Smart Systems Integration in the era of Solid State Lighting

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Smart Systems Integration in the era of Solid State Lighting

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Abstract: In this paper we present the integration work currently ongoing in the area of Solid State Lighting. The research addresses compact and complex system integration and reliability. The major research activities are 3D wafer level integration; advanced packaging level integration (SiP); control and interface engineering of complex systems; design for component, product and complex system reliability; fast reliability qualification and testing. As one of the leading research groups for Solid State Lighting (SSL), our group develops generic technologies for SSL and other micro/nanoelectronics systems. In the presentation we will give an overview of the past and future work and our view on the relevance to the lighting industry.

1 Introduction

Nowadays the lighting industry experiences an exponential increasing impact of digitization and connectivity of its lighting systems [1]. The impact is far beyond the impact on single products, but extends to an ever larger amount of connected systems. Continuously, more intelligent interfacing with the technical environment and with different kind of users is being built-in by using more and different kind of sensors, (wireless) communication, and different kind of interacting or interfacing devices. Figure 1 gives two examples towards these controlled and connected systems, just to highlight the scale of it.

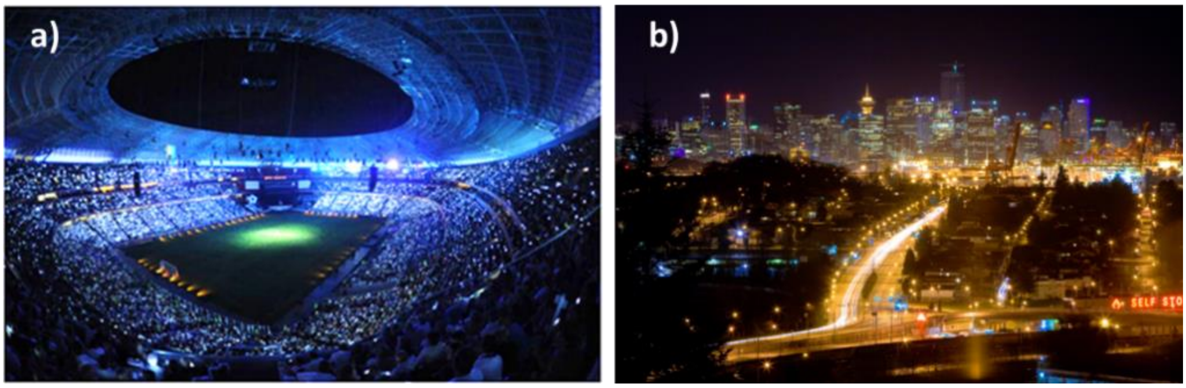

Fig. 1: Two examples of controlled and connected systems, with a) >1000 connected luminaires on one theatre system and b) >10.000 connected street luminaires in one city.

Integration of functions is required to decrease the complexity of the systems and still offer the new functions. Integration in solid state lighting is optional at all levels, see also Figure 1.

1. Integration on chip level (L0)

Here, different functions are integrated be it CMOS with EPI or more. Either by stacking them (so called 3D ICs) or by creation in one technology (monolytic integration).

2. Integration on package level (L1)

Here function are integrated into one package, most common is to create 3D packaging solutions. This level of integration can also be achieved by stacking packages on top each other.

3. Integration on board level {L2)

Commonly available is the driver-on-board technology where the LED engine is combined with electronics resulting into a mains compatible light source. Further integration with sensor technologies or IOT solution is currently under development. Eventually, smart light sources will be the end result.

4. Integration on higher aggregation levels (L3 to L5)

In smart systems or smart cities, the functions in a complex lighting product can be listed as 4 basic properties [2, 3], being the i) traditional lighting unit and its components, ii) the software needed for processing data, iii) a monitoring function for getting this data and iv) the communication to for example the user or the product. Sensors are required for the monitoring function and IoT for communication. It is the software that creates the integration on this level.

With the increasing amount of complexity, it is imperative that the reliability of such systems will enter a next frontier.

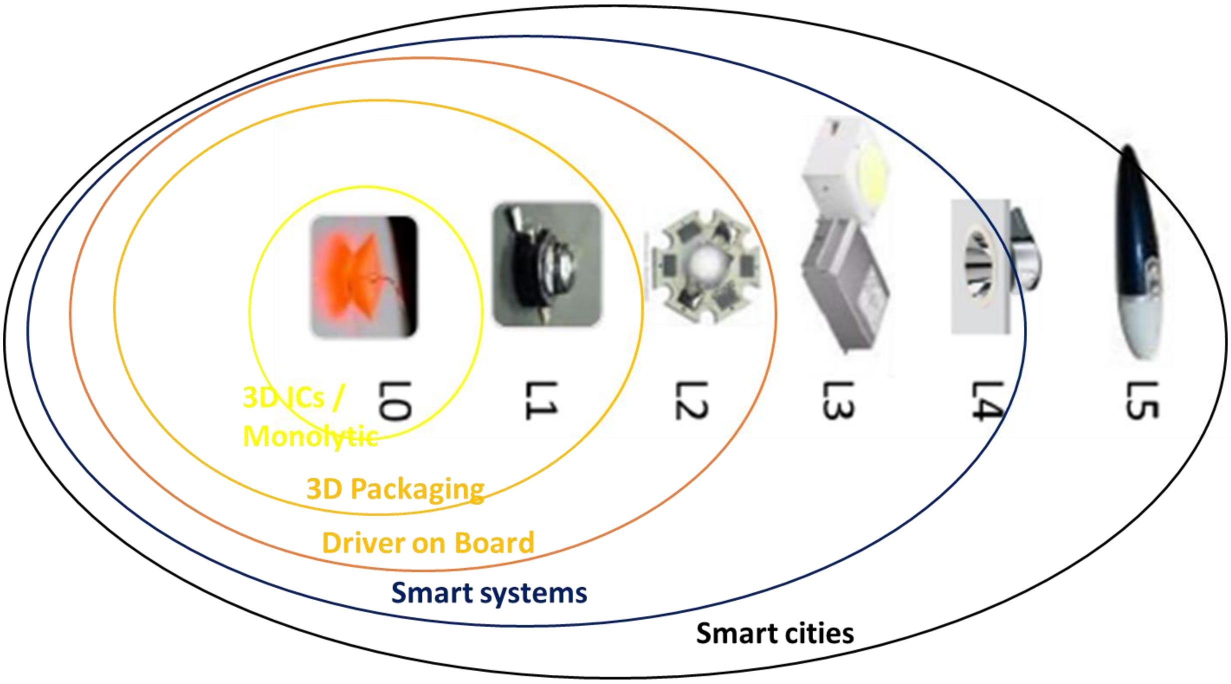

Fig. 2: Levels and integration in solid state lighting.

In this paper and our presentation we will highlight our progress and results for the integration of functions in solid state lighting products. We will focus on the above mentioned items 1) and 2) and only discuss the integration on LED and Package level.

2 3D Smart Wafer Level Package for LEDs

Besides the increasing use of LEDs for various application, there are different reliability issues for LED systems such as change in brightness and color temperature due to high working temperature and aging. So system performance monitoring and further control options become more essential. In addition Silicon based wafer level packaging can be a promising way to integrate different smart functions to LED system and furthermore use wide benefits of silicon technology. To address such issues a new monolithic package is introduced [3 - 7]. All the steps are just done in a few mask step BiCMOS process, which is optimized for performance of different passive and active components. To monitor the system performance, temperature and light sensing elements are integrated. To control the performance of the package light feedback and sensor readout circuits are designed and fabricated. This process flow integrates simultaneously the photodiodes, the CMOS and BJT transistors and feedback and sensor readout circuits. This IC includes several functional devices for a smart wafer level LED packaging. In 3D version of the package the Aluminum coated cavity is used as a local reflector cup and high aspect ratio interconnects are used for supplying LED power. Having different kind of sensors in the same package with LED chips and readout circuit can be an appropriate demonstrator for different applications such as biomedical diagnostic devices. Figure 3 presents a view on the integrated device.

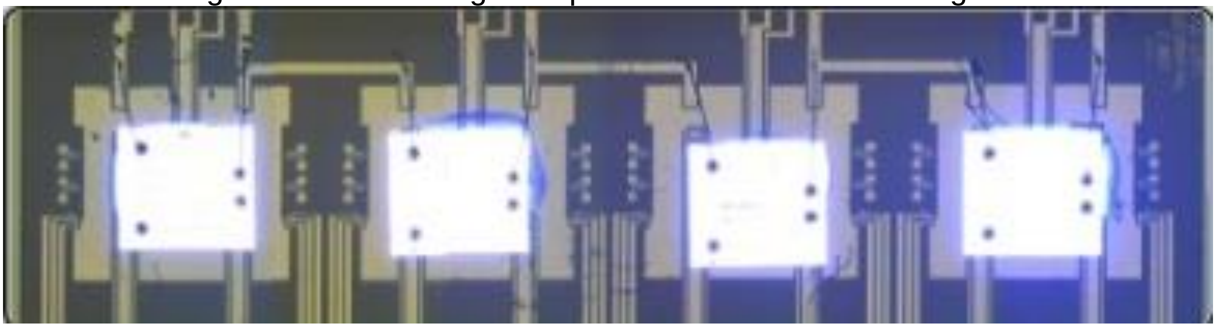

Fig. 3: View on the 3D Smart Wafer Level Package for LEDs

3 Integration with more sensor functions

A multi sensors system for real time air quality monitoring mainly include one or more gas sensors for target analyses such as CO2, CO, H2S, volatile organic compounds (Benzene, Toulene, Formaldehdye), temperature sensor, humidity sensor, barometer and microcontroller based data processing unit. In wireless sensor network, wearable and mobile devices there is a need for miniaturization of this multifunctional sensor modules that can be easily integrated within a small footprint. Silicon based MEMS technology offers benefits such as miniaturization, CMOS compatibility and low cost mass manufacturing. MEMS based metal oxide sensors (MOX) mainly consists of a SnO2 (Tin oxide) functional material deposited on micro-heater. Oxidized and reduced gases react with this layer at temperature of 300-400°C to produce a resistive change which is measured by the electrodes on the micro-heaters. However during gas sensing parameters such as temperature, humidity and air pressure play a significant role in quantifying the gas being measured. The variations of these parameters must be taken into account during calibration and measurements. The microcontroller functions as the processing unit to perform such component analysis and also provide automatic recalibration periodically. Although sensors for temperature, humidity, MOX and air pressure are fabricated using MEMS technology they are used as individual components on a printed circuit board that have constraint in space limited devices. In order to solve such integration issues, we can look into two methodologies such as packaging level integration (2D) and 3D integration implemented using through silicon vias (TSV). In packaging level integration, a lead frame forms the base where MEMS dies of micro heater (MOX) temperature and humidity sensor, air pressure are die bonded. These individual dies are wire bonded to ASIC that provides analog read-out and processing unit for control algorithms. After the wire bonding process, film assisted molding techniques are used to encapsulate and package using epoxy mold compounds. The molding process is specially developed for these MEMS devices to protect the sensing layers of micro-heater gas sensor, humidity sensor and barometer to enable an open cavity for exposure to environment. The second methodology of 3D integration mainly comprise of stacking the MEMS sensors using silicon as sub mount with interconnect define using through silicon vias (TSV). Using lithography solder bumps are defined on the silicon and the MEMS devices are flip chipped on these patterns. The lithography defined through silicon via (TSV) patterns enable connection to ASIC dies on the back side of the silicon-sub mount. The through silicon vias uses electro-plated copper layers or nano-copper paste as conducting layer. 3D stacking of devices allow further miniaturization of the multi-sensor modules.

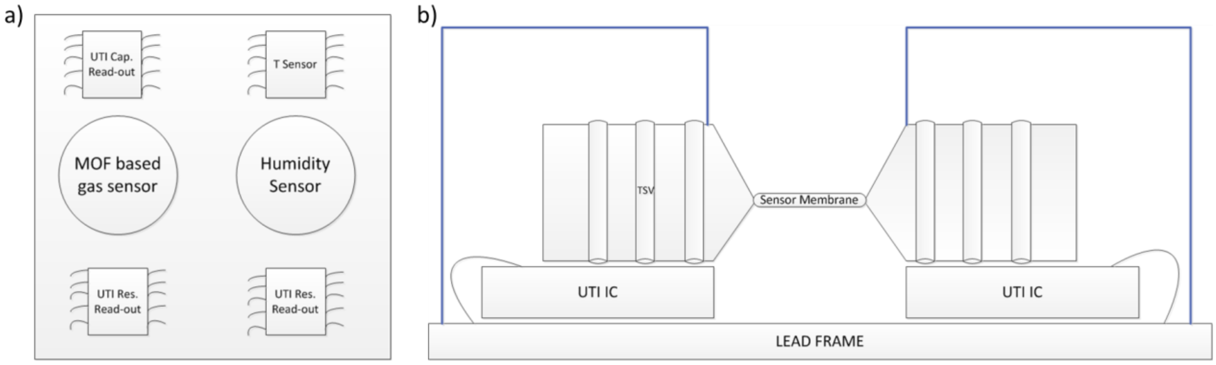

Fig. 4: a) 2D and b) 3D concepts for Multi Sensor System Integration.

4 Conclusions

Heterogeneous integration of a wide variety of micro/nano devices, components and technologies bridges between micro/nano technologies and macro-scale applications. There is a variety of possibilities to integrate on system level, either in hardware or in software. In this paper and in our presentation we highlight our work in this area and how it can serve solid state lighting applications.

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