temperature and kinetic energy distributions of single-charged ions of heavy noble gases in current sheets

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Temperature and kinetic energy distributions of single-charged Ar II and Kr II ions were measured for the first time along the normal to the midplane of the current sheet (y axis). Current sheets were created in the TS-3D device in the magnetic field with X-line and field gradient 0.6 kG/cm. The working gas pressure was of ~30 mTorr, the current amplitude in the sheet was of 45 kA, and the current half-period was T/2 = 6 µs. Part of the experiments were carried out in 3D magnetic configurations, in which additional homogeneous magnetic field of ~3 kG was applied in the same direction as the plasma current [1, 2]. Profiles of spectral lines Ar II 480.6 nm and Kr II 473.9 nm were recorded, whose broadening is caused by the Doppler effect. To differentiate the thermal and directed motion of ions, measurements were conducted simultaneously in two mutually perpendicular directions (in detail, see [3, 4]).

It is determined that during the current sheet formation, when the density and temperature of electrons increase rapidly [5], the temperature of Kr II ions, in contrast, remains constant for a long period of time, and equal to the temperature of the initial plasma, Ti ≈ 60–70 e V [6]. The ion temperature is the same both in the current sheet, and in its vicinity. At later stages of the current sheet development (t ≈ 4 µs), the temperature of Kr II ions in the sheet grows rapidly and reaches Timax ≈ 130 eV. It was found that the FWHM of Kr II temperature distribution along the normal to the midlplane of the current sheet Ti(y) exceeds the sheet sickness, which was estimated using the distribution of intensity of the Kr II line along the sheet thickness.

It is shown that during the current sheet evolution, the temperature of Ar II ions increases insubstantially compared to the initial plasma temperature [6], and reaches Ti ≈ 35–40 eV. This is caused by singly-charged Ar II ions being localized in the cold boundary regions of the sheet, whereas in the central region of the sheet, the temperature of Ar III ions reaches ~120 eV, and the temperature of Ar IV ions reaches ~200 eV [7]. For the first time, Ar II ions with a temperature Ti ≈ 65–75 eV (higher than their temperature inside the sheet) were found outside the current sheet.

It was found that the maximum energy of Kr II ions, which are accelerated under the action of Ampère forces along the maximum transverse dimension of the sheet (x axis) (the current sheet width), is Wx ≈ 460 eV, and the maximum energy of Ar II ions is of 65 eV. The energy distribution of Kr II ions reaches its maximum in the midplane of the current sheet, while the energy distribution of Ar II ions reaches its minimum in the midlplane.

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