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In-situ monitoring of megasonic cleaning

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Acoustic agitation is used in ultrasonic cleaning to induce a physical force to remove nanoparticles in semiconductor processing. The performance of cleaning tools is commonly quantified ex-situ by the particle removal efficiency η (i.e. the ratio of the remaining to the original particle concentration). The resulting η-wafer maps often reveal spatial non uniformities related to tool design. The local study of the cleaning dynamics, quantified by the removal frequency ($f_R[s^{-1}]$) also indicates that the density of cleaning events over a wafer can be strongly non homogeneous.
Because the sound frequencies used in industrial tools are in the MHz range, visualization of the cavitating bubbles (resonant size 3 μm) is highly challenging, both in time and in spatial resolution. Considering that the cleaning effect of a cavitating bubble is permanent a method is presented here to determine the acoustic cleaning event size ($A_{event}[\mu m^2]$) and the event flux ($\phi[\mu m^{-2}s^{-1}]$) through visualization techniques. The method consists of time-resolved imaging of the removal of a nanoparticle layer deposited on a transparent substrate. The microscopic cleaning activity can then be correlated to the actual removal frequencies f_R through the relation f_R=ϕA_{event} to further clarify the cleaning mechanisms in industrial tools.