Development of plasma information based virtual metrology to trace the drift of plasma-assisted processes

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Insemiconductor-fabrication industry, virtual metrology (VM) is one of promisingtechnology to achieve advanced process control (APC) for plasma-assistedprocess because it can provide metrology data for every wafer. VM is defined asthe technology of prediction of metrology variables using process state(equipment and sensor) and wafer state variables. However,as the requiredprediction reliability of VM is getting higher, previouslydeveloped VM models face the degradation of prediction accuracy as the reactor-wallcondition drifts in long-term process. In line with this trend, development ofphenomenological-based VM which includes information about the environment ofplasma-assisted process reactor is important in VM technology forplasma-assisted process. In this work, aphenomenological-based virtual metrology (VM) based on plasma-information(named PI-VM) is developed for predicting the silicon nitride film-thickness innitride/oxide multi-layer plasma-enhanced chemical vapor deposition (PECVD).Particularly, the analysis of optical emission spectroscopy based on theexcitation kinetics in nitrogen plasma is used to develop plasma-information(PI) variables. One variable, PI_{Wall}, is determined by analyzing thelight transmittance of the nitrogen emissions at the contaminated window,representing the drift of reactor-wall condition. The other variable, PI_{Volume},is determined by analyzing vibrational distribution of $N_2(C^3\Pi_u$, v=0+4) states, representing the drift of plasma density and temperature.These PI variables are applied as part of input variables of VM to improve theprediction accuracy. The partial least squares regression (PLSR) is adopted asthe statistical method. Compared to conventional VM, PI-VM improves thereliability more than twice in long-term variation by implementing PI variableson PLSR. The evaluation of influence of each variable on PI-VM shows that $PI_{Wall}$is the highest contributing variable, implying that the drift of nitride/oxidemulti-layer PECVD mainly comes from the phenomena related to residueaccumulation on reactor wall. Also, it is shown that PI_{Volume}further improves prediction reliability at the latter region of layers,implying that the variation of plasma state become important with increasinglayers. Therefore, it is expected that PI-based monitoring technology forplasma-assisted process provides key index to apply APC by enabling reliable predictionof wafer state variables and tracking the root cause of process faultsimultaneously.

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