Manufacturing of holes in supported films: transition from beam dependent to shock dependent radius of hole as absorbed energy increases

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Abstract. Thin films on supporting substrates are important class of laser targets for surface

nanomodification for, e.g., plasmonic or sensoric applications. There are many papers devoted to this problem. But all of them are concentrated on dynamics of a film, paying small attention to substrate. In those papers the substrate is just an object absorbing the first shock. Here we present another point of view directed namely onto dynamics of a substrate. We consider (i) generation of a shock wave (SW) in a supporting substrate, (this si generation by impact of a film/support contact on supporting condensed medium); (ii) transition from 1D to 2D propagation of SW; (iii) we analyze lateral propagation of the SW along a film/support contact; and (iv) we calculate pressure in the compressed layer behind the SW decaying with time. This positive pressure acting from substrate to the film accelerates the film in direction to vacuum. Above some threshold, velocity of accelerated film is enough to separate the film from support. In the cases with large energy absorbed by a film, the circle of separation is significantly wider than the circle of high heating around the focal laser spot on film surface. Absorbed laser heat exponentially decays around an irradiated spot F = Fc exp(-r^2/RL^2), where RL is radius of laser Gaussian beam. While the law of decay for the 2D SW in substrate is the power law. Therefore in the mentioned cases of powerful laser action, the edge of a separation circle is driven by SW in support.

Illustrative materials are posted on youtube:

https://www.youtube.com/watch?v=TI09nMubgww

This movie shows the map of evolution of density field. The gold film is the narrow horizontal strip, "vacuum" is above, supporting substrate is below the strip

https://www.youtube.com/watch?v=5fQHFuwImek

This is the pressure map. We see two shocks: one above and second below the film. Don't pay attention to the shock above, i.e. to shock in "vacuum", because in our simulation we cannot use real vacuum rho=0, p=0. Therefore we use low density media in place of vacuum. Pay attention to the left and right wings of crescent type shock propagating down. These wings pass along the film. Shock pressure in the wings accelerate the film up thus separating it from the silica substrate.