



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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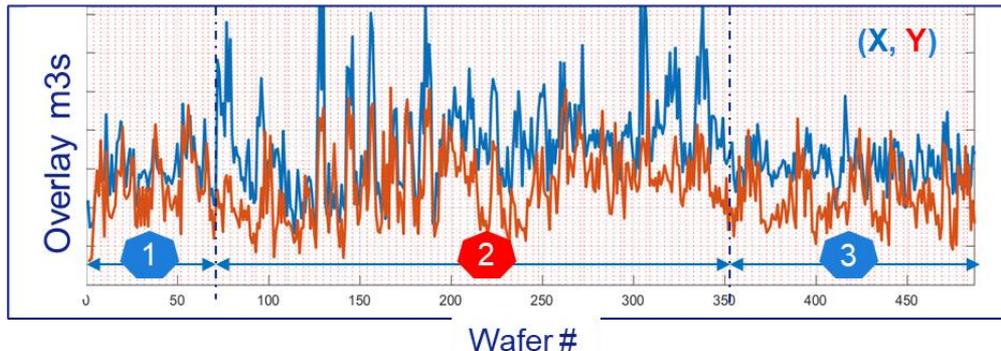


- **Introduction**
- **Overlay variation root-cause analysis**
 - Current overlay trend analysis
 - Principle Component Analysis for grouping effect
- **Using feedforward in control loop**
 - Effect of FF + FB control for lots from the whole three periods
 - Effect of feedforward for lots from the new process
- **Automation in HVM environment**
- **Conclusions**



- 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.





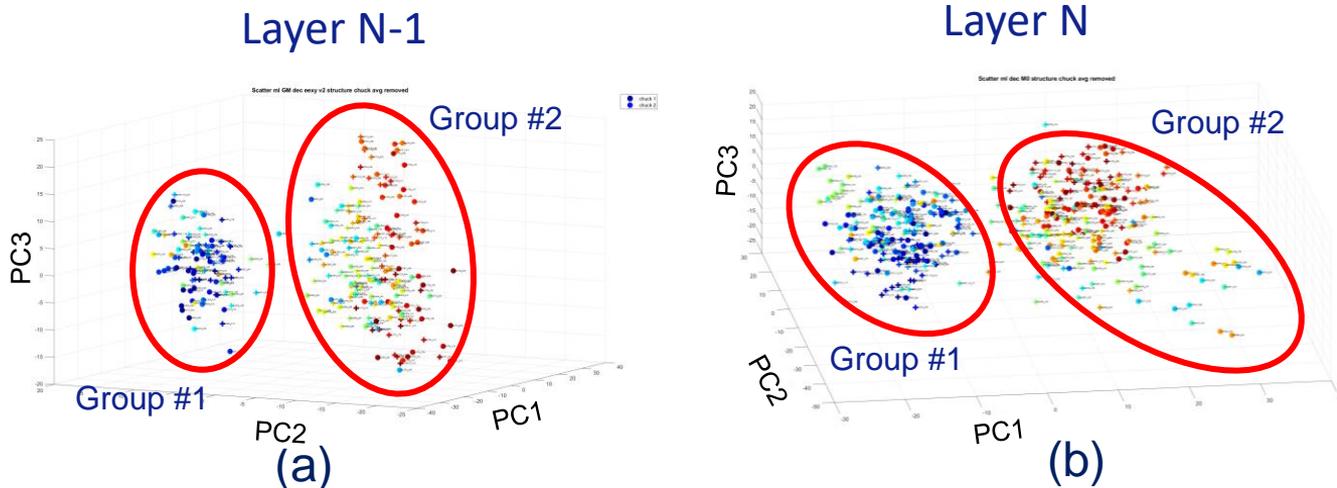
Layer N OPO trend (sorted by time): a critical MEOL layer of an advanced node in HVM

- **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**).



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

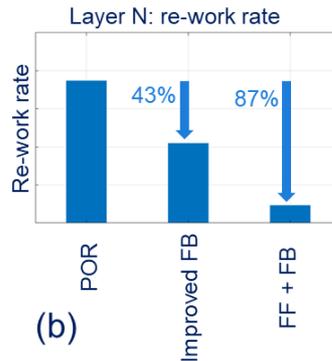
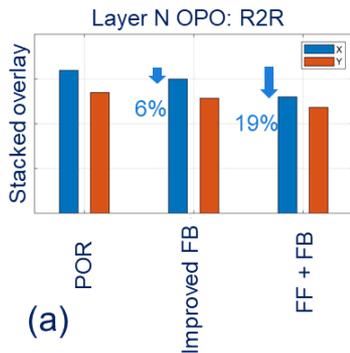
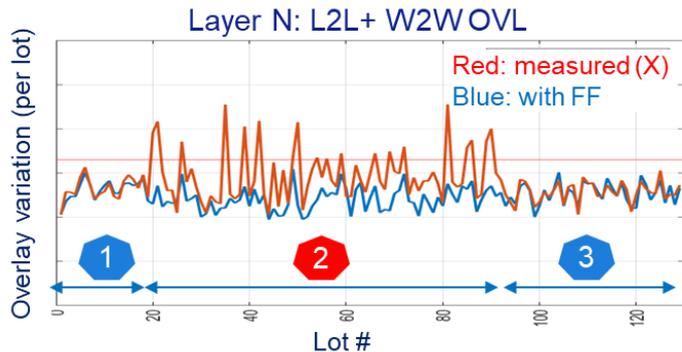
Dark red: wafer processed latest



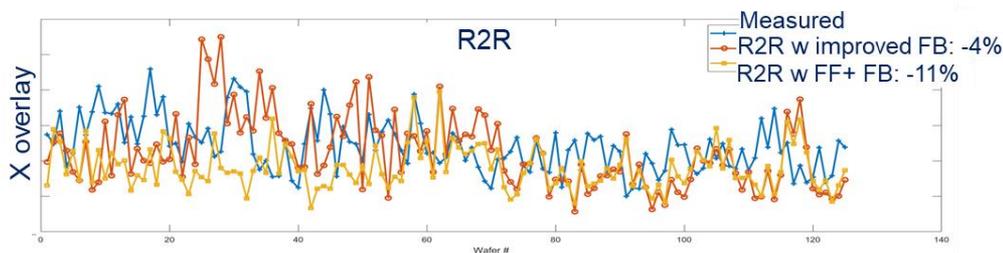
Using feedforward in control loop

Effect of FF + FB control for lots from the whole three periods

- 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).



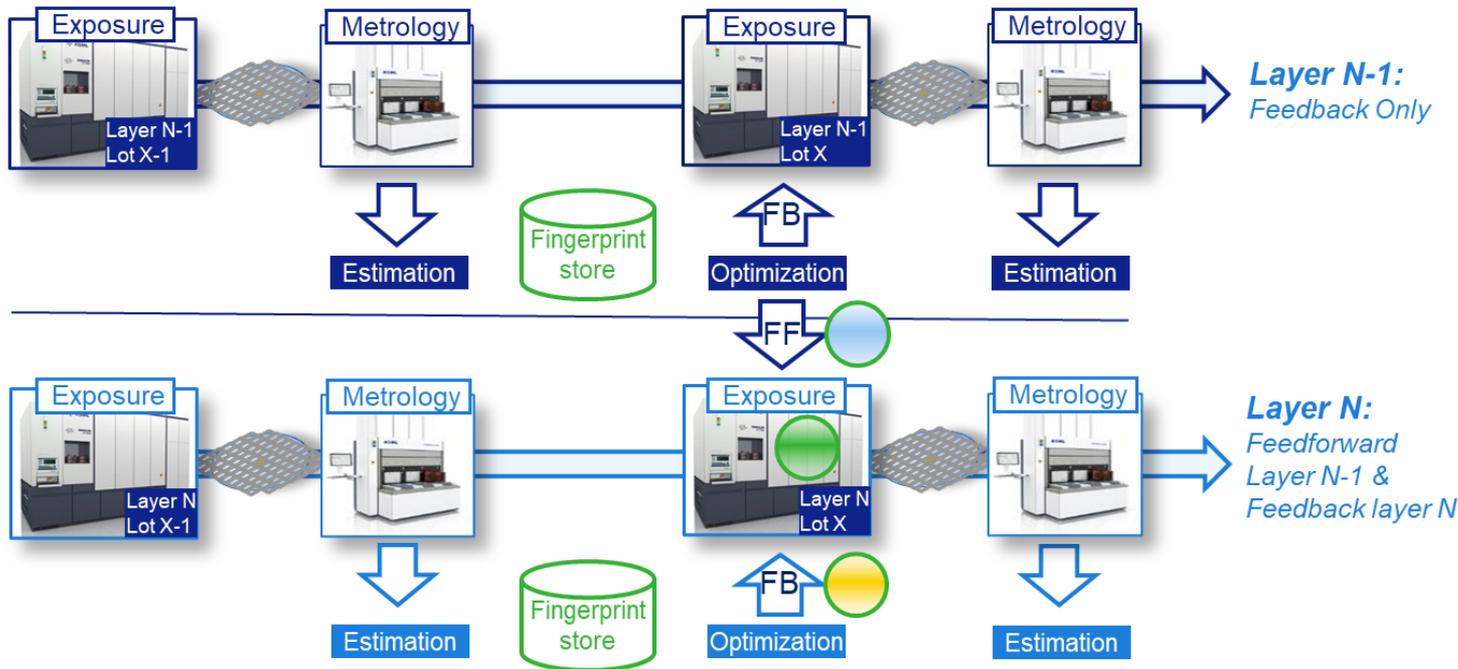
- By using 35 lots of data from new process (i.e. lots in Period **3**) for simulation, FF can still improve overlay by appr. 11%.
- This improvement indicates that even when the process is stable, still the HO variations from bottom layer (**layer N-1**) do propagate to the top one (**layer N**) which could potentially be resolved by FF control.



- **General conclusion:**
 - 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.



- 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.

