

Research Topic : **Substrate Damage in Nanoparticle Removal under LIP Exposure**  
 Duration : **2005-Present**  
 Sponsor(s) : **Intel Corp., SEMATECH and CAMP/Clarkson University**  
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### Synopsis of Research and Sponsored Projects

Damage-free sub-100nm particle removal is a challenge in the semiconductor industry and nanotechnology. Laser induced plasma (LIP) is an emerging technique for fast, dry, chemical-free, non-contact, precision and selective cleaning of sub-100 nm particles. Determination of the primary causes for material alterations and damage due to LIP application in nanofilms deposited on substrates utilized in EUVL/photomasks, as well as investigation of the onset of these material alterations were the objectives of this investigation.

The two possible sources of damage (excluding direct contact of the LIP with the nanofilms/substrate surface) are identified as (i) the thermo-mechanical excitation from the LIP shockwaves from gases (convection heating) and ii) the laser radiation heating (due to the very high plasma temperature) from the plasma core. Radiation energy ( $E_{rad}$ ) (measured) and LIP shockwave pressure and temperature, were applied as load for conducting computational studies to determine transient thermoelastic responses of the

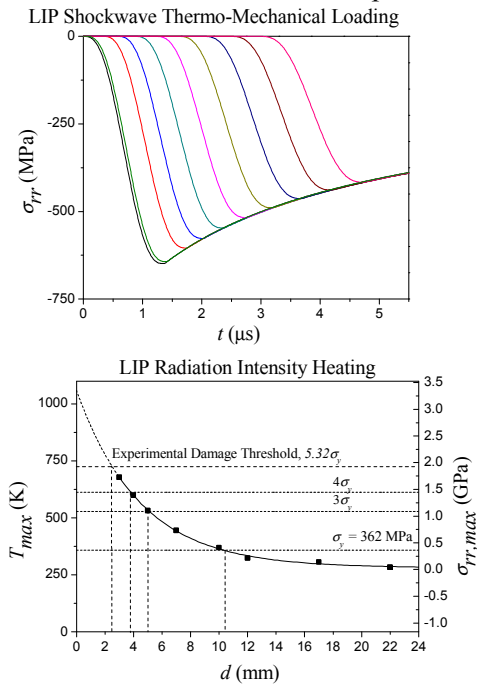


Fig. 1 Radial stress ( $\sigma_{rr}$ ) due to LIP shock waves (top) and radiation intensity heating (bottom).

substrate. The radial stress component  $\sigma_{rr}$  was determined as the most critical stress component in both cases for damage (Fig. 1). The damage threshold for LIP on 100 nm Cr film on a quartz substrate was at the firing distance of  $d_{cr}=2.5$ mm (as slight damage was experimentally detected at  $d=2$  mm) (Fig. 2). Surface cracks and channeling were the first experimentally observed material alteration modes on the Cr nanofilm (as the firing distance  $d < d_{cr}$ ). FE analyses show that radiation heating dominated the shockwave loading. At  $d_{cr}=2.5$  mm, the damage limits for maximum radial stress component amplitude and surface temperature are  $\sigma_{rr,max}=1.93$  GPa and  $T_{max}=725$  K. It is found that irradiative heating of the nanofilm is the major source of damage. Applying pre-tension on the mask would reduce resultant film surface stresses and temperature rise, possibly arresting material alterations of these thin films.

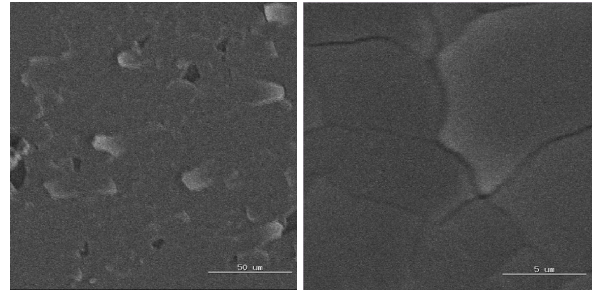


Fig. 2 SEM images of material alterations (cracks, channeling, peeling, film strip-off, fracture) observed on Cr nanofilm (photomask).

### Recent Publications

1. M. D. M. Peri, D. Zhou, I. Varghese, C. Cetinkaya, *Transient Thermo-Elastic Response of Nanofilms under Radiation Heating from Pulsed Laser Induced Plasma*, Accepted: IEEE Trans. Semicond. Manuf., 2008.
2. I. Varghese, D. Zhou, M.D.M. Peri, C. Cetinkaya, *Thermal Loading of Laser Induced Plasma Shockwaves on Thin Films in Nanoparticle Removal*, J. Appl. Phys., 101, 113106, 2007.