Statistical learning methods for Predictive Maintenance in plasma etching processes

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Abstract

This contribution is a joint work of academicians and a research group of STMicroelectronics (Italy) a leading industry in semiconductor manufacturing.

The problem under investigation refers to a predictive maintenance manufacturing system. Zonta et al. (2020) present a systematic literature review of initiatives of predictive maintenance in Industry 4.0. According to Mobley (2002) industrial and process plants traditionally employ two types of maintenance management: run-to-failure or preventive maintenance. In run-to-failure maintenance, action for repairing equipment is performed only when the equipment has broken down or been run to the point of failure and no attempt is made to anticipate maintenance requirements hence, a plant must be able to react to all possible failures. This forces the maintenance department to maintain extensive spare parts in the plant. Preventive maintenance is based on hours of operation. All preventive maintenance management programs assume that machines will degrade within a time frame typical of their typology and interventions are made on a scheduled basis.

Modern predictive maintenance has a different philosophy. Predictive maintenance is a condition-driven preventive maintenance program that uses possibly huge amount of data for monitoring the system to evaluate its condition and efficiency. Machine learning and statistical learning techniques are nowadays the main tool by which predictive maintenance operates in practice. We has tested the efficacy of such tools in the context of plasma etching processes.

More specifically the semiconductor manufacturing process flow (Chao, 2001), from bare silicon wafer up to the final integrated circuits (ICs), involves hundreds of chemical and physical material modifications grouped in technology steps (Photomasking, Etching, Diffusion, Ionic Implantation, Mentalization). One of the most critical step is the dry etching (Lieberman et al., 2005), in which a precise pattern on the wafers surface is defined by means of ion enhanced chemical reactions inside

some complex equipment allowing controlled plasma discharges. In particular, due to the erosion of the hardware surface (Quartz, Anodized Aluminium) exposed to the operating plasma, equipment maintenance nowadays needs advanced controls and strategies to reduce costs, increase the parts lifetime and assure high process repeatability (Sutanto et al. 2006, Ramos et al. 2007)

The data considered in this paper refers to an entire production cycle and had been collected for roughly six months between December 2018 and July 2019. 2874 timepoints were considered in total. Quartz degradation was monitored in terms of the reflected power (RF).

In addition to the reflected power, the values of more than one hundred other variables have been collected. Results suggest that the considered variables are related to the quartz degradation differently in different period of the production cycle, with predictive models that might change over time. Hence causes of quartz degradation are potentially different in different phases of the production process. In addition, many of the variables mentioned above are found highly collinear .

Blending different penalized methods to shed light on the subset of covariate expected to be prone of signals of the degradation process, it was possible to reduce complexity allowing the industrial research group to focus on them to fine tune the best time for maintenance.

References

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