# A hybrid chemical mechanical planarization (CMP) model for time-dependent, spatial material removal rate optimization

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Driven by the PHM Data Challenge 2016, dozens of machine learning models have been trained to successfully predict material removal rates (MRR) in CMP. Solely relying on equipment-specific reference data, while ignoring established physical theory, those models are limited to a narrow control parameter space and are not transferable from one polisher to another. Furthermore, they lack spatial information crucial for ensuring homogeneous removal rates and low within-wafer non-uniformity.

Our work closes the gap by combining a data-based machine learning model with a time-dependent, spatial physics model. In the case of tungsten CMP, we show that the resulting hybrid model enables model-based process optimization regarding a homogeneous material removal along the wafer, for a wide range of control parameters and with only few equipment-specific data.

The data-based model operates on data available from Araca's Planarization Knowledge Foundry® archives. The latter contains polishing results from thousands of sound DOE-based runs using hundreds of control parameter combinations collected over fifteen years of CMP research, together with pre-polish and post-polish film thickness profiles as well as high-frequency time-dependent temperature, shear force, and normal force data obtained during each run. Using additional data from the polishing equipment, the model is updated on a run-to-run basis to capture characteristics of the specific polisher and process drifts.

The physics-based model compensates for missing information due to incomplete or small reference datasets, enabling the exploration of large parameter spaces and the application in a high-mix-low-volume research environment, or during the early stages of mass production.

We use a modified two-step Langmuir-Hinshelwood tribochemical model as a top-level model and introduce spatiality by including established models for kinematics, pressure, and conditioning as lower-level models that support the overall kinetic expression. Time-dependency is introduced through the temperature in the chemical reaction term, as well as the coefficient of friction in the mechanically-driven term.

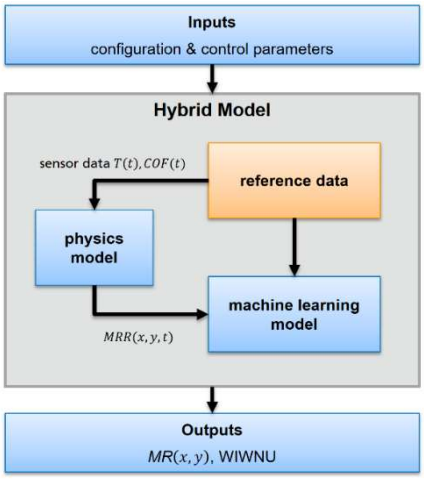


*Fig. 1: Schematic view of the hybrid CMP model.*

The implementation of our model allows for easy extensions to other materials as well as additional physics models. Interaction is possible via a graphical user interface. The methodology to combine physics knowledge and data to construct a hybrid model can be applied to other semiconductor processes.

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