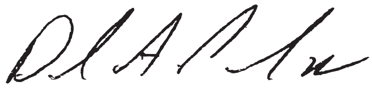
Foreword

Analytical Instruments in Semiconductor Development

Dale A. POOLE Jr

Corporate Officer
HORIBA, Ltd.
Senior Corporate Officer,
HORIBA STEC, Co., Ltd.
Executive Vice President, HORIBA Instruments Incorporated



In 1959 Jack Kilby of Texas Instruments and Robert Noyce of Fairchild developed and patented the basic concept and manufacturing technology of the integrated circuit. Soon after this, in the early 60's, computers were being constructed with what we would consider this very basic technology. The remarkable part of this semiconductor-based device was the scalability of silicon with a simple planar structure. Currently with billions of transistors on a single die, a basic smartphone processor has far more power than a Cray Supercomputer of the late 70's. This revolution in materials and design has fundamentally changed the world and ushered in the age of information. One could compare how early electrification opened a new world of possibilities in a similar way to what is happening today. With the common use of the internet, smartphones and cloud computing, we are quickly entering the age of ubiquitous computing and our lives and world are defined by it. This now has enabled the 4th industrial revolution and with the advent of artificial intelligence (AI), it is easy to see how the world as we know it is completely dependent and defined by the computational capability of integrated circuits (IC's).

The Semiconductor market has become a key strategic business for HORIBA. HORIBA is the leading company for the components of Fluid delivery to the Dry process chamber and Chemical Concentration monitoring in Wet processes with some products in metrology for reticle inspection. The Scientific segment has concentrated on high-end analytical benchtop equipment, thin film ellipsometry, and the original equipment manufacturer (OEM) end-point market with good results. One important aspect of the Semiconductor market is that it is constantly evolving. The planar structure is no longer the basis of the most sophisticated IC's such as 3D NAND flash memory and FinFet three dimensional (3D) transistors used in CMOS logic. These devices require new materials and manufacturing techniques that are reshaping the demands of the Semiconductor industry.

New technologies are needed as node shrink[*1] comes to an end point with existing planar structures, in other words, one is no longer able to manufacture a semiconductor chip with reliable performance utilizing the techniques of the past. Moore's law stated that the number of transistors on an IC will double every two years, and this was possible for many years but completely new approaches such as the FinFet 3D transistor and advanced packaging are required to keep Moore's law relevant. One of the key parameters for any semiconductor design is the bandgap which basically defines the parameters which causes a device transistor to turn on or off and as well as the transistor gate leakage. As transistors get smaller and smaller, using materials that provide the correct electron mobility and insulating properties for the gate no longer work correctly in a planar architecture. The gate area becomes so small that the transistor will not function. One way to continue to shrink the gate 2D area is to build a 3D structure that provides a larger volume for the gate. This approach is beginning to reach its limit and a new structure called Gate All Around (GAA) will be required which brings with it many new processes and materials. Eventually a GAA transistor will reach its limits and new materials called 2D materials[*2] will allow transistors to be stacked on top of each other allowing for a big improvement in transistor density. While GAA is being implemented in Semiconductor Fab's now, 2D transistors[*3] are at least 5 to 10 years away from mass production. This means that Moore's law is still relevant and has a device roadmap even though the transistor count scaling per year has slowed down from the previous doubling rate.

To achieve the process results required, the OEM's and integrated device manufacturers (IDM's) need new measurement techniques that will feed into sophisticated machine learning control systems for advanced process control. As new materials are developed for advanced processes these materials need precise characterization of their stability and purity for the process environment. From the point of view of a process or equipment engineer, every subsystem on the tool must work at such a high-level of precision that they cannot leave any factor uncontrolled or not understood. What this means for HORIBA is there are many areas where we can contribute to our customers' success by integrating the Semiconductor and the Scientific segments approach to the market. Our vision is to develop a new way of understanding and executing in the Semiconductor market starting with the materials point of view all the way to process in a so called "Lab to Fab" approach.

The challenges that the semiconductor industry is facing can be addressed with HORIBA's analytical tools and will be used to determine the key measurement techniques that will be needed to measure and control complex device structures. While thin film, wafer inspection and metrology solutions are evolving to keep up with new device dimensions and applications, the new challenge is taking on the increasingly 3D nature of structures as well as 2D materials. To meet the needs of these new materials and devices analytical technologies based on optical, X-ray, electron beam and scanning Atomic Force Microscopy (AFMs) techniques will be required.

Node shrink[*1] : Refers to the reduction in distance between the Source and Gate in a transistor. The source provides electrons, while the drain collects them.
2D materials[*2] : A new family of materials characterized by a one-monolayer thickness (the size of one atom), such as Carbon Graphene.
2D transistors[*3] : Transistors composed of two-dimensional materials, offering efficient electron transfer and high flexibility.

* Editorial note: This content is based on HORIBA's investigation at the year of issue unless otherwise stated.