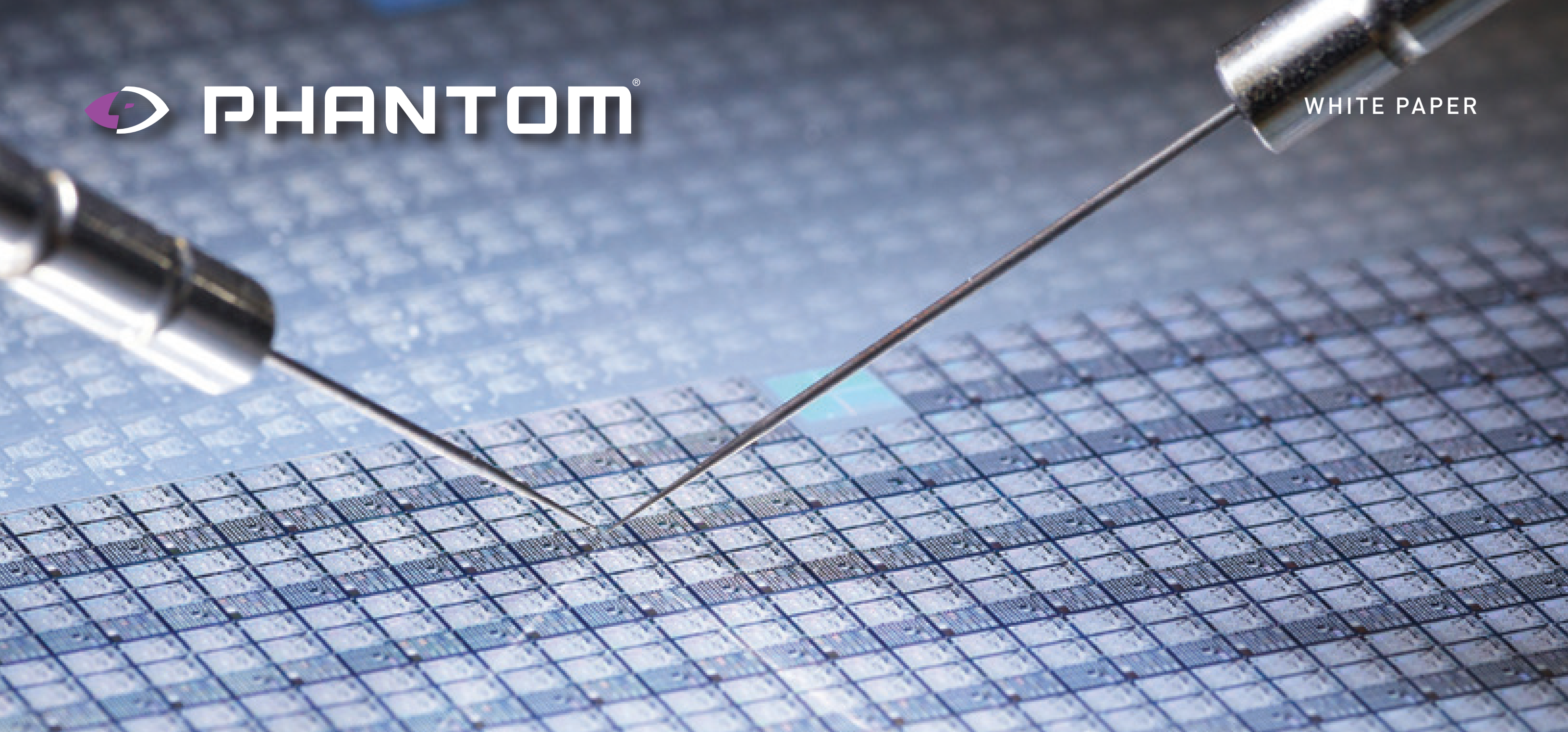

PHANTOM

WHITE PAPER

Optical Semiconductor Inspection Using Phantom High-Speed Machine Vision

Learn how to increase inspection speeds up to three times without compromising the quality of test results.

Optical semiconductor inspection presents complex challenges, including the diminutive size of the target and proximity of individual dies in the wafer space. At the same time, the quality of wafer inspection results is critical due to the risks involved if requirements are not met. For these reasons, vision systems with exceptionally high speed and resolution capabilities can play an important role in semiconductor inspection.

One example of a camera that excels in this area is the Phantom S640 — a CoaXPress high-speed machine vision area-scan camera that streams data directly to a backend machine for processing. The nature of semiconductor inspection requires robust image processors, such as graphics processing units (GPU) and field-programmable gate arrays (FPGA), as well as high-end and powerful central processing units (CPU) depending on the configuration and required throughput.

This paper addresses the challenges that can arise during the semiconductor inspection process, including reticle inspection in patterned and unpatterned wafers, the identification and flagging of deformed wires, and the presence and absence of features. It also explores the benefits of the Phantom S640 in maintaining uncompromised resolution and speed in optical machine vision inspection.

DEVELOPED BY:

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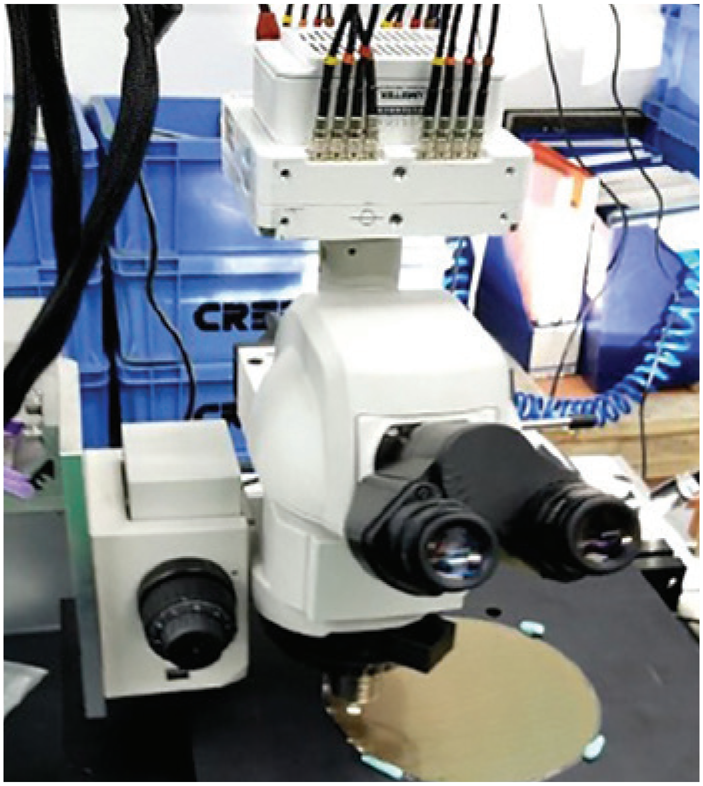

Figure 1. Phantom S640, a 4 Mpx Machine Vision camera, mounted on a Nikon microscope equipped with a 5x magnification scanning wafer on an Anti-Gravity table. The Field of View (FOV) of the sensor was reduced to 1920 × 1100 with an exposure time of 100 µs and 2500 fps speed. The Anti-Gravity floating table is set to scan the wafer at 300 mm per second.

THE SYSTEM

The system is comprised of three major components: a high-speed camera, a microscope and an air bearing X-Y stage to safeguard Z-axis movement of the wafer. As shown in Figure 1, a Phantom S640 4 Mpx (2560 × 1600) Machine Vision camera is integrated with a Nikon LV-M microscope. Both camera and microscope were mounted on an HybrYX air bearing stage to isolate any movement in the Z-direction. The air bearing stage helps to avoid any inconsistency in depth of field (DOF) of die that might skew the focal length of the lens. For this particular test, the Field of View (FOV) of the sensor was reduced to 1920 × 1100 pixels with an exposure time of 100 µs and speed of 2500 fps to meet the inspection requirement. In addition, the air bearing stage's X-axis speed was set at 300 mm per second and the camera is receiving an external trigger signal from the system controller via a general purpose input/output (GPIO) cable.

CAMERA AND WAFER SYNCHRONIZATION

Synchronizing a single die unit in a two-dimensional moving table with the exposure time of the camera is a critical part of the setup. If accomplished correctly, the result will be consistent image analysis with a defined FOV.

A Phantom high-speed camera allows the use of a GPIO cable to send external signals to the camera for trigger, sync, IRIG and other functions. In this setup the camera was synchronized with the speed of the table in relation to a single die unit, such that the trigger signal aligns with the exposure time of the frame. Alignment with the edge of the beginning of a single die within a wafer is thereby achieved. This precise synchronization of the trigger signal to the camera avoids a scenario in which the camera receives a trigger signal in the middle of a die.

The trigger-in signal should be sent at the beginning of the falling edge of the frame, when the sensor begins exposure — with two consecutive falling edges defining a single frame. A time between a falling edge and a rising edge is an exposure time. Thus, in the synchronization process the falling edge of an exposure time is where a trigger-in and sync signal is sent to the Phantom S640 via the GPIO cable.

The camera begins to capture footage at first edge of the die. Exposure stops when the camera sees the last edge of the die, or before the beginning of the next die. The first edge of the die is synchronized with the falling edge of the frame (the start of exposure time) and the last edge of the die is synchronized with the rising edge of the frame (the end of exposure time) as shown in Figure 2. The camera follows this task repeatedly, scanning the entire wafer. As shown in Figure 3, the key takeaway from this mechanism is that the entire die in a wafer can be precisely scanned in a very short period of time by synchronizing the external signal with the camera to capture an image with intended FOV, perspectives and contrast.

A well-designed Machine Vision system will improve product quality, decrease inspection time and reduce takt. For semiconductor inspection, the faster the cycle time, the more quickly inspection can be completed, which reduces overall process time and production costs.

In our test system, the implementation of the Phantom S640 increased the manufacturing and packaging process significantly by increasing wafer-per-hour inspection from 1 to 2 wafers to 10 to 15. To further analyze the data:

v = 300 mm/s
d = 1600 px × 10 µm = 16 mm
t = d/v = 16/300 = 53 ms/die
Die per wafer = 1000

Total time per wafer = 1000 × 53 ms/die = 53 sec ~ = 1 min

Assume there is 100% overhead time due to software image processing. Cycle time per wafer goes from 1 to 2 minutes.

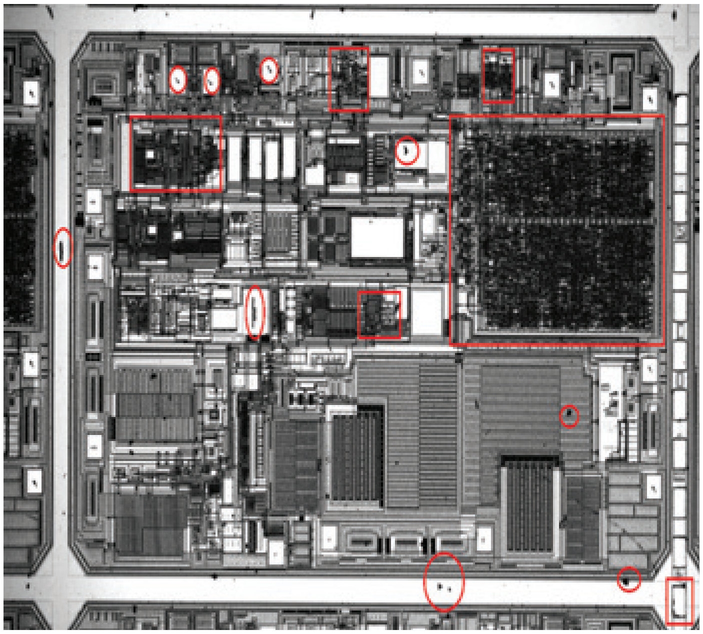

Figure 2. *A single die footage following the setup in Figure 1. The sensitivity of the sensor, dynamic range and SNR will make it a simple inspection task for software to identify foreign objects, damaged parts and any protrusions on the parts.*

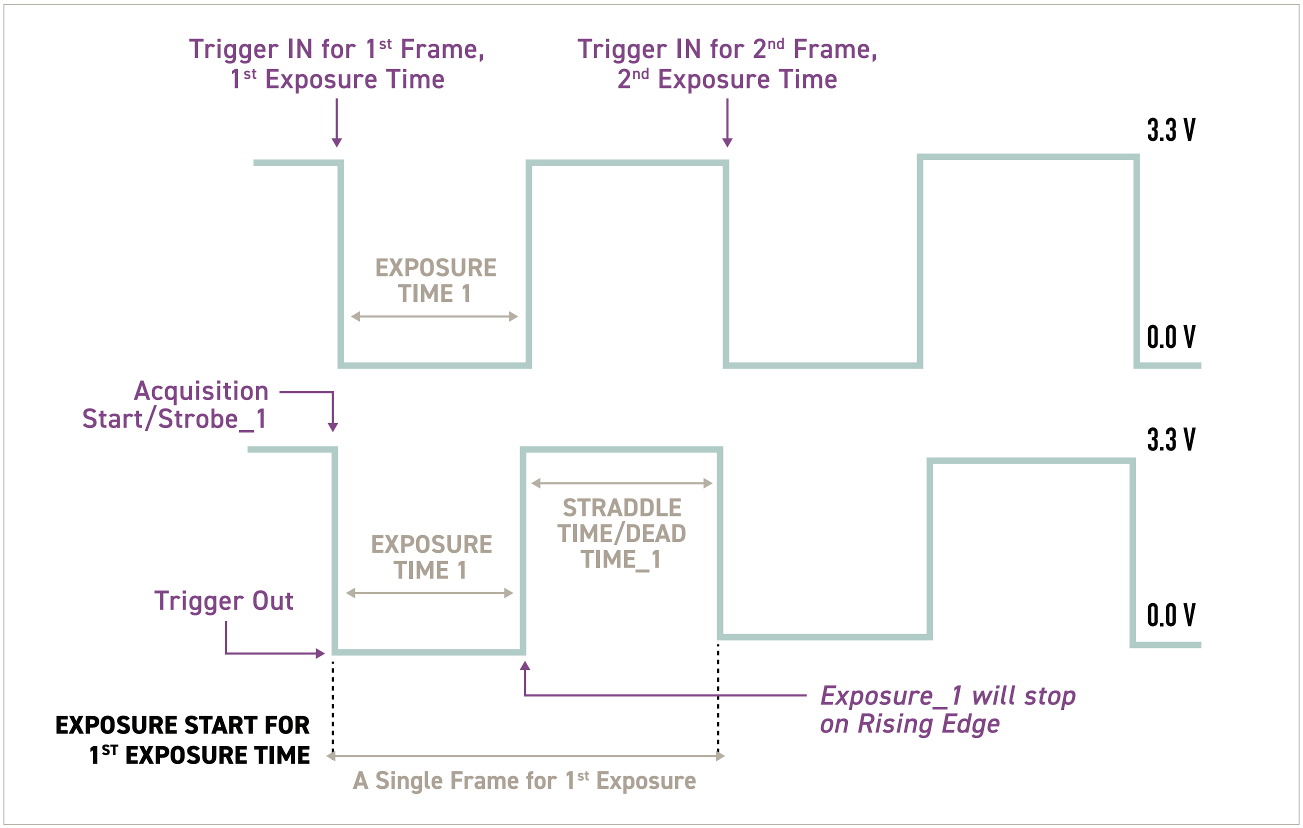

Figure 3. *A trigger-in signal synchronization between Phantom S640 and an external trigger source. Each exposure time of the camera is synchronized with the width of a single unit of Wafer. Such synchronization avoids the capturing of "junk" frames and allows a complete single die unit to be captured in frame.*

The number of wafers the S640 and software can process per hour equals 30 wafers. This is 15 times more than ASML or similar systems can process per hour.

Replacing a line scan camera with a high-speed area scan camera like the S640 reduces takt time and increases yield by increasing the amount of wafer range inspected per given time. In the past, line scan devices have been credited for scanning a larger line range and post-processing stitched images. However, high-speed cameras like the S640 can scan 1,000 times more area than line scan cameras, not to mention that the image is available immediately for processing without an image stitching process.

CONCLUSION

A CoaXPress high-speed camera such as the 4 Mpx Phantom S640 provides superior speed when implemented in semiconductor inspection, increasing quality of product and reducing takt and cost significantly. Previously, a line scan camera was preferred to achieve relatively higher speeds by scanning larger surface areas and stitching lines to form a single frame. The Phantom S640 demonstrates that high-speed inspection of a larger surface area of a wafer can be achieved with a high-resolution area scan camera, which scans significantly faster than a line scan camera. In addition, the CoaXPress interface on the Phantom S640 allows faster image processing, making images available instantly on image processing units such as FPGA of the frame grabber, GPU or CPU.

To learn more, visit www.phantomhighspeed.com/Semiconductor

ABOUT VISION RESEARCH

Vision Research, a business unit of the Material Analysis Division of AMETEK Inc, designs and manufactures high-speed cameras. The Phantom camera brand is known for unparalleled light sensitivity, image resolution, acquisition speed and image quality — necessities for analyzing high-speed events.

Vision Research offers both standard and machine vision high-speed cameras to meet the needs of a variety of industries. Standard cameras with on-board memory from the VEO Series to the TMX Series are perfect for research and development applications. Phantom Machine Vision cameras offer the same high-quality imaging performance for applications that require real time processing or long-record times. They provide the performance needed for challenging applications such as deformation cytometry and detailed electronics inspection.

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