UV laser ablation induces Fe and Fe+2%Si plasmas

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Recently works have demonstrated that chemisorbed impurities on target surfaces affect significantly the ion emission from laser-produced plasma. This phenomenon is very attractive for applications like laser ion sources as well as in the field of high-energy particle production by ultrashort laser pulses focused on thin foils [1–3].

The characterization of the ion component of the laser-produced plasma is useful to understand the processes involved in the laser-target interaction as well as in the plasma formation. The simplest method to diagnose the ions component is based on the application of the time of flight (TOF) method, which makes it possible to measure the time-resolved currents, the charge-states and the energy spectra of ions, utilizing ion collectors [4,5].

In this work, we compare the ion current of a plasma induced by the laser ablation of Fe and 2 mass% of Si admixture target with the ion current obtained by a pure Fe plasma.

The experiment employed a KrF laser ($E_{laser} \leq 0.2\,J$ at $\lambda = 248$ nm, $\tau_{FWHM} = 23ns$) focused with an angular of 70° respect to the target normal. The operating laser fluence was set at different values ranging from a lowest value of 7 J/cm^2 to a maximum value of 122 J/cm^2. As targets, we used Fe and Fe+2 mass% Si single crystals placed into a vacuum chamber (limit pressure of $\approx 3 \times 10^{-6}$ mbar), which were grown at the Institute of Physics, ASCR, v.v.i., Prague by the dynamical strain annealing method [6]. The etched and polished surfaces of targets were made on (111) surface.

Time resolved ion current signals were recorded by using an ion collector of 8 cm in diameter placed at 44 cm from the target. The bias voltage of ion collector was set to-100 V in order to record the positive charges and to assure the saturation regime.

Examples of TOF spectra of ions emitted by Fe and Fe+2 mass% Si plasmas induced by 122 and 72 J/cm^2 laser fluences are shown in Fig. 1.

For a prompt comparison, the signals of time-resolved ion current density per surface unit are rescaled to a standard distance of 1 m from the target. We should emphasize that the maximum in the time-resolved currents of ions emitted by the Fe+2 mass% Si plasma is higher than the maximum of the ion currents emitted by the pure Fe plasma produced under identical irradiation conditions. Fig. 2 shows the simplest quantification of these distinctions as fluence dependencies of the total collected charge Q. It is possible to observe that the value of the ratio $Q_{Fe+2mass\%Si}/Q_{Fe}$ decreases from a maximum value of 1.6 to a value of 1.2 on fluence increasing. From these results, we can state that the plasma produced by the Fe+2 mass% Si attains in average an enhancement of the charge yield of ≈20% respect to the plasma produced by pure Fe target.

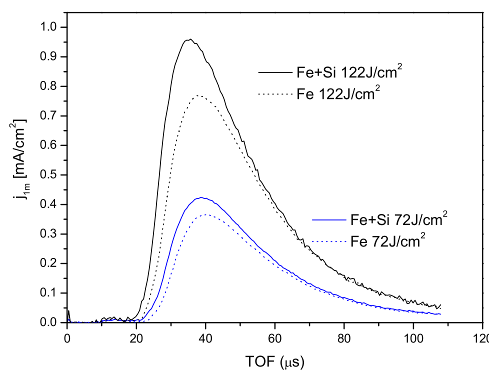

Figure 1. Comparison of the time resolved ion currents density emitted by Fe (dash line) and Fe+2%mass Si plasma (solid line) rescaled to a standard distance of 1 m at 122 J/cm^2 and 72 J/cm^2 laser fluences.

It is noteworthy that the presence of 2 mass% Si admixture could modify the thermodynamic properties as well as the optical properties and the thermal diffusion of the Fe single crystal getting arise to differences on the processes of laser abla-

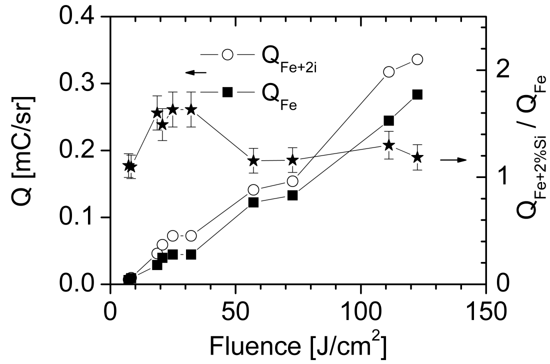

Figure 2. Fluence dependencies of the total collected charge of Fe and Fe+2%mass Si plasma per the unit of solid angle (left) and the corresponding ratio (right). The error bars correspond to 10% of data due to the laser fluctuations.

tion. Nevertheless, the value of energy needed to vaporize both the materials are not considerably different (enthalpies of vaporization of pure iron and silicon are 349.6 kJ/mol and 384.22 kJ/mol) and the measurements of the ablation yield, performed by the analysis of the crater profiles obtained at 72 J/cm^2 and with 40 laser shots, reveals an ablation etching of 0.275 μm/pulse for the both targets. This hardly measurable difference indicates that the 2 mass% of silicon admixture very weakly affects the target ablation; the appropriate influence of the admixture on the surface properties of the target, for example the target reflectivity, could be significant only in the initial stage of the plasma formation. Therefore, the enhanced emission of ions due to the 2 mass% Si admixture exclusively depends on the processes involved during the interaction of the laser pulse with the plasma plume [7] and on the recombination processes during the plasma expansion into the vacuum. The presence of Si ions could affect the recombination of the expanding Fe ions because the Si ions release a higher recombination energy than the Fe ions can do which is fed to the free electrons [8]. Thus, the released recombination energy can sustain the electron temperature at a value greater than the adiabatic expansion slowing down the recombination of Fe ions resulting in the enhancement of charge carried by ions.

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