

To the Origin of the Watermarks formation.
Liquid Film Curriculum Vitae: Physics and Chemistry of the Phenomena Occurring During
Thin Liquid Film Drying on the Semiconductor Wafer Surfaces

Yehiel Gotkis
KLA-Tencor Corp., San Jose, CA
Lou Kondic,
NJIT, Dept of Mathematics, New Jersey, NJ.

Phenomenon of drying water and/or water based thin film solutions is continuously under intent attention of the scientific community due to its significant importance for many scientific, technical and life science problems. Driven by the necessity to understand the origin of so-called “watermarks”, a hot issue in the advanced semiconductor manufacturing technology, we investigated in details the film drying process, identified, classified and interpreted the phenomena observed. Together with already known features, a few seemingly new important details of the drying thin film behavior were observed, for example formation at the film edge of a thick roll-cell convection followed by a thin valley at its internal to the film center side. Short wavelength waviness was observed to appear once the liquid film thins down below some critical thickness values of 8-10 μm . In practically all the integrity breakage events we have observed, the catastrophic film integrity failure, (film rupture, hole nucleation or frame separation) started to develop at and propagate at the thin valley along the internal side of edge convection roll-cell. Mechanism of periodically structured residue frame ring formation was also investigated in details and interpreted in terms of phase transitions induced first along the thin valley. Some global correlation phenomena managing the synchronous dynamics of small scale events were also observed and an explanation for their origin is discussed. A large selection of the Marangoni convection appearances from almost isolated “cells-on-umbilical-cord”, so-called “fingers” and large individual convective cells to integrated roll-cell convections, as well as a large number of other drying thin film evolution features are also presented and discussed in the paper with emphasis of their significance for the wafer wet processing.

The Figure below presents some examples of the phenomena observed and discussed: a- case when edge Marangoni convection cells generate a global flash-back wave, b- “cells-on-umbilical-cord”; c- waviness at the film edge and along the thin valley, d- periodically structured frame framing; e,f- cases of direct and reversed framing.

