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Characterization Algorithm of Equipment-caused Particle Trends for LSI Yield Improvement

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This paper proposes three mathematical differential equation models, which can efficiently characterize new particle density trend on a wafer, to predict a reason for yield degradation in it. We have analyzed relationship the number of particles on a wafer versus the cumulative treated-wafers in a plasma metal-etching chamber [1]_[6]. We have classified successfully the results into three types to get clues about forecasting the particle outbreak as follows.

Type-A (insufficient by-product removal model)
This model indicates a chart shown in Fig. 1 and an exponential increasing trend as follows [1].
$Y= Y0 \cdot \exp [KX]$ ... (1)
Here, Y is the number of particles on a wafer, Y0 is the Y when X is zero, exp [ ] is the exponential function, X is cumulative treated-wafers since the chamber cleaning, K is a constant larger than zero.
The increasing rate of the peeled-particles is proportional to the number of the particles on the wall as follows.
$dY/ dX= KY$ ... (2)
Here, dY/ dX is the increasing rate of the particles. You can get the equation (1) from the differential equation (2) by mathematical integration.

Type-B ("half-dry" chamber model)
We found many AlF_3 particles in the "half-dry" chambers for shorter time since the chamber cleaning [2]. The phenomenon indicates a chart shown in Fig. 2 and an exponential decreasing trend as follows.
$Z= Z0 \cdot \exp [- HX]$ ... (3)
Here, Z is the number of the corrosion particles on a wafer, Z0 is the Z when X is zero, H is a constant larger than zero. So, we researched on the phenomenon with a chart shown in Fig. 3 and a polynomial exponential equation trend as follows.
$N= Y + Z= Y0 \cdot \exp [KX] + Z0 \cdot \exp [- HX]$ ... (4)
An H_2O desorbs from inside wall of the vacuum chamber during exhaust. The desorption rate is proportional to the retained H_2O on the wall. The retained H_2O catalyzes an Al_2O_3 versus fluoride chemical corrosion reaction as follows.
$3 F_2 + 2 Al + 3 H_2O \rightarrow 6 HF + Al_2O_3 \rightarrow 2 AlF_3 + 3 H_2O$ ... (5)
So we can replace the retained H_2O trend with the corrosion particles trend [3].

Type-C (inter-chamber contamination model)
A multi-chamber system for plasma etching connects each processing chambers to a common transfer chamber with gate-valves. You can process and overhaul the processing chambers alternately. Some particles or erosion gas can penetrate from higher-pressure chamber to lower-pressure chamber through the opened gate-valve shown in Fig. 4. For the multi-chamber system, we found a strange shape chart shown in Fig. 5.
At first, we tried to classify an outlyer from the chart shown in Fig. 6. Then, we searched the reason why the outlyer vanished suddenly. Finally, we found an inter-chamber contamination phenomenon. The phenomenon indicates a chart shown in Fig. 7 and a polynomial exponential increasing equation trend before the timing of the co-chamber cleaning (Tcc) as follows. This "type-C" is a new model in our papers.
$Y_{(X < Tcc)} = Y0 \cdot \exp [KX] + Yc0 \cdot \exp [KcX]$ ... (6)
Here, Yc0 is the number of the contamination particles on a wafer when X is zero, Kc is a constant lager than zero. The particle trend of after the "Tcc", $Y_{(X > Tcc)}$ is similar to the "type-A".

Hence as conclusion, in the dry-etching process, our algorithm using the mathematical equation models can classify the particle outbreak phenomenon into the three cause-types successfully as follows.

1. The insufficient by-product removal model shows an exponential increasing equation trend as follows (the cleaning quality by the Y0, the process condition by the K and the maintenance opportunity by the Y).
$Y= Y0 \cdot \exp [KX]$

2. The "half-dry" chamber model shows a polynomial exponential equation trend as follows (the dry quality by the Z0, the exhaust condition by the H).
$N= Y0 \cdot \exp [KX] + Z0 \cdot \exp [- HX]$

3. The inter-chamber contamination model shows a polynomial exponential increasing equation trend before "Tcc" as follows (the co-chamber affection by the Yc0 and Kc).
$Y_{(X < Tcc)} = Y0 \cdot \exp [KX] + Yc0 \cdot \exp [KcX]$

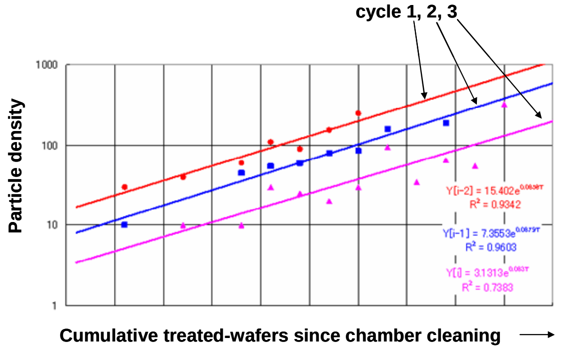

Fig. 1. Example chart of insufficient by-product removal model (exponential increasing function)

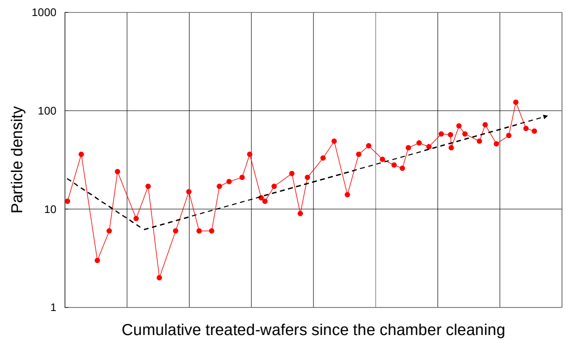

Fig. 2. Example chart of "half-dry" chamber model (v-orbital)

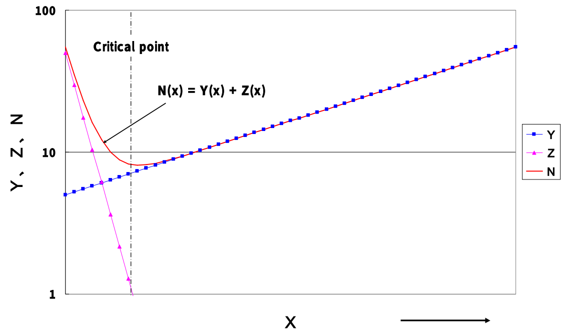

Fig. 3. Simulation model for “v-orbital” shape chart (mix of exponential decreasing function Z and previous exponential increasing function Y)

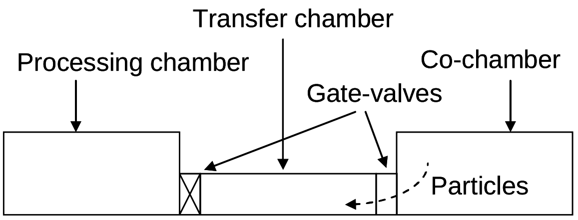

Fig. 4. Image of particle migration in multi-chamber system during a gate-valve open

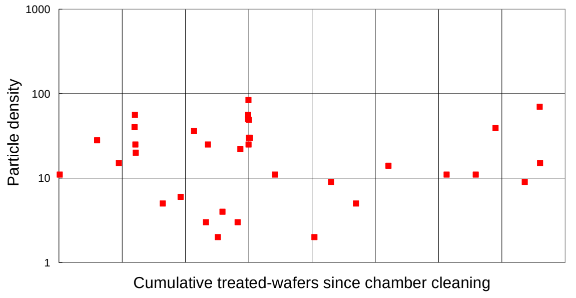

Fig. 5. Example strange-shape chart of multi-chamber system for plasma metal-etching (seems like random-orbital)

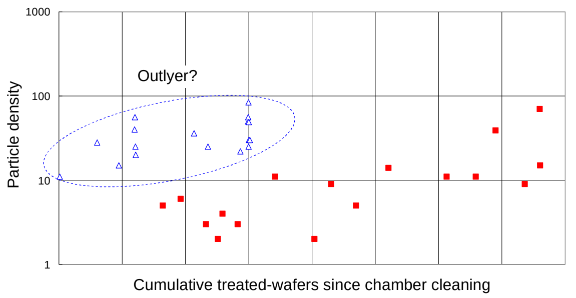

Fig. 6. Outlyer classification from previous chart

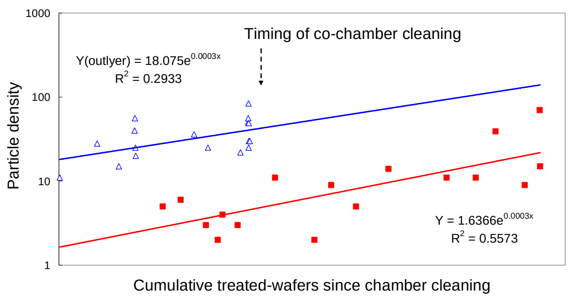

Fig. 7. Example chart of inter-chamber contamination model for multi-chamber system

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