Implementation of background scattering variance reduction on the RapidNano particle scanner

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Introduction

The RapidNano is a dark-field particle scanner developed by TNO for the qualification of EUV reticle handling equipment on particle cleanliness[1]. In two development steps the RapidNano technology will be extended to meet the sensitivity for detecting defect sizes given by the ITRS roadmap. The first development, presented here, aims on reducing the background scatter variance. After successful implementation the second step, using 193 nm light, will be made to reach a lower detection limit of 18 nm LSE.

Multiple azimuth illumination

With a recently developed model[2] we calculated a reduction of the variance of the speckle-like background distribution, predicting a lower detection limit of 43nm LSE. On a test bench experimental verification it was shown that the background variance could be reduced by a factor of 9. This reduction is achieved by summing independent speckle patterns that result from illumination from different azimuthal angles[3].

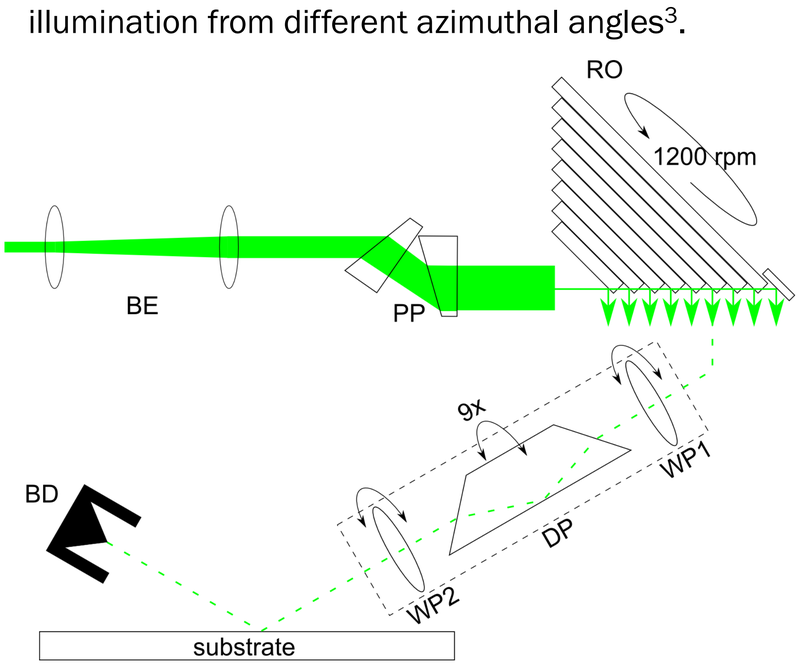

Figure 1: The upgraded illumination system consisting of a beam-expander (BE), anamorphic prism-pair (PP), rotor (RO), half-waveplates (WP1/2), dove prisms (DP) and beam-dumps (BD). The system has 9 copies of the illumination tubes and beam-dumps, oriented in different azimuth angles.

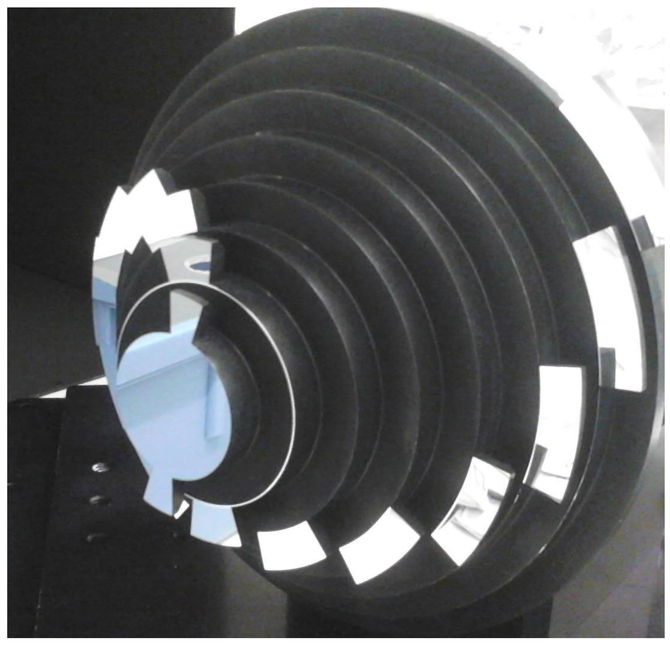

Figure 2: The rotor used to time-multiplex the 9 illumination arms. 16 symmetrical mirrors are on the rotor. Two gaps between the mirrors and a fixed mirror behind the rotor illuminate the 9th arm. The symmetrical design allows the rotor to run at 1200 RPM, illuminating all 9 arms each 25 ms.

Implementation

The RapidNano was upgraded with a 9-arm illumination system with:

- Splitter wheel for multiplexing the arms in time (Figure 2)
- Beam shaping components to homogenize intensity from each arm over the image field (Figure 1)
- Polarization components to optimize transmission and illuminate the substrate with p-polarized light (Figure 1)

Results

Figure 3 shows background histograms for a single beam and the 9 azimuth illumination. The new illumination system decreases the variance of the background histogram by the theoretical predicted factor 9.

Qualification according to SEMI M50 showed a detection limit of 42 nm at 95% capture efficiency.

Conclusion

1. Reduction of the background variance has been achieved meeting the prediction of our model.
2. By using 193 nm illumination detection of particles down to 18 nm can be achieved.

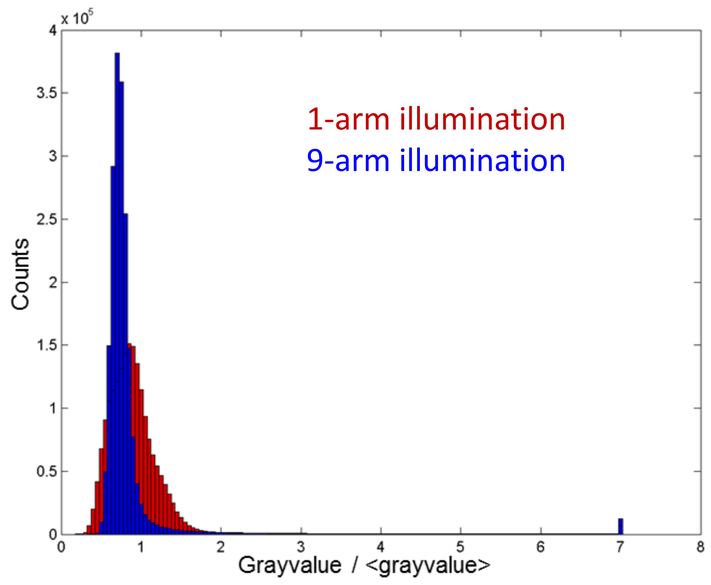

Figure 3: Histograms of the background signal for a single arm illumination and a 9-arm illumination. The variance is a factor of 9 lower in the 9-arm case.

Table 1: Predicted and measured performance of different RapidNano generations.

	PSL on Si [nm]	Al on Si [nm]
RN1: 532 nm, 1-azimuth Predicted	**59**	**35**
Measured	**59**	**35**
RN3: 532 nm, 9-azimuth Predicted	**43**	**25**
Measured	**42**	
RN4: 193 nm, 9-azimuth Predicted		**18**

1. Donck, J.C.J. van der, Snel, R., Stortelder, J.K., Abutan, A., Oostrom, S., Reek, S. van, Zwan, B. van der, Walle, P. van der, "Particle detection on flat surfaces", Proc. SPIE 7969, 1S (2011).
2. Walle, P. van der, Kumar, P., Ityaksov, D., Versluis, R., Maas, D.J., Kievit, O., Janssen, J., Donck, J.C.J. van der, "Nanoparticle detection limits of TNO's Rapid Nano: modeling and experimental results", Proc. SPIE 8522, 2Q (2012).
3. Walle, P. van der, Kumar, P., Ityaksov, D., Versluis, R., Maas, D.J., Kievit, O., Janssen, J., Donck, J.C.J. van der, "Increased particle detection sensitivity by reduction of background scatter variance", Proc. SPIE 8681, 16 (2013).

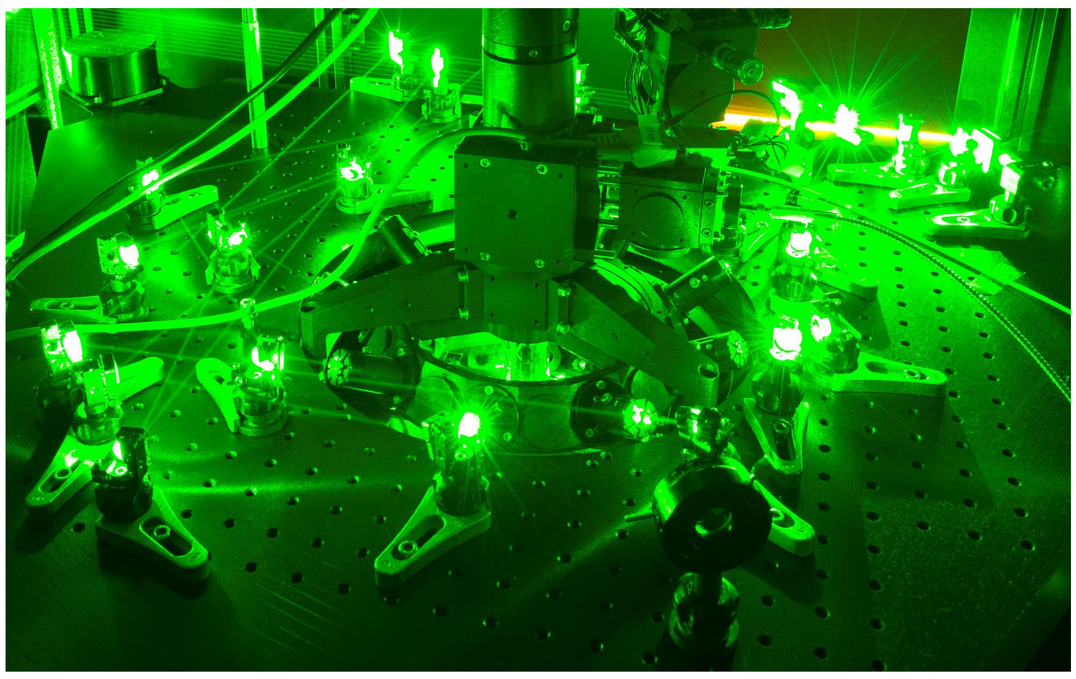

Figure 5: Inside the Rapid Nano with multi-azimuth illumination in operation. In the top left 9 beams enter the system that are distributed over the illumination arms by several mirrors.

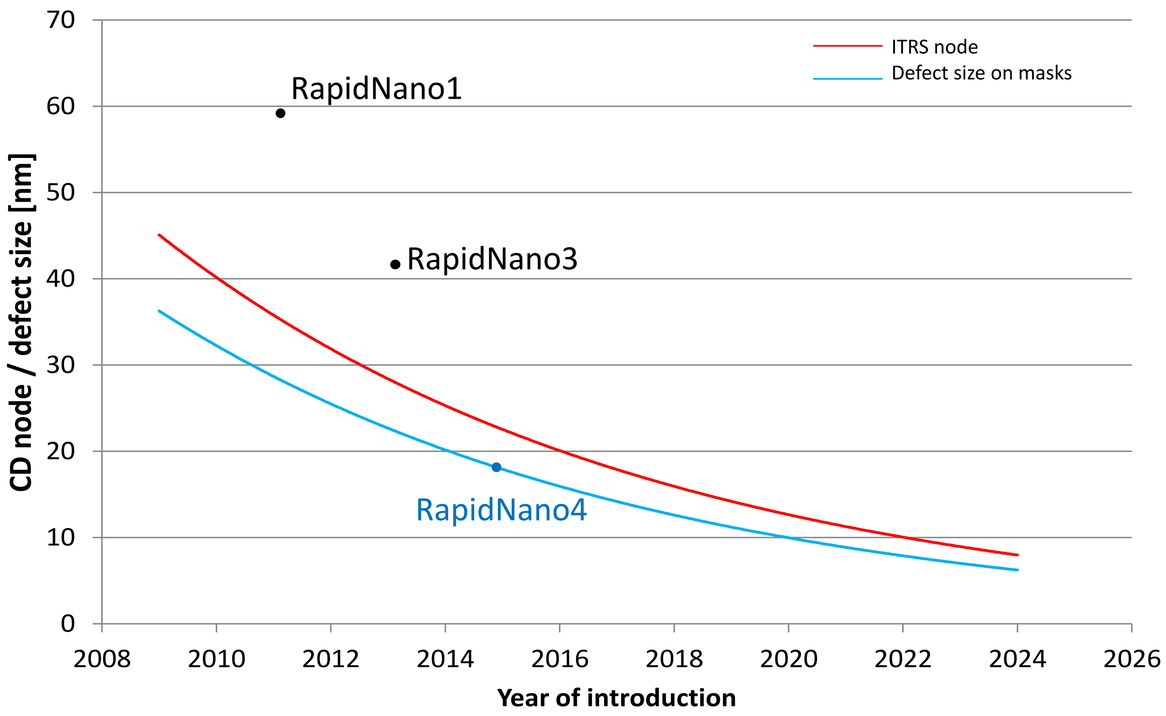

Figure 6: Sensitivity of different generations of the RapidNano particle scanner plotted on the ITRS roadmap for maximum allowable defect sizes.

This work has been performed in the framework of the International Center for Contamination Control, established by TNO. Partners are welcome to join ICCC in the challenging development of dedicated contamination control solutions.