Target surface cleaning by fs laser desorption at PHELIX

G. Hoffmeister[*1], *M. Bender*[2], *H. Kollmus*[2], *R. Jaeger*[1], *F. Wagner*[1], *M. Wengenroth*[2], *B. Zielbauer*[2,3], *and M. Roth*[1]

[1]Institut für Kernphysik, TU Darmstadt, 64289 Darmstadt; [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt; [3]Helmholtz Institut Jena, 07743 Jena

In laser ion acceleration experiments like the target normal sheath acceleration (TNSA) the target design has an essential influence on the resulting ion spectra. Apart from studies about elaborate geometries like cone or hemispherical targets [1] the target surface structure plays a crucial role. In almost all laser proton acceleration experiments it is the contamination on top of the target surface -mainly consisting of hydrocarbons and oxygen- which is ionized and accelerated.
The fs laser desorption constitutes a promising technique which enables to remove these surface contaminants successively, thereby learning more about their amount and composition. Due to the ultrashort laser pulse duration the energy transfer from the laser to the target is nonthermal i.e. melting is almost no issue [2]. The target surface remains undamaged and smooth. Combining this method with a sophisticated target design like a characterized multilayer target could allow to scan through the TNSA field distribution giving information about its penetration depth and about the TNSA field strength.

Experimental setup We performed a fs laser desorption experiment using the PHELIX laser frontend at GSI Helmholtzzentrum für Schwerionenforschung GmbH. The PHELIX laser frontend delivered pulses of 400 fs pulse duration with 10 Hz repetition rate. The pulse energies were varied between 0.1 mJ and 3 mJ. With a focal spot size of 560 μm this led to laser intensities between (10^{10} - 10^{12}) W/cm^2.
The laser irradiated 1 mm thick aluminum, copper and gold foils which were mounted in a special ultrahigh vacuum (UHV) chamber at a pressure of 10^{-10} mbar realized by a titanium sublimation pump and an ion pump. The UHV was necessary to observe even small pressure increases. The analysis of the gas composition was performed by a residual gas analyzer (RGA) represented by the quadrupole mass spectrometer QMA 200 by Pfeiffer Vacuum.

Results The intention of this experiment was to determine the threshold intensity for plasma formation as well as to investigate the target cleaning in dependence of the laser parameters. At intensities of $I = (5 - 10) \times 10^{10}$ W/cm^2 there were no explicit desorption effects visible. The total pressure rise was negligible. With increasing intensity in the mid 10^{11} W/cm^2 regime we observed clear signals of target surface cleaning. Figure 1 shows the total pressure rise during the continuous laser irradiatiation at 10 Hz on a 1 mm thick gold foil. In the left image, three irradiation cycles with 1000 s, 2100 s and 500 s, respectively, were applied. The first two cycles show an initial pressure rise due to the desorption of surface contaminants. Probably the laser spot was slightly shifted between those two cycles since the UHV conditions prevent the re-establishment of a contamination layer on the desorbed surface. In the third irradiation cycle this pressure rise did not occur any more, indicating that the irradiated region had been cleaned and there were no more surface contaminants to be removed. Additionally, the laser intensity was still low enough such that plasma formation was no issue. In contrast, the right image of Figure 1 demonstrates that at a laser intensity of $I = 8.5 \times 10^{11}$ W/cm^2 the total pressure rise shows a completely different behavior. Instead of decreasing after a short time of laser irradiation it increased more and more. Plasma formation set in and the laser intensity sufficed to immediately ionize the contaminants as well as the gold atoms.

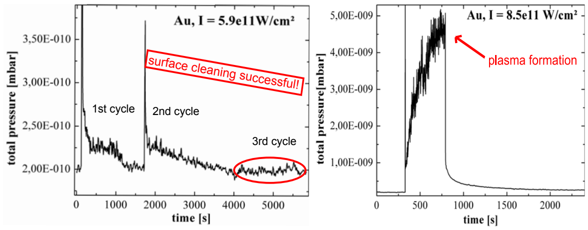

Figure 1: Total pressure as function of time of laser desorption at 10 Hz with $I = 5.9 \times 10^{11}$ W/cm^2 (left) and $I = 8.5 \times 10^{11}$ W/cm^2 (right).

Similar results were obtained by irradiating aluminum and copper foils. While for copper the plasma threshold turned out to be at the same intensitiy as it was observed for gold foils, for aluminum we determined a minor threshold intensity for the plasma formation at $I = 3.5 \times 10^{11}$ W/cm^2.
With this desorption experiment at the PHELIX laser we could experimentally determine a plasma threshold intensity for gold, copper and aluminum targets. Furthermore, we found clear evidence of a complete target surface cleaning in the intensity regime of $I = (2 - 6) \times 10^{11}$ W/cm^2.

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References

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* g.hoffmeister@gsi.de