Electrical Conductivity Changes Induced by High Intensity Heavy Ion Beams in Metallic Targets

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The electrical conductivity of matter under extreme pressure and/or temperature conditions is of fundamental as well as practical interest [1]. The availability of high intensity heavy ion beams at GSI makes it possible to drive matter to extreme conditions, either through direct interaction or shock wave compression. As previously reported [2], we developed a method for measuring the mean electrical conductivity of plasmas created by direct interaction. During the last year this method was applied to obtain first experimental results on electrical conductivity changes induced by the interaction of high intensity heavy ion beams with solid (metallic) targets.

For the experiments Pb, Cu, Ag and Al were used as target materials. All the targets consisted of a 0.25mm diameter and 10mm long wire fixed on an insulating support and connected to the diagnostics device through a 50Ω coaxial cable. Measurements were done using two different positions of the target, namely, perpendicular to the focused ion beam due to an easier mechanical adjustment of the wire related to the beam, and along the focused ion beam which is demanding in terms of alignment but should give better measurement precision. During the different beamtimes ion beams with the following characteristics were used: ^{83}Kr, 300MeV/u, $1\div2\cdot10^{10}$ ions/bunch; ^{197}Au, 300MeV/u, $1\div2\cdot10^{9}$ ions/bunch; ^{18}O, 200MeV/u, $1\div2\cdot10^{10}$ ions/bunch; ^{40}Ar, 300MeV/u, $5\div8\cdot10^{10}$ ions/bunch.

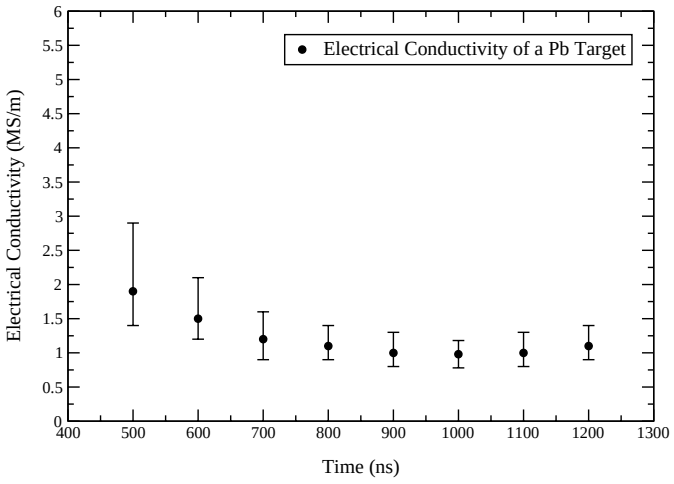

Figure 1: Mean electrical conductivity of a Pb target heated by a ^{18}O beam, with an intensity of $2\cdot10^{10}$ions/bunch, and focused to 0.7mm FWHM. The time is given with respect to the beginning of the irradiation.

The electrical signal obtained from the target is proportional to the changes of its resistance and thus to the changes in the mean electrical conductivity. Figure 1 shows the time evolution of the electrical conductivity of a Pb target irradiated by an ^{18}O beam.

The measurements show that at the end of the beam irradiation, the conductivity of the target corresponds to that of metals at temperatures of about 10^{-1}eV, and solid state density [3]. Due to the hydrodynamic expansion of the target, the conductivity drops in time, thus the electrical resistance grows. The rate at which this conductivity drop takes place depends strongly on the energy deposited in the target by the ion beam (i.e. on ion species and energy, beam intensity and focusing, and target material) and the thermodynamic properties of the target. This differences are shown in Figure 2.

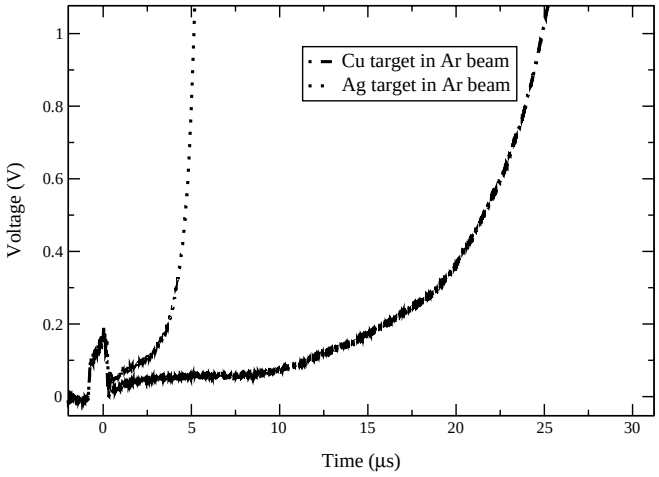

Figure 2: Electrical signals from Cu and Ag target heated by a ^{40}Ar beam, with an intensity of $7\cdot10^{10}$ions/bunch, and focused to 1.0mm FWHM. The beam bunch is visible arround t=0.

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References

[1] G.W. Collins et al., Science 281 (1998) 1178
[2] S. Udrea et al., GSI Scientific Report 1999
[3] Gmelins Handbuch der Anorganischen Chemie, Verlag Chemie GmbH, 1972