Estimation of evaporating water film thickness during different drying processes

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Introduction

Classical ways of single-wafer drying rely on the convective outflow of liquid by spinning at high speeds. However, under the process conditions typically used there, a film of significant thickness is still left to evaporate from the surface [1] thereby depositing all contaminants present in it. Furthermore, the use of high spinning speeds during drying should be avoided because of the large amount of contaminants that can redeposit when entrained by the highly turbulent gas flow over the wafer [2].

Recently, the Rotagoni™ drying technique was proposed to allow for quick and efficient drying of a single wafer[3] at reduced rotation speeds. In this paper, we compare the performance of spin dry vs Rotagoni dry from the viewpoint of the amount of water that is not physically removed but evaporates during the drying step.

Experimental

The setup consists of a spinner onto which a moveable arm containing two nozzles is mounted. These two nozzles deliver a flow of N_2 with Isopropanol (IPA) and UltraPure Water (UPW) respectively.

P-monitor 200mm <100> Cz wafers were imec-cleaned in a Steag automated wet bench with an ozonized last step, rendering the surface hydrophilic.

Wafers were manually prewetted by dispensing a thick layer of DI water spiked with KCl as a tracer and dried using spin drying or Rotagoni-drying. After the drying step, the remaining KCl was determined using Total Reflection X-Ray Fluorescence (TXRF, Atomika 8010). From the amount of KCl in the spiking solution and on the wafer surface one can calculate the amount of liquid which is evaporating from the wafer surface (called henceforth the “equivalent thickness”). It should be emphasized that the UPW water used in the Rotagoni drying step was spiked with the same concentration of KCl as the initial wetting film, eliminating possible dilution effects during Rotagoni drying.

Results and discussion

The physical removal of water by centrifugal forces during spin drying essentially only takes place during the first 10 to 20 seconds. After this time evaporation becomes dominant. This fact was demonstrated by interrupting the spinning process at various time intervals. A typical example is given in figure 1. It represents the equivalent thickness for a 500 rpm spin dry interrupted after 15,30,45,60 and 120 seconds after initial dispense of KCl. Different markers represent different distances from the wafer center. Except for one measured centerpoint per condition all other markers represent averages of 4 points (N,E,S,W). Vertical error bars are below marker size. Horizontal error bars are taken at 3 seconds and represent the error due to wafer deceleration on the spinner. The lines on this graph represent theoretical profiles for a newtonian liquid without evaporation [4] for different values of initial thickness H_0. One can see that after approximately 20 seconds the thickness value reaches a constant values in the order of 6 µm and starts to deviate from the theoretical profiles which do not account for the evaporation.

Increasing the rotation speed does not significantly decrease this film thickness, as represented in figure 2. It represents final film thickness values for spin drying at different rotation speeds. Appended to this graph are results from Rotagoni drying at 500 rpm. For both drying techniques the contact time with the KCl solution before drying started was varied from 5 seconds (= drying as quickly as possible) to 2 minutes (to evaluate possible time related effects of adsorption). While the thickness values after spinning are in the order of several µm (3 to 6 µm), the Rotagoni values are about 2 orders of magnitude smaller (≈50 nm). This value is of the same order of magnitude as values reported for other advanced drying techniques[1]. Although there do not seem to be time related effects, a fraction attributed to adsorption can not be evaluated from these data. Therefore, the values indicated for Rotagoni represent upper values.

Summary and Conclusions

After spin drying a layer of several µm evaporates from the surface while in the Rotagoni drying process this layer is ≤ 50 nm. This implies that by using Rotagoni instead of classical spin dry, the amount of residues left by evaporation can be drastically improved.

References

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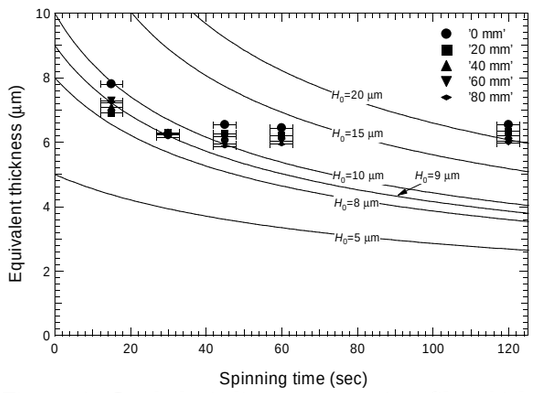

Figure 1. Symbols indicate evaporating film thickness based on measured K-concentration. Lines represent model for convective outflow without evaporation [4].

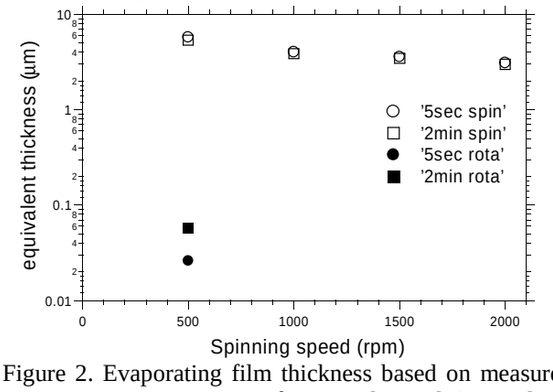

Figure 2. Evaporating film thickness based on measured K-concentration for spin dry and (upper limit for) Rotagoni dry.