integration of these technologies to create chip-scale microsystems.

Advanced Micro Electronics

Microelectronics is a core information system technology and DARPA has a long history of investments in this area. Only a few years ago modeling predicted that scaling CMOS below 70nm would not be possible. Our Advanced Microelectronics Program challenged this prediction and successfully demonstrated devices with useful transistor characteristics and critical dimensions below 20nm. With the industry only now gearing up for the 100nm generation and with many problems still remaining to be addressed, these landmark results provide measurable milestones assuring significant extension of the life of scaled CMOS. The challenge now is how to take full advantage of the capabilities that a trillion-transistor nano-scale silicon chip will make possible.

The insights gained from our programs leave us confident that alternative technologies will allow for extending operation to even smaller dimensions and the possibility of exploiting new physical phenomenon. To investigate these possibilities we have launched programs exploring the nano-scale domain that lays Beyond Scaled-Silicon CMOS. These include programs within my office investigating small bandgap, Antimony based, very low power III-V electronics, nano-scale MEMS devices, and Molecular Electronics. DARPA’s Defense Science and Information Technology Offices are pursuing research in quantum and spin physics related approaches to advanced electronics, addressing what might be the most challenging endeavor, to develop quantum electronics based communication and signal processing technology.

Our programs also continue to drive breakthroughs for very high speed, high frequency applications. Achieving record-breaking 100GHz performance for SiGe bipolar transistors, a result that is enabling this silicon-based technology to begin to encroach on applications that previously were the sole domain of compound semiconductor devices. At the same time, progress in III-V based transistors continues with transfer of very high-speed HBT technologies from university labs to industry. We take pride in the significant pay-offs that our past investments in RF applications for III-V technologies are having in the booming commercial wireless world.

Applications of Micro-Electro-Mechanical Systems (MEMS)

DARPA began investing in MEMS Technologies in 1992, when there was little industry involvement and virtually no MEMS fabrication infrastructure anywhere in the world. Today our significant investments are yielding revolutionary capabilities.

In addition to the recognized applications for MEMS for inertial sensing, monitoring readiness of missiles and projectiles, fuze/safing and arming devices, there are emerging applications in commercial and military RF applications that provide flexible, low insertion loss, chip-scale manipulation of high frequency signals for antenna and other signal processing applications, and Photonic applications in optical switching and beam steering.

The focus of our current efforts includes MEMS chip-scale bio-microsystems, MEMS based uncooled high-resolution IR detector arrays, and MEMS based agile optical beam steering and control for free space laser communication and target designation. For these diverse applications MEMS devices are meeting new challenges: mixing complex on-chip fluid and mechanical components for chip-scale, pico-liter chemical processing, achieving high densities of very small bolometers with precision thermal management for efficient, sensitive uncooled IR sensor arrays, and replacing bulky gimbaled optics with precise, three dimensional laser beam positioning.

Significant remaining MEMS challenges include extending MEMS technology to nano-scale dimensions and developing on-chip power generation compatible for extending the life of MEMS remote sensors. These are topics that we are just beginning to explore.

Photonics for Information Systems

DARPA’s photonics programs have been a major source for innovative technologies, and are having significant impact on data communication in military systems. Beginning over a decade ago DARPA investments helped create multiwavelength technologies for today’s WDM optical networks. These DARPA programs lead to the technology base for multi-gigabit Next Generation Internet applications.

Over the same period our investments in Vertical Cavity Surface Emitting Lasers (VCSEL's) may be proven to be of even greater value, delivering laser performance in a package that is nearly as inexpensive to manufacture as low cost Light Emitting Diodes. DARPA can claim credit for pioneering VCSEL technology and identifying their first applications in interconnections in data networks with links spanning tens of meters down to between racks. For these applications VCSEL technology is being transitioned to a number of service programs.

Our current program focus is successfully integrating VCSEL's with detectors and electronics to form large two-dimensional "smart-pixel" arrays and these form the basis for very high capacity interconnection in tera-bits per second. Commercial interest in applying this technology to a wide range of high performance computing applications is already building. Future applications will mix these technologies with MEMS for hyper-spectral sensing and compact free space optical communications applications.

In the future, we anticipate extending the networking versatility afforded by Wavelength Division Multiplexing (WDM) to seamless, and more importantly, to signal format independent routing of information on all military networks. We believe that platform scale WDM networking will be one of the next major technology breakthroughs for the application of photonics to military information systems.

Conclusion

The range of innovation that is occurring across the three core technologies of the Microsystems Technology Office discussed here are just the beginning. Going forward we look to achieving even greater levels of integration among these technologies to realize chip-scale Microsystems that will be the key to even more versatile future information systems than those that are transforming the way we live today.