SEE HOW NXP OPTIMIZES WAFER MANUFACTURING WITH VISION-BASED EDGE DEVICES

IIoT 4.0, Industrial IoT or Smart Factories — no matter which term you use, all of them refer to the same goal: increasing the efficiency, reliability, security and safety on the factory floor.

At NXP, we not only design and produce innovative chips that are at the core of the next generation of Industry 4.0 applications, we also integrate Industry 4.0 concepts to increase the efficiency of our factories even further. In this case study, we will show you how NXP is leveraging its own technology in conjunction with Basler's advanced embedded vision technology to create a new visual inspection concept for our factories that can be adapted for others.

USE CASE

NXP has silicon wafer factories around the world. Within each facility, quality and efficiency are at a very high level; however, we continually seek ways to exceed the requirements of the demanding semiconductor market. A typical silicon wafer manufacturing process ends with a delicate packaging process of the wafers in a transport box before they leave the factory, as Figure 1 illustrates.

Visual check after closing transport box | **First: Placement of sticker Second: Wrapping** | **Ready to be taken out of the clean room for shipment**

Figure 1: Last stage in silicon device manufacturing

Once the transport box is closed, before wrapping, an operator performs a visual inspection. This inspection, among others, is meant to detect incorrect positioning of the wafers within the box. This check is crucial in order to avoid issues downstream in the supply if wafers are shipped in the wrong position.

The error rate in the boxing process is very low. As a consequence, an operator rarely encounters an error. With such low rates, natural human behavior leads

to a higher chance that the rare error is not spotted by the manual inspection. As part of our continuous improvement activities, the wafer factory is testing a new concept for automated visual inspection. Automation can add value to our manufacturing efficiency. Automation will also provide evidence of the status of the transport boxes before they leave the factory.

BEHIND THE TECHNOLOGY

To make this initiative a reality, we joined forces with our official partner, **Basler AG**, a leading global manufacturer of computer vision applications. Building on our close collaboration in the development of vision-based edge devices, we were able to take advantage of the strong synergy between our companies. Widely recognized for their extensive expertise on factory automation and embedded vision solutions, Basler was capable of building the complete vision application at hand. In addition to delivering a cost-efficient and powerful vision system, Basler also provides the complete application software to perfectly complement our use case. The powerful industrial-qualified i.MX 8 family of applications processors from NXP ensured the high performance needed to efficiently run the algorithms in real time.

For this specific use case, we integrated a Basler Add-on Camera Kit (**daA2500-60mci-IMX8-EVK**), which comes with a 5 Megapixel dart camera module, cable, lens and a BCON for MIPI to Mini SAS adapter, supporting up to 750 MB/s of data transfer. Additionally, Basler provided optimized drivers specifically designed for easy integration with various **i.MX 8M evaluation boards**.

For the processing platform, we chose NXP's i.MX 8M Mini evaluation board **8MMINILPD4-EVK**, with an industrial-qualified **i.MX 8M Mini Quad applications processor** with four (4)

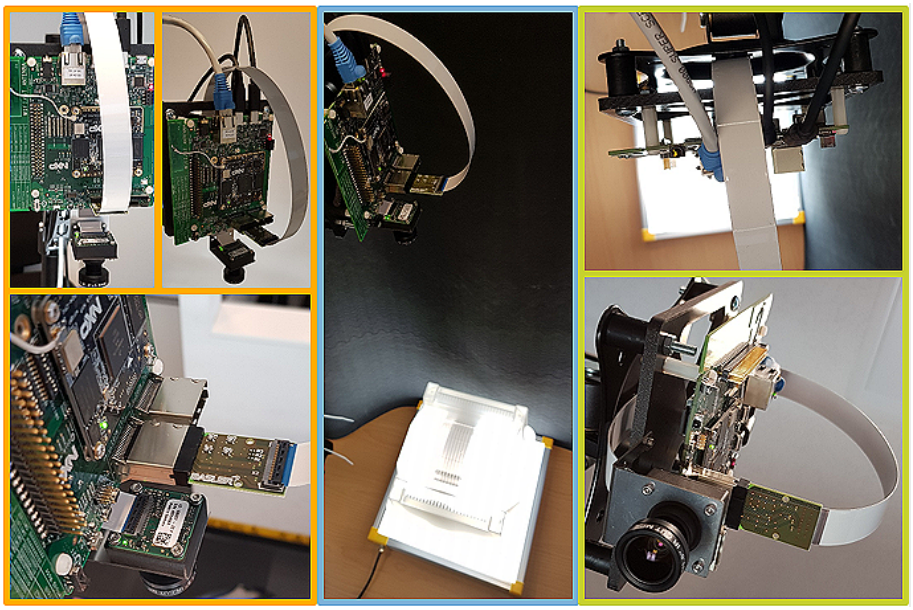

Figure 2: Basler Add-on Camera (daA2500-60mci-IMX8-EVK) with i.MX 8M Mini Evaluation board (8MMINILPD4-EVK)

Arm® Cortex®-A53 cores running at 1.6 GHz for the main CPU platform and one (1) Arm Cortex-M4 core running at 400 MHz as low-power/security CPU, making this board an excellent candidate for efficiently computing image processing routines. Besides, the i.MX 8M Mini evaluation board provides the right peripherals to meet the requirements of this proof of concept. Not only does it support a MIPI-CSI camera mini-SAS connector, but it also comes with a 1Gbit Ethernet port allowing direct communication with the factory's manufacturing execution system (MES). It is a powerd-efficient board and exposes enough digital I/O signals capable of interacting with other devices on the shop floor.

THE PROOF OF CONCEPT

The i.MX 8M Mini evaluation board together with the Basler Add-On Camera Kit was installed at the station where the visual inspection takes place. The applications processor already had running an image processing algorithm tuned by Basler for the specific illumination conditions expected in the clean room. The algorithm uses "classic" image processing methods such as segmentation and blob analysis. To communicate with the MES backend via Ethernet, the application sends/receives JSON messages to/from an MQTT broker.

To start the automatic visual inspection, the transport box with the wafers is positioned on top of an industrial-grade backlight platform, as Figure 3 shows. The Basler camera, connected to the i.MX 8M Mini board, is located approximately 1 meter above the transport box. The applications processor starts the checking process once it receives a message from the MES backend's MQTT broker, or when the operator manually activates a digital input connected to the evaluation board.

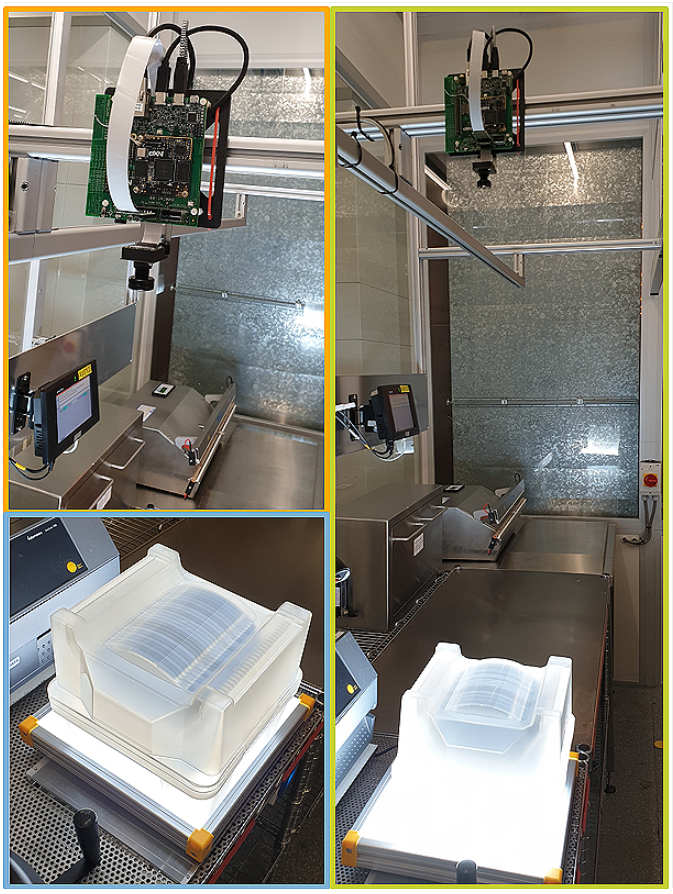

Figure 3: Proof of concept with finished wafer box

Once the image is captured and pre-processed by the Basler camera, in a first step the actual image processing algorithm searches the box in the image and aligns it for the subsequent steps (just in case the box is tilted).

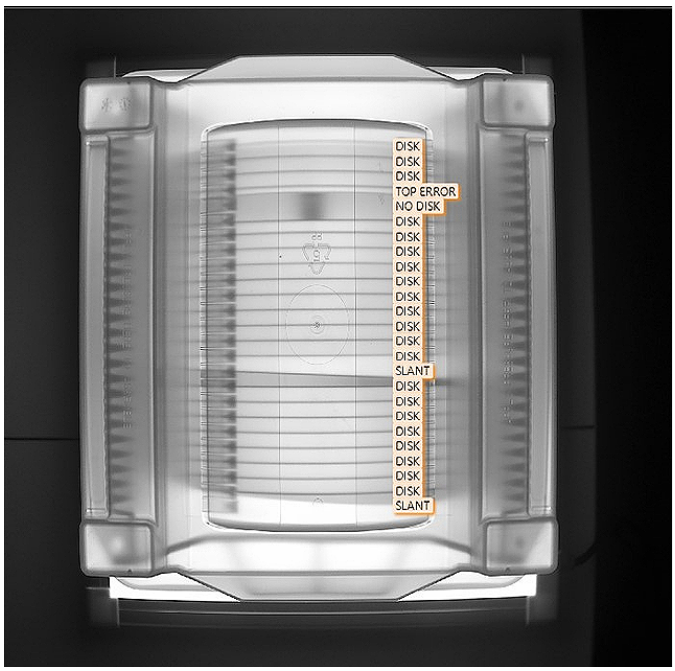

Figure 4: Wafer box centered and aligned to subsequent processing steps, even if box was placed tilted on the backlight

In the following processing steps, the algorithm looks for empty slots as well as for slanted wafer disks or disks not fully inserted into their slots. Additionally, the disks in the box are counted.

As a result of this image processing routine, the i.MX 8M Mini sends an MQTT message to MES with the conclusion of the inspection as follows:

- OK message if there was no wafer in the wrong position or NOK message if at least one wafer was in the wrong position; in case of NOK, a new picture is taken to double-check the first result
- Message with the number of wafers within the transport box
- Message containing an index that identifies what wafers had a wrong position

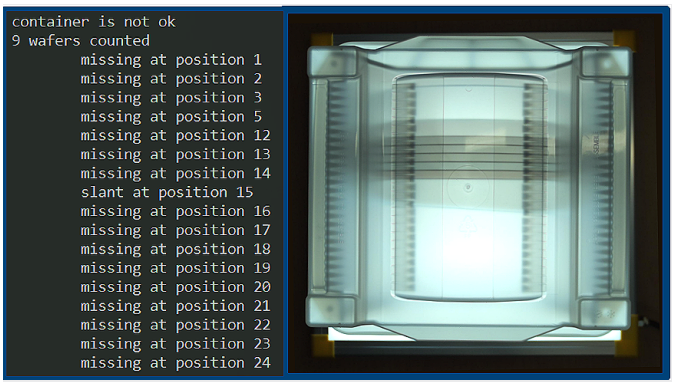

Figure 5: Automatic identification of position errors

Finally, the 16-bit images of the analyzed wafer are sent to the MES and stored for the traceability of the factory's processes.

CONCLUSION

The use of embedded vision technology in factory automation applications is a rising trend with obvious benefits. The ever-shrinking form factor and power consumption, combined with growing processing performance, makes it much easier to substitute big PC-based vision systems with lean and cost-efficient embedded technology solutions.

We are collaborating closely with our partners to bring innovative machine vision solutions to factory automation applications. This automated visual inspection system is only one example of what the strong synergy of NXP and Basler technologies can solve in the area of factory automation.

Please visit our respective websites to learn more about our product portfolios.

- NXP i.MX 8M Mini applications processor: **www.nxp.com/imx8mmini**
- Basler Embedded Vision Portfolio for NXP i.MX 8 applications processors: **www.baslerweb.com/en/embedded-vision/embedded-vision-portfolio/embedded-vision-for-nxp-i-mx-8**
- NXP i.MX 8M Plus applications processor: **www.nxp.com/imx8mplus**

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