Using Feedforward in On-Product Overlay Run-to-Run Control Loop for Reducing Lot-to-Lot Variation for a MEOL Layer of an Advanced Logic Node

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Agenda

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Introduction
Overlay control is crucial for semiconductor high-volume manufacturing

- Overlay control specification is getting tighter and is posting a challenge to the control strategy during the rapid development of advanced nodes.
- Feedback (FB) run-to-run (R2R) is usually used in on-product overlay control.
  - It requires the overlay of new lots as similar as possible to that of the previous ones.
  - When there are larger lot-to-lot (L2L) or wafer-to-wafer (W2W) variations:
    - FB control has limited effect in correcting the variations.
    - FB control may also introduce noise which makes FB less useful.
- Feedforward (FF) method is investigated in this study for a critical MEOL layer (called layer N) of an advanced node in high-volume manufacturing (HVM) environment.
Overlay variation root-cause analysis
Current overlay trend analysis

- POR (FB only) R2R control of layer N: overlay trend can be divided into three periods.
  - Period 2 shows larger variations comparing with period 1 and 3 under POR control.

- Further analysis indicates that the large variation in period 2 is associated with a mismatch between the HO overlay corrections applied to the overlay bottom layer of the same lot, i.e. layer N-1, and that of the top one (layer N).

Layer N OPO trend (sorted by time): a critical MEOL layer of an advanced node in HVM
PCA analysis shows clear two-group effect for both layers

- The two groups in layer N are in fact propagated from that of layer N-1.
- The temporal stamps (early lots in one group, and later ones in another) indicates a process change early in a process module before layer N-1.

**Wafers are color-coded:**
- Dark blue: wafers processed earliest
- Dark red: wafer processed latest
• By applying FF, R2R simulation shows that the large L2L variations in period 2 are now reduced to the baseline level similar to that in periods 1 and 3.

• R2R simulation shows OPO can be reduced by 19% (a) and re-work rate by a significant 87% (b).
Using feedforward in control loop

Effect of feedforward for lots from the new process

• By using 35 lots of data from new process (i.e. lots in Period 3) for simulation, FF can still improve overlay by appr. 11%.

• This improvement indicates that even when the process is stable, still the HO variations from bottom layer (layer N-1) do propagate to the top one (layer N) which could potentially be resolved by FF control.

General conclusion:
  o If done correctly (depending on the overlay and alignment tree), a feedforward control can help reduce the overlay or at least will not have any negative side-effects.
• FF + FB R2R control loop is implemented in a HVM environment in combination with ASML Litho Insight (LIS) product.
Conclusions

- We investigated a large dataset from a MEOL layer (layer N) of an advanced node, for possible variation root-cause as well as OPO improvement solution.
- It is identified that the large variation is associated with a mismatch between the HO corrections applied to the bottom layer of overlay of the same lots (layer N-1) and that of the top one (layer N).
- FF is demonstrated to be an effective method to compensate this HO correction mismatching from layer N-1 to layer N when doing R2R control.
- Integrating this FF method into fab automation system for R2R control has also been realized. Good overlay results have been verified and confirmed by product wafers.

Real production OPO with FF + FB R2R, see 17% overlay improvement