Heterogeneous Integration Roadmap - Package Level Systems Integration: A key to maintaining the pace of progress

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ABSTRACT

In this talk we plan to provide an overview of the heterogenous road map and how it relates to photonics. Within the talk we shall also set in context the role photonics play within the package level systems integration of electronics, photonics and sensor integrated circuits with the aim of maintaining the pace of progress, as Moore's law scales.

Keywords: Heterogeneous Integration, Package Level Integration.

1. INTRODUCTION

The most efficient path for progress in electronic systems for more than 50 years has been Moore's Law scaling but the advantages of scaling CMOS are now approaching their economic end. Information technology must identify new approaches if the economic and societal benefits are to maintain their pace of progress in the post Moore's Law era. This need has accelerated innovation in new technologies to maintain the improvements in size, cost, performance and power efficiency that has driven information technology into every corner of human activity over the last 50 years. The coming changes are evident with evolutionary progress in advanced packaging, introduction of new system architectures, new device types, new materials and new processes for both design and production. The evolution includes wafer level packaging, 3D integration and heterogeneous integration of known components into a single package [1].

The revolution that is just beginning will include a complete remake of the global network, new devices for both logic and memory functions, an array of sensors of all types. The emergence of big data, the internet of things and migration of memory, logic and applications to the cloud are moving the majority of power usage from logic towards memory transport. The path toward maintaining the pace of progress for decades to come will, however, transform this evolution in the industry to an industrial revolution where new device types and other components are integrated into systems at the package level. The ultimate realization of this revolution will be full system integration of complex products in the package.

The difficult challenges that must be overcome to realize this revolution include: Cost and time required for new system design and verification; Thermal management of the increased volumetric thermal density; Stress management in both production and use cases with diverse materials and device types; Compatibility with hostile environments; Reliability issues including test access and test capability for systems with components that wear out during the useful life of the system; Security with low latency on the global network to support many of the health, safety and entertainment applications with low latency requirements

Many of the elements of this revolution are in development today and will be discussed in this presentation. These include: Artificial Intelligence as part of our design and simulation capability as well as improving speed and accuracy of decisions; Quantum computing and photonic switches will accelerate performance at dramatically lower energy levels; Quantum dots and plasmonics will decrease power and cost while reducing the need for expensive precision in thermal management; New processes and new materials to resolve thermal density and stress management issues; Orders of magnitude increase in simulation capability that can accelerate the pace of progress in development and understanding of complex systems such as the human brain; Incorporation of 2D materials into logic and memory as well as insulation, isolation and connectivity applications; Augmented reality to expand the human capability both physically and mentally

The development horizon in these areas of emerging research is 25 to 30 years. Looking back to the time before the smart phone was introduced June 29th 2007, no one imagined the impact it would have on every aspect of our lives. Today the number of smart phone users is more than 52 % of the world's adult population and that does not include cellular phones without a camera or iPads and other similar devices. It should be clear that the most important innovations in the next 25 years are things that we cannot yet imagine.

2. Relevance to Photonics

Photonics dominated long range data and telephony by the 1970s due to cost and power advantages but made slow progress during the next 30 years due to small market size and high component cost. Since the turn of the century much progress has been made due to expanding market size driven by increasing data traffic and the cost advantages of expanding volume. The global internet traffic is projected to reach 2.0 zettabytes by 2019 from .7 zettabytes in 2014, a 23% CAGR. Two thirds of this traffic will originate from non-PC devices by 2019 with growth coming from TVs, tablets, smartphones and machine to machine communication. Each one of these growth sources has some important differences that will impact their packaging requirements. Broadband speeds will more than double in the 5 year period from 2014 to 2019.

The packaging of photonic integrated circuits (PICs) will face the same challenges faced in packaging electronic ICs with the added complexity of integrating both active and passive photonic elements. Wherever possible industry must adopt and adapt the packaging technologies developed for electronics to decrease cost and time to market for packaging of individual PIC circuits and incorporating PIC circuits, photonics, plasmonic and other components into complex 3D SiP through heterogeneous integration.

There will be many specific challenges in realizing the benefits of integrating electronics and photonics into the fabric of the global network and the components attached to it. The solutions, however, cannot come from just packaging photonic components. The co-packaging of electronics, photonics and plasmonics will be required to address these substantial new challenges and meet the expanding requirements for higher performance, higher bandwidth density, higher reliability, increased security, lower latency and lower cost in the future. There will be new device types, new materials, new package production processes and new equipment required to accomplish these objectives. Some of these required innovations we know today but many specifics that must be addressed over the next 15 years are yet not known. The scope of this Roadmap Chapter is to identify electronic-photonic integration challenges with sufficient lead time so potential solutions can be identified and proven before they become roadblocks to the pace of progress for the industry. This scope covers integration of these components into emerging packaging solutions to decrease size, cost, power and latency while increasing performance and bandwidth.

3. CONCLUSIONS

In this talk we plan to provide an overview of the heterogenous integration roadmap and how it relates to photonics. We shall also discuss the many difficult challenges associated with system level of integration of photonics+ electronics. We shall also set in context the role photonics play within the package level systems integration of electronics, photonics and sensor integrated circuits with the aim of maintaining the pace of progress, as Moore's law slows down.

REFERENCES

[1] https://eps.ieee.org/technology/heterogeneous-integration-roadmap.html.