Relationship between Normalized Image Log Slope and Exposure Latitude in advanced technodes

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INTRODUCTION

In this paper, a more detailed study is taken in advanced technode to have further understanding on the relationship between NILS and EL. Firstly, we will go back and elaborate this problem with mathematically deduction shown below. As is known, EL is an important metric that shows the process latitude and an important quantity from the viewpoint of the productivity of production lines. EL is obtained according the following definition:

$$\mathrm{EL} = \frac{\Delta \mathrm{CD}}{\mathrm{E}}\frac{\mathrm{dE}}{\mathrm{dCD}} \times 100\%$$

Since E=I ×t, where t is the exposure time. As shown in Figure 1, a cutline is drawn along x direction. EL can be further transformed with CD substituted with x. Considering the difference between dCD and dx, a multiple of 2 is added.

$$\mathrm{EL} = \frac{\Delta \mathrm{CD}}{\mathrm{I}}\frac{\mathrm{dI}}{2 * \mathrm{dx}}$$

Now, it becomes pretty clear that EL can be related to NILS directly:

$$\mathrm{EL} = \frac{\Delta \mathrm{CD}}{\mathrm{I}}\frac{\mathrm{dI}}{2 * \mathrm{dx}} = \frac{\Delta \mathrm{CD}}{2 * \mathrm{CD}}\left(\frac{\mathrm{CD}}{\mathrm{I}}\frac{\mathrm{dI}}{\mathrm{dx}}\right) = \frac{\Delta \mathrm{CD}}{2 * \mathrm{CD}} * \mathrm{NILS}$$

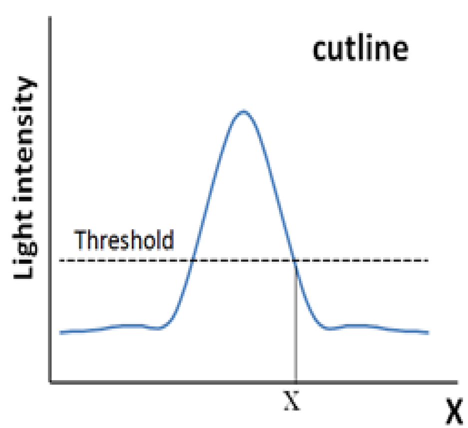

Figure 1 Illustration of cutline for a transparent pattern

In addition, the above deduction is totally based on aerial image, without considering any resist contrast effect. However, it is known that the resist contrast can not be infinite in reality and the response of the resist to light intensity distribution is nonlinear by nature. In order to obtain NILS relationship with EL with resist effect considered, SEM data of a set of patterns is collected and analyzed combining with simulation based on compact resist model.

RESULTS AND DISCUSSION

In this part, two different line-dominated processes are studied, called P-A and P-B. For each process, target patterns are selected with different sizes and environments. According to the definition of EL and NILS, the values are obtained based on the simulation results of a compacted model. To obtain NILS values, cutline for each spot is firstly simulated as illustrated in Figure 1, and then the slope is achieved near model threshold intensity within ±10% CD variation. For EL values, the ADI data under ±2% dose variation is collected on wafer, or simulated with model, and then is used to calculate the EL_wafer and EL_RI corresponsively according to its definition.

PTD process

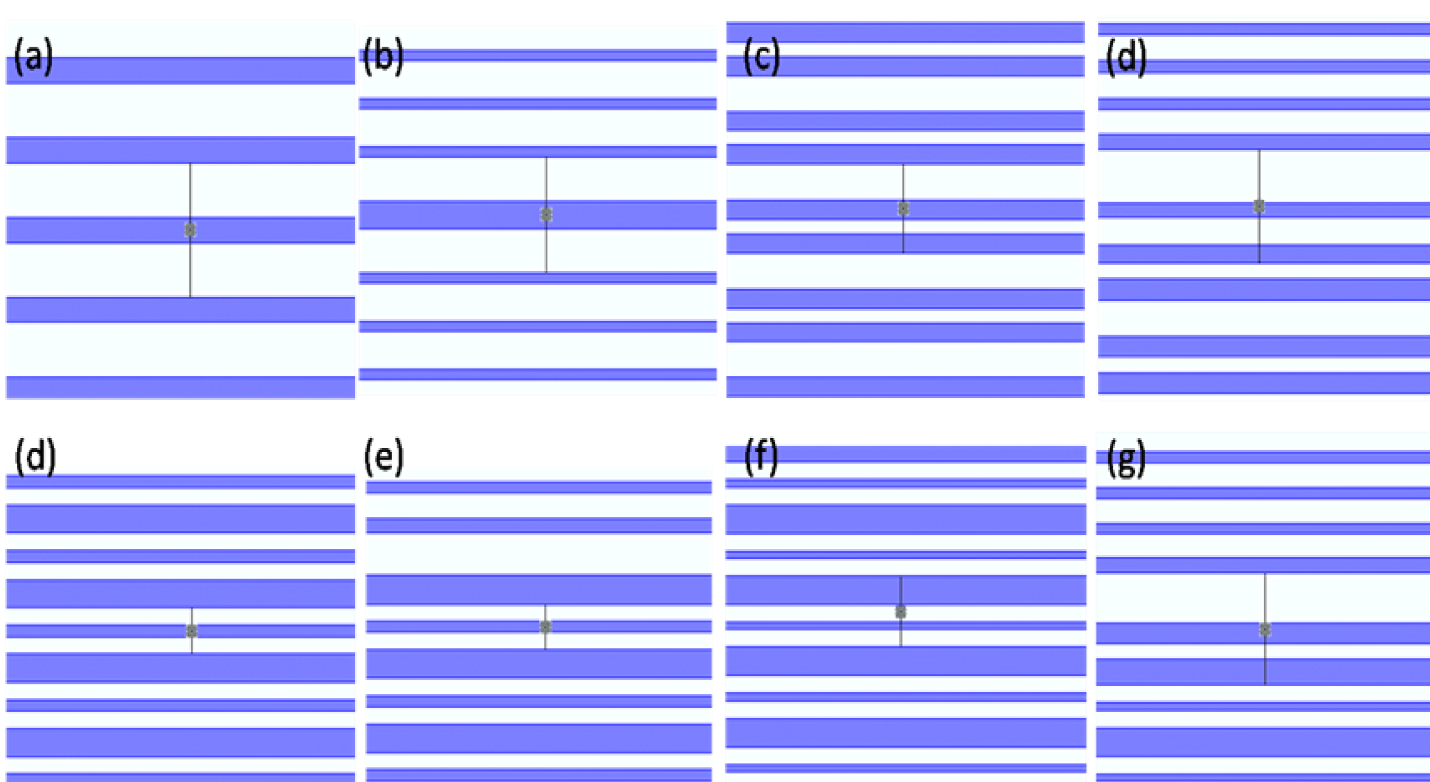

Figure 2 demonstration of several patterns selected for process (P-A)

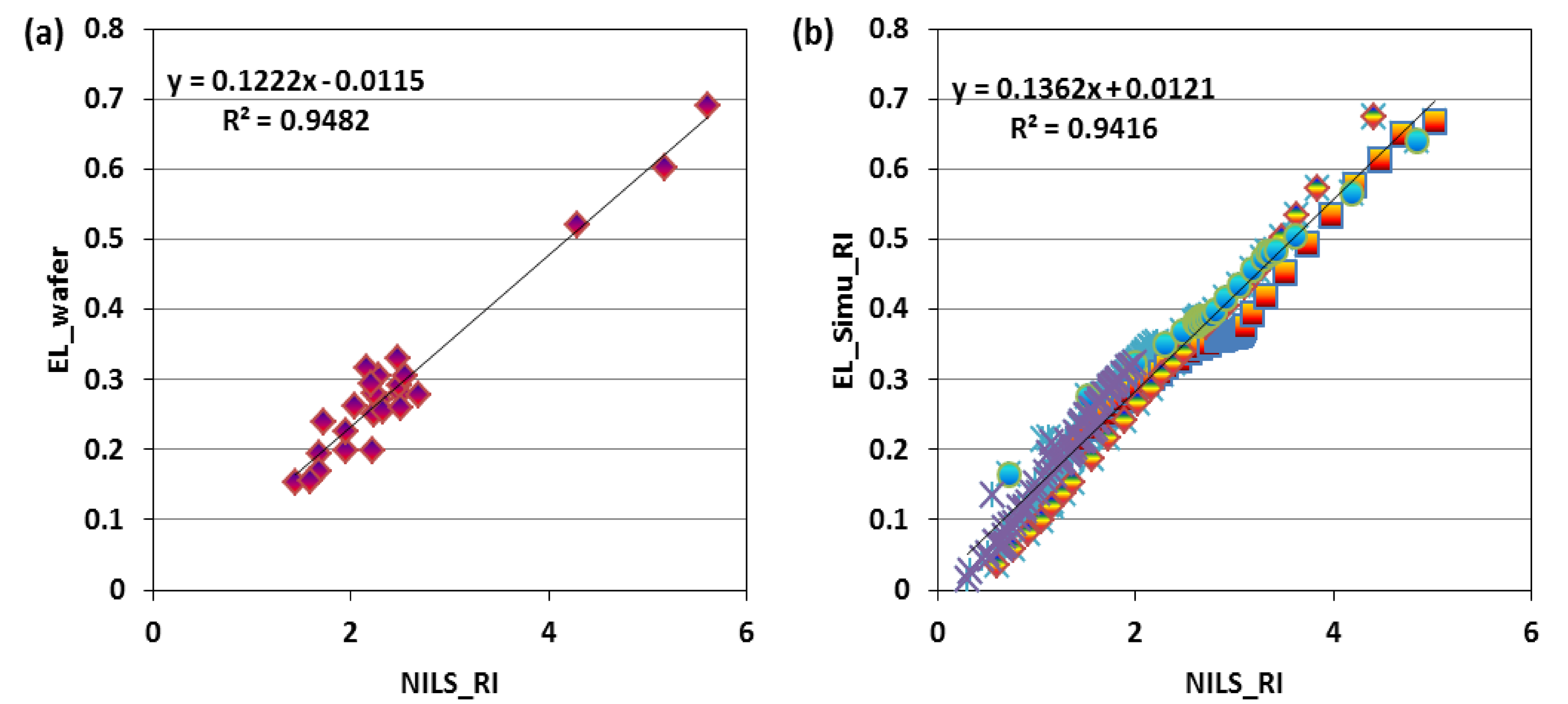

Figure 3 The relation between EL_wafer and NILS_RI in process P-A: (a) wafer results, (b) simulation results of IsoLine, DenseLine, PitchLine and HeadToHead. The fitting is on all patterns.

NTD process

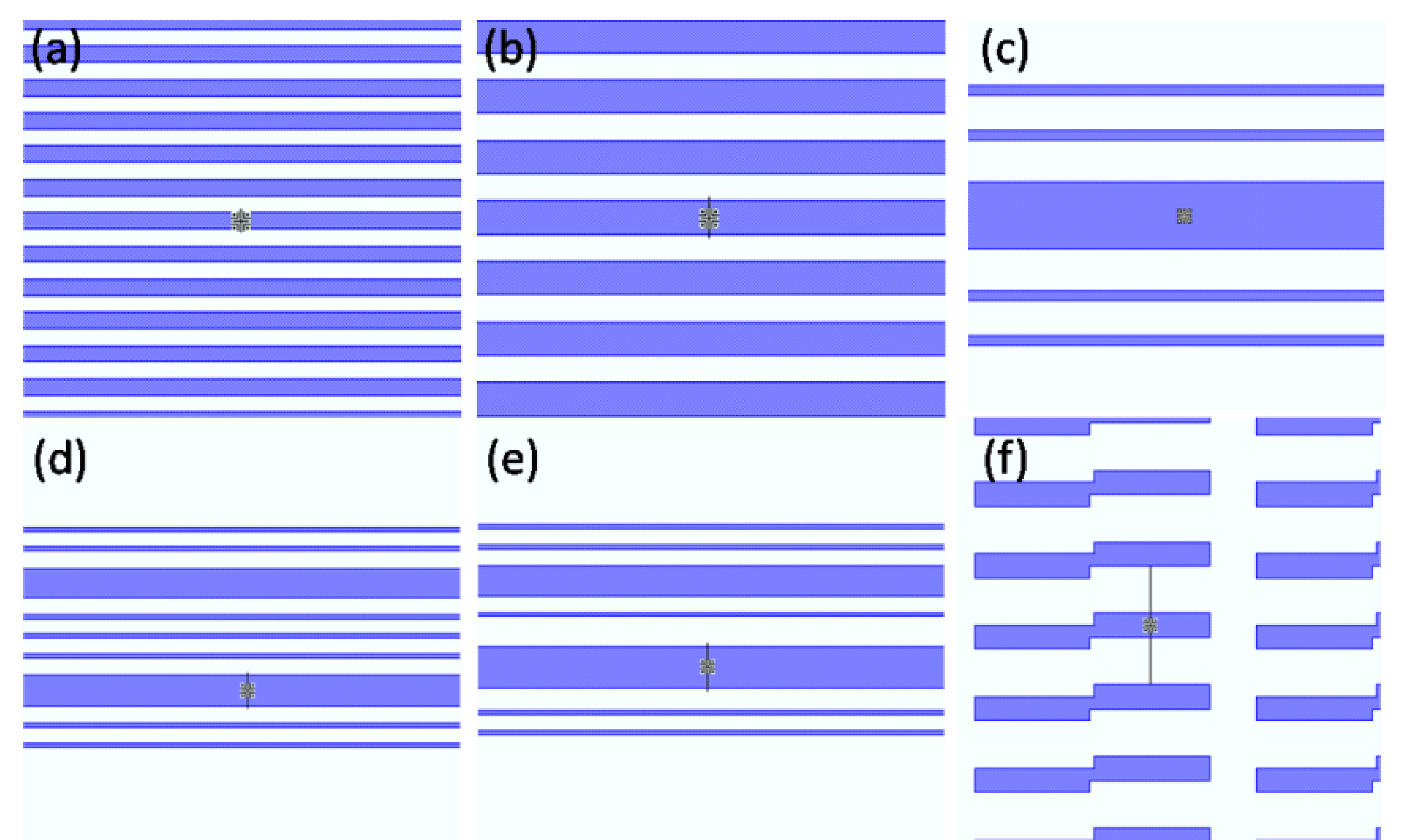

Figure 4 demonstration of several patterns selected for process (P-B)

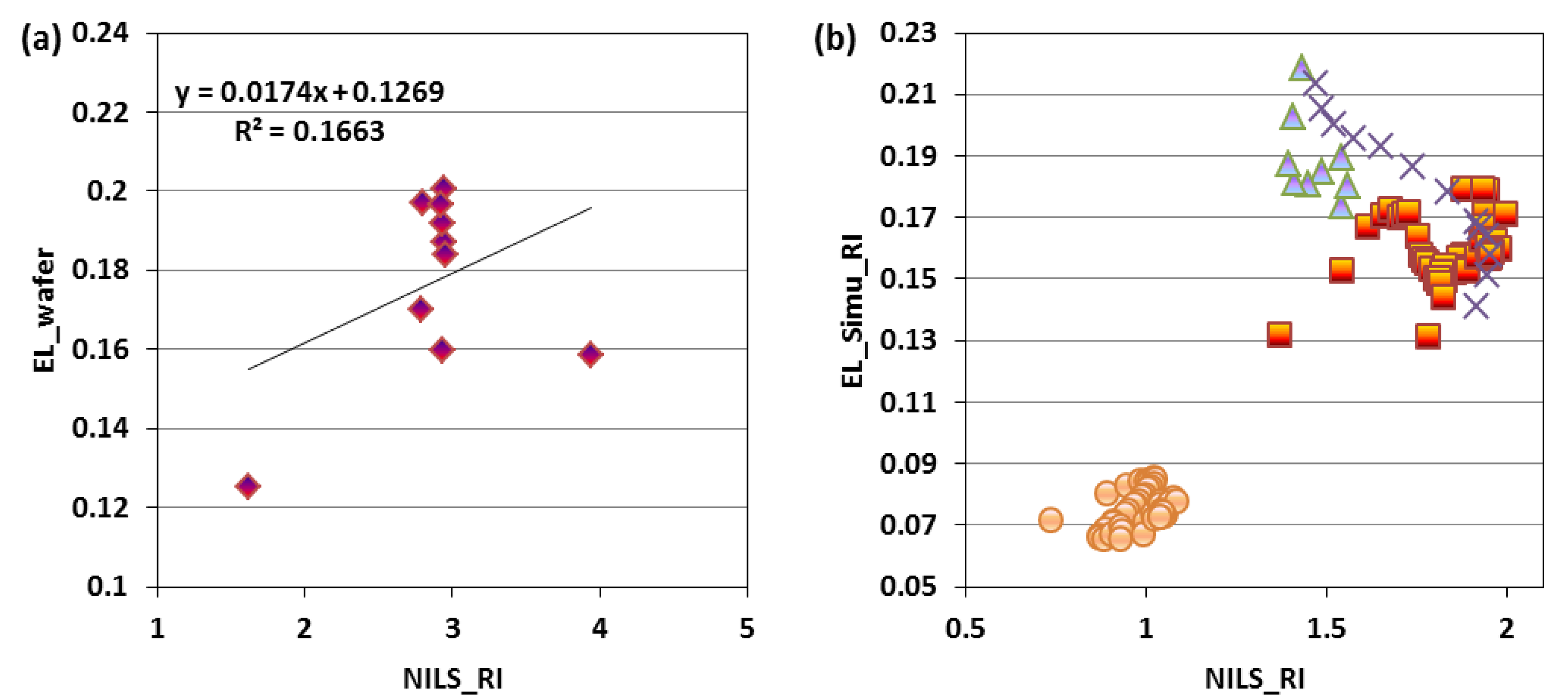

Figure 5 The relation between EL_wafer and NILS_RI in process P-B: (a) wafer results, (b) simulation results of IsoLine, DenseLine, PitchLine and HeadToHead.

CONCLUSIONS

Overall, we can see that a linear relationship between EL and NILS is only proximately true in PTD while the relationship in NTD is much more complicated. Besides, the relationship varies among different pattern type in NTD process. The simulation results of 1D and 2D pattern show that their difference does not show in PTD process, as a matter of fact, the linearity behavoirs are quiet similar between them. In contrast, when it comes to the non-linearity relationship beteen NILS and EL in NTD process, the distribution of different patterns varies form pattern to pattern.

REFERENCES

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