Advanced Defect Classification By Optical Metrology

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Introduction

Particle defects on masks and wafers are major contributors to yield loss in semiconductor manufacturing [1]. RapidNano3 is a fast optical inspection technique for particles larger than 43nm, capable to create defect maps on large area substrates [2]. RapidNano3 (see fig. 1) is used for root cause analysis and qualification on particle cleanliness. Classification of the observed defects supports a root cause analysis and thus shortens improvement cycles.

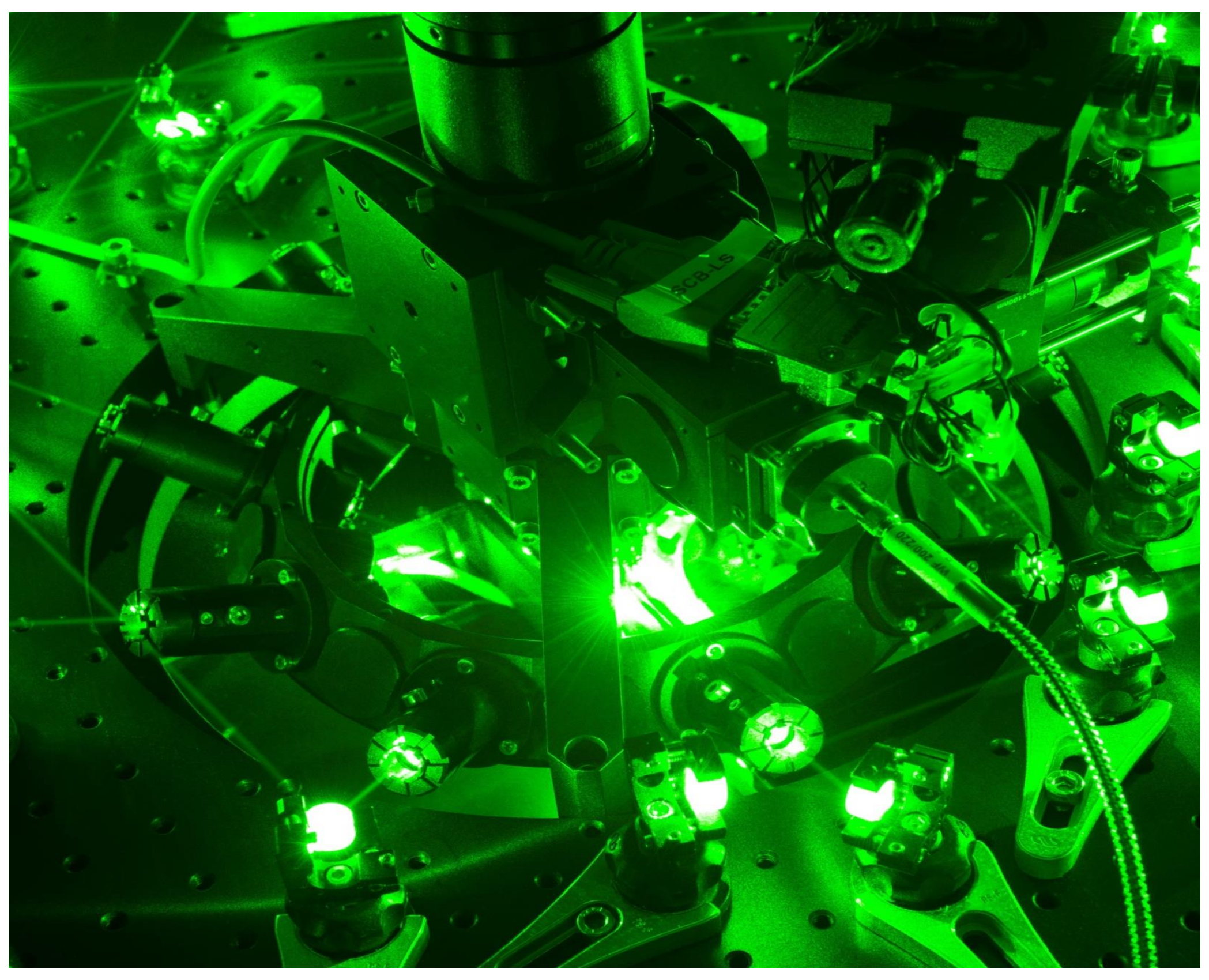
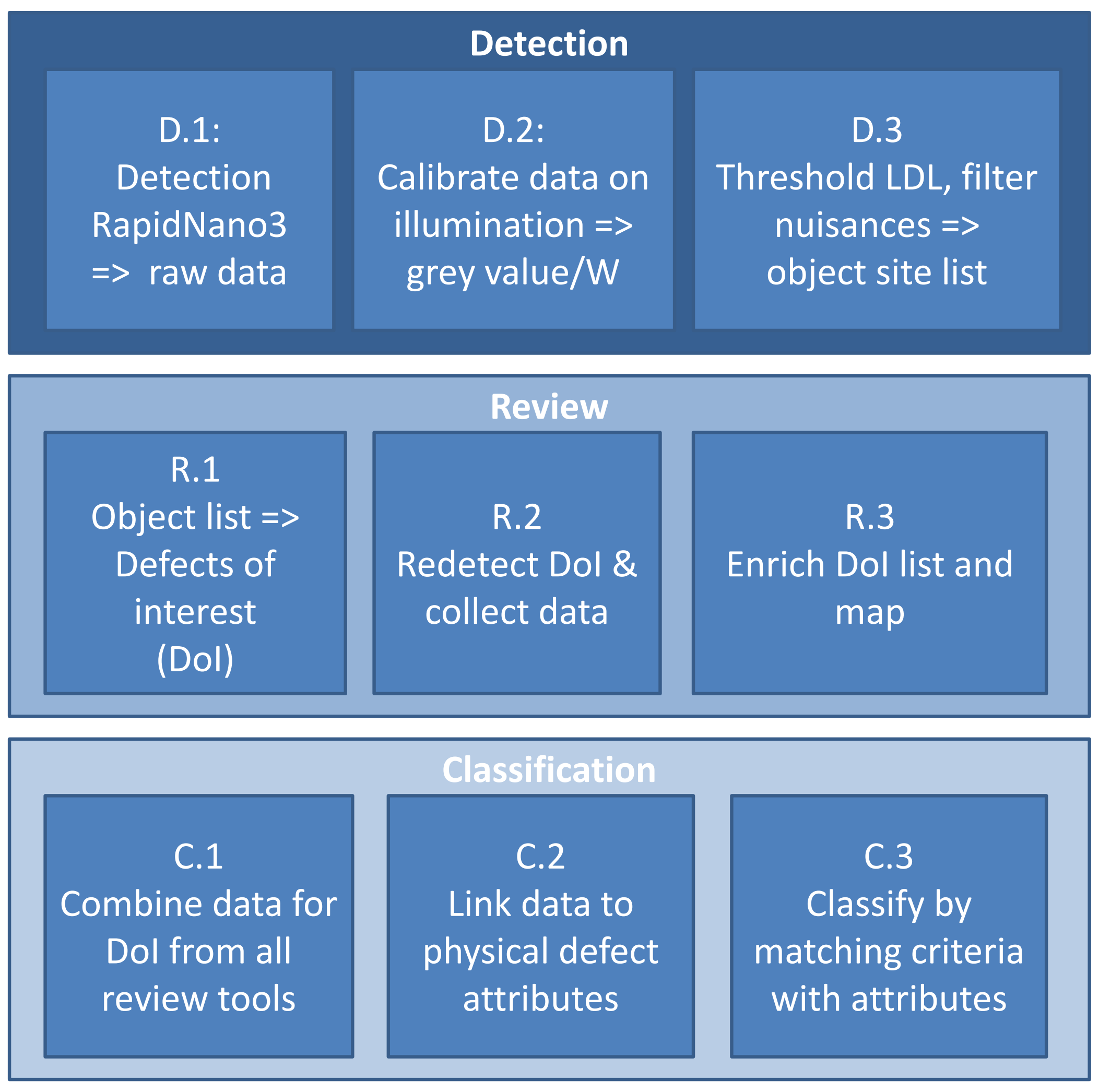


Fig. 1. RapidNano3 setup with 9-azimuth illumination.

Classification approach



Detection

- D.1: Detection RapidNano3 => raw data
- D.2: Calibrate data on illumination => grey value/W
- D.3 Threshold LDL, filter nuisances => object site list

Review

- R.1 Object list => Defects of interest (DoI)
- R.2 Redetect DoI & collect data
- R.3 Enrich DoI list and map

Classification

- C.1 Combine data for DoI from all review tools
- C.2 Link data to physical defect attributes
- C.3 Classify by matching criteria with attributes

Fig. 2. Schematic approach for classification.

Development steps

RapidNano3.1 measures a scatter intensity of defects. It is expected that the scatter intensity of irregularly shaped particles will vary for illumination from different azimuths.

Near-field scattering of defects will be simulated in COMSOL [3]. The calculated field is transferred to the far-field using an open source code [4].

Experimental verification will be carried out by measuring programmed defects (see fig 4) with RapidNano3 and real defects found in our application.

Simulations

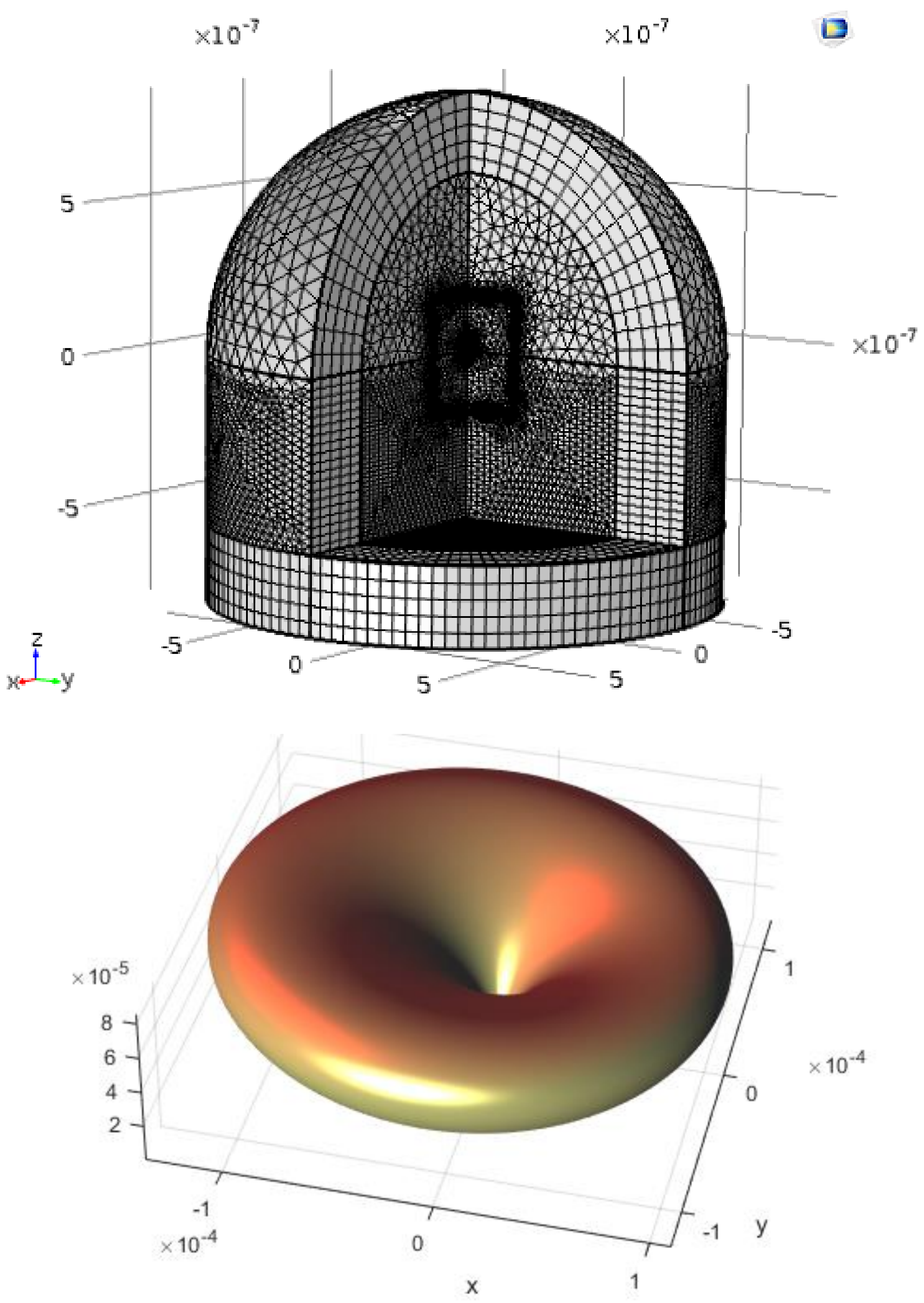


Fig. 3. A numerical model was made in COMSOL [3] to predict the scattering of a spherical defect; geometry and mesh used in the numerical model are shown (top), differential scattering cross section for a 30nm radius spherical gold particle on a Si substrate illuminated by p-polarized light coming in at a 60º angle (bottom).

The model was validated by simulation of the scattering of spherical particles on a substrate as a function of size. The results followed the Bobbert-Vlieger model [5]. This showed that the simulations give valid results. In a next step, scattering of programmed defects will be simulated. In these simulations, the size, shape and orientation of the defect axis w.r.t. the illumination (the azimuth) will be varied.

Experimental validation and results

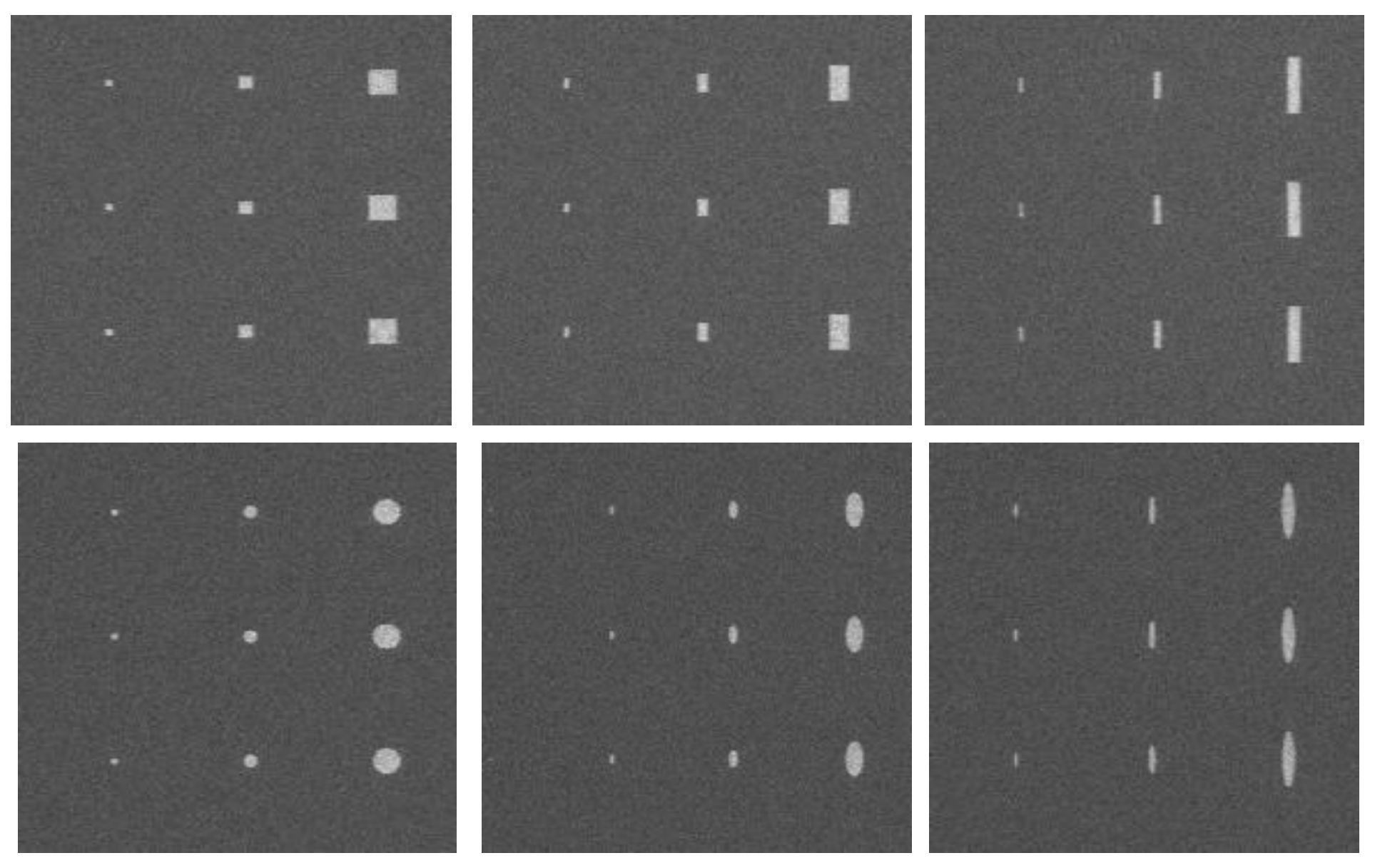


Fig. 4. Programmed defects, gold on silicon (rectangles and ellipses with different aspect ratio).

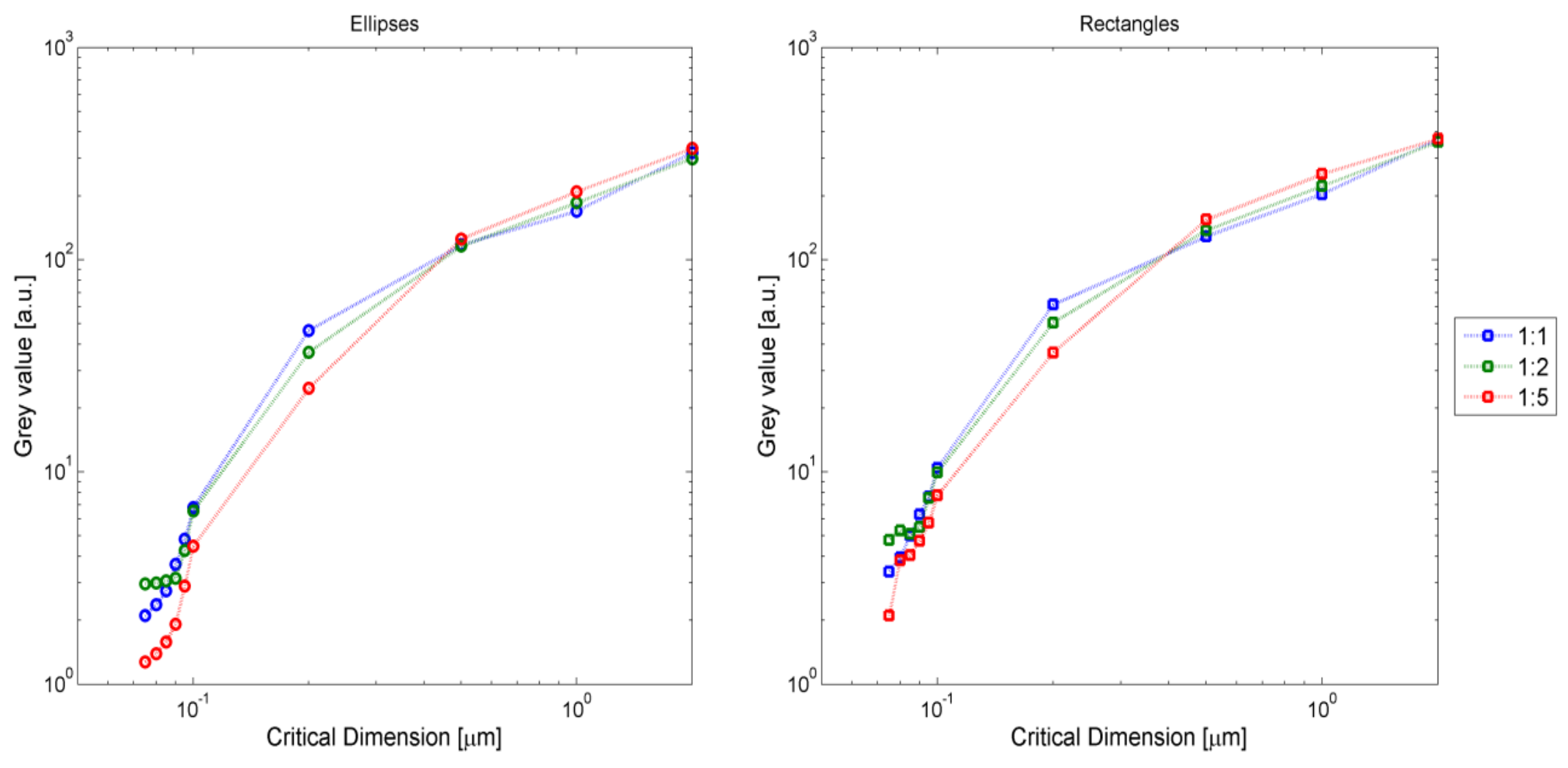


Fig. 5. Scattering of gold ellipses (left) and rectangles (right) for 3 aspect ratios as a function of size. Scattering of large aspect ratios is low compared to high ratios leading to an under estimate in "equivalent sphere" size.

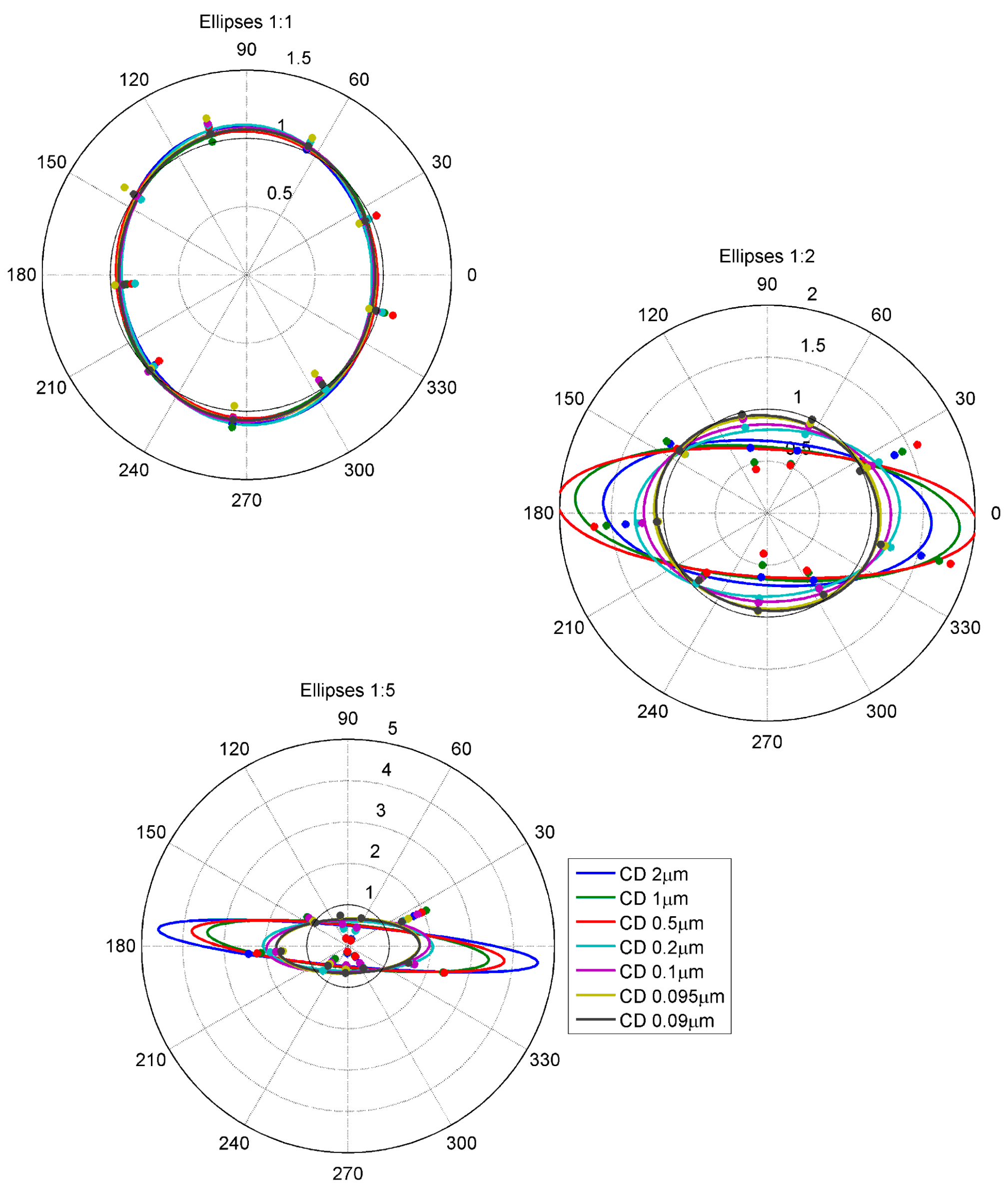


Fig. 6. Polar plot of the normalized RapidNano signal for all 9 separate detection angles from gold ellipses of varying aspect ratios. Repeated for a number of different critical dimensions.

Conclusions

A work flow for advanced defect classification with the RapidNano3 has been defined. Variation in scattering at different azimuths is expected to provide information on particle shape. It was shown that deviations from a sphere have an impact on the measured "equivalent" size. The polar plots of high aspect particles showed clear ellipsoid patterns that can be used to classify defects.

In a next step simulations in COMSOL will be used to model the azimuth dependent scattering of defects.

References

1. Van der Donck, J., Bussink, P., Fritz, E. and van der Walle, P. (2016) ', MRS Advances, 1(31), pp. 2225–2236. doi: 10.1557/adv.2016.299.
2. Van der Walle, P., Hannemann, S., van Eijk, D., Mulckhuyse, W., van der Donck J.C.J., SPIE Proc. 9048 (2014)
3. COMSOL Multiphysics, v5.0, 3D wave optics module
4. J. Yang, J., Hugonin, J.-P, and Lalanne, P., ACS Photonics, **2016**, 3 (3), pp 395-402
5. Bobbert, P.A. and Vlieger, J., Physica **137A** (1986) 209-242

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