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SPECTROSCOPIC STUDIES OF THE VELOCITY DISTRIBUTION OF HELIUM AND NEON ATOMS RELEASED FROM CARBON AND TUNGSTEN LIMITERS IN TEXTOR-94

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Introduction

Impurity transport is one of the key problems on the way to controlled nuclear fusion. In addition to particle transport in the plasma core, processes occurring at the plasma edge, namely the penetration of impurity neutrals released from the plasma facing components into the confined plasma, have a direct and significant influence on the central impurity density. Helium and neon are impurities of special interest in this context: helium is the product of the DT- fusion process unavoidably present in a burning plasma, and neon is representative for candidates in the concept of power exhaust from a radiating plasma mantle in a next step device like ITER. As a consequence, there is an urgent need to investigate the plasma surface interaction of these species and their penetration into the confined plasma volume.
The velocity distribution of helium and neon atoms has been determined at TEXTOR from the Doppler shift of atomic line emission. For the first time three different release mechanisms of helium and neon at carbon and tungsten limiters could be distinguished in a tokamak: thermal desorption, ion induced desorption and particle reflection. Under the assumption that the thermal desorption can be described by a Maxwellian velocity distribution, the ion induced desorption profile can be expressed by a Thompson velocity distribution [1],which is normally reserved to physical sputtering. Calculating the particle reflection by the Monte Carlo code TRIM[2], these processes could be separated in the measured velocity distribution.

Experimental arrangement and principles of measurements

The experiments have been performed on the Tokamak TEXTOR with the major radius R=1.75 m and a minor radius a=0.46 m, a toroidal magnetic field $B_T = 2.25T$ and a plasma current $I_P = 350kA$. The plasma was heated by neutral beam co-injection ($P_{NBI} = 1.3MW$) and the line-average central electron density was varied between $2.5\ 10^{13}cm^{-3}$ and $5\ 10^{13}cm^{-3}$. Neon feedback was applied to vary the fraction γ_{rad} of the radiated power with respect to the total input power. The measurements shown below have been carried out using test limiters made of two different materials (carbon and tungsten) which are introduced into the vacuum vessel with the help of a limiter lock system at the bottom of the torus. The Doppler broadened intensity profile of line emission from neutral helium and neon has been measured from the top by guiding the emitted light with fibers to a high resolution ($\lambda/\Delta\lambda = 10^5$) spectrometer. In addition to the Doppler broadening, the line shape is determined by the Zeeman- effect. For the Ne I transition

$3s'[1/2]_{J=1} \Rightarrow 3p'[1/2]_{J=0}$ at $\lambda = 582.48$ and the He I transition $1s3s^1S \Rightarrow 1s2p^1P$ at $\lambda = 728.13nm$ the π-component (ΔM=0) has been selected out of the Zeeman pattern by a polarizer. A neon or helium glow discharge through a Pluecker tube has been used for an exact in situ determination of the reference wavelength λ_0. The remaining Doppler shift $\Delta\lambda = \lambda_0 v/c$ of a line emitted by an atom moving with the velocity v in the direction of the observer allows to deduce the velocity distribution $f(v)dv$ from the Doppler broadened profile. The profiles of electron temperature (T_e) and density (n_e) which are obtained by means of a thermal helium beam diagnostic, govern the plasma sheath and consequently the ion energy distribution, the ion angle of incident, the excitation and the ionization processes of atoms in front of the limiter.

Results and discussion

In fig. 1 an intensity profile of the above mentioned Ne I line in front of a tungsten limiter is shown. Although a polarizer has been used, still small σ-components are visible, originating from diffuse reflected radiation at the rough surface of the limiter. The diffuse reflection is always included in the further calculations.

Fig.2 a) shows the dependence of the velocity distribution of neon on the edge electron temperature (T_e) at the last close flux surface (LCFS) ($r = 46cm$). With the increasing T_e the fraction of fast atoms ($v > 10^4 m/sec$) is decreasing. Comparing the carbon and tungsten targets (fig. 2 b)) the latter shows a significantly higher velocities of fast neon components. This result can be explained by an increasing particle- and energy reflection coefficient (R_N, R_E) when going to low temperature (=low energies of ions hitting the limiter) and comparing low Z and high Z targets.

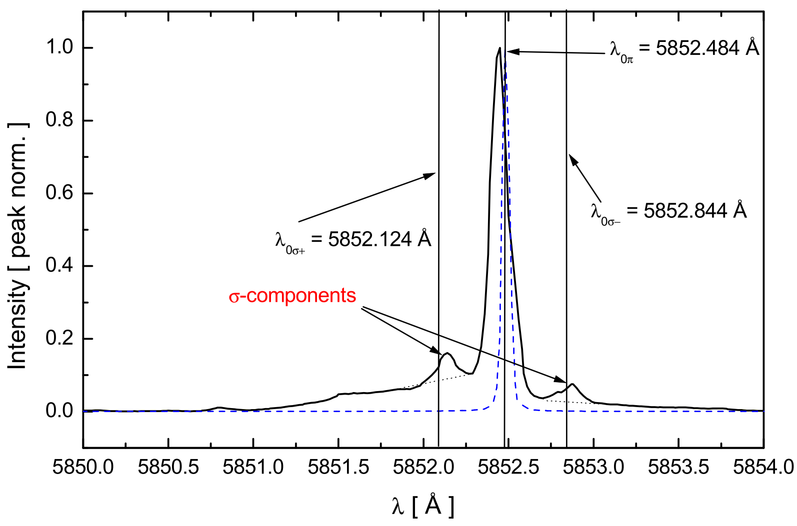

Figure 1: Profile of Neon I $\lambda = 5852.484\mathring{A}$ at the tungsten test limiter, with $T_e = 22eV$ and $n_e = 9.6 \cdot 10^{12} cm^{-3}$

The energy distribution, which is related to the velocity with $E = 1/2 m_{He} v^2$, shows a maximum between $E_{He} \approx 0.07 - 0.12eV$. In the logarithmic plot (fig. 3 a)) a linear dependence in the region of $E_{He} \approx 0.3 - 1.0eV$ is illustrated. This result can be associated to the thermal desorption of atoms from the plasma-facing surface.

In the intermediate energy range $E \approx 1 - 2eV$ a $E^{\sim -2}$ dependence was determined(fig. 3 b)). This dependence is explained by ion induced desorption. The exponent varies between -1.75 and -2.25. The variation has its origin in the intersecting processes and in the background substraction.

Taking these three processes into account and describing the thermal desorption by a

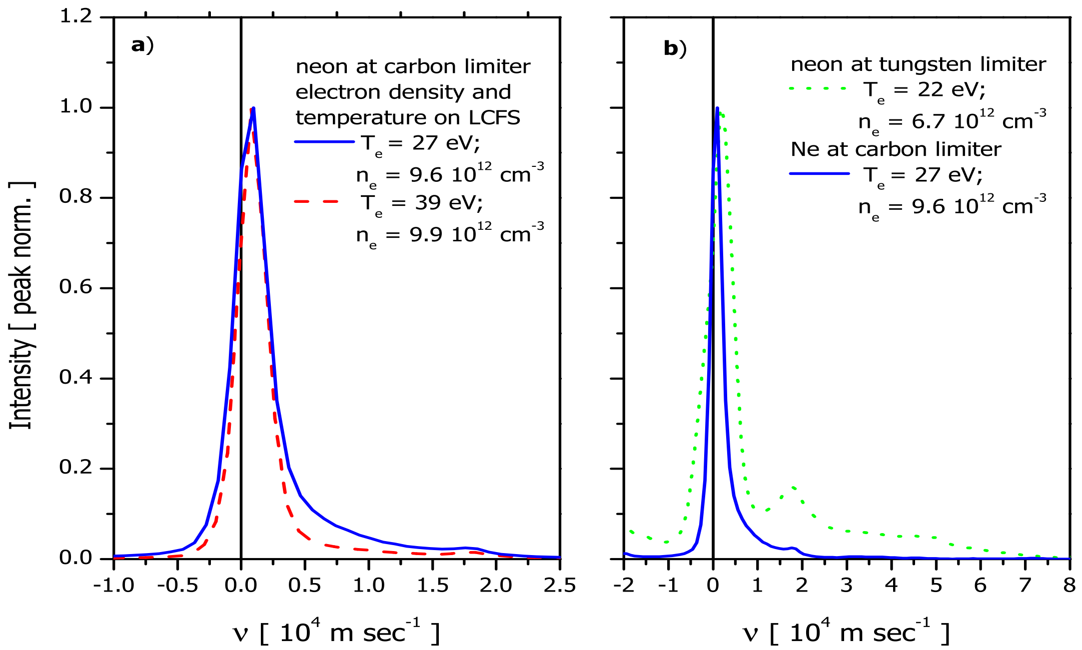

Figure 2: Velocity distribution of neon in front of a carbon and a tungsten limiter

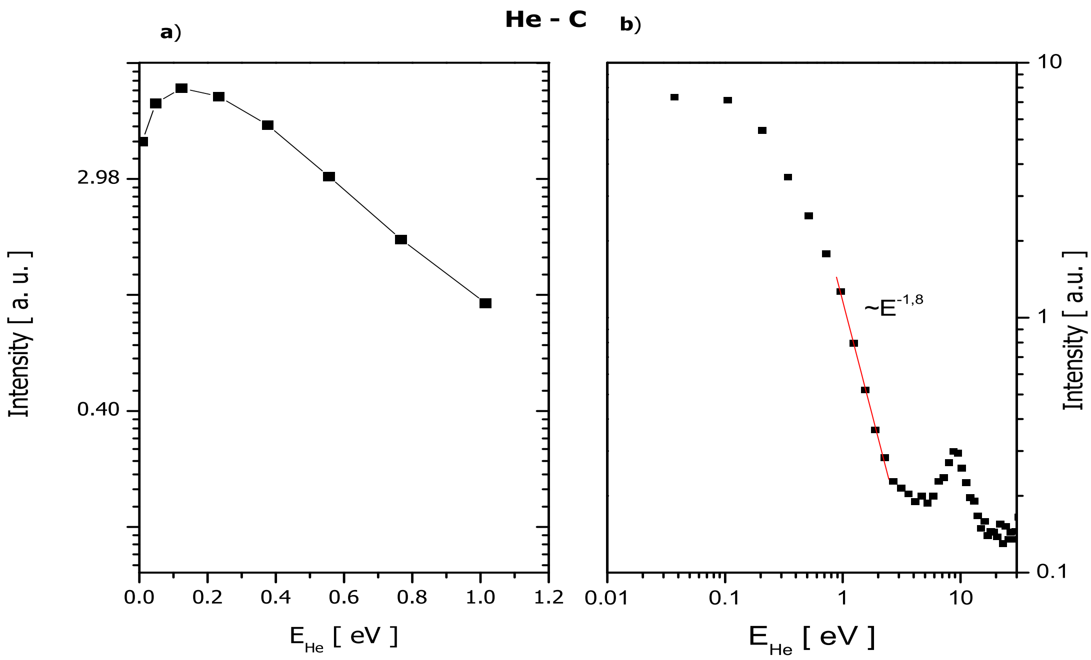

Figure 3: Energy distribution of helium in front of a carbon limiter

shifted Maxwellian velocity distribution and the ion induced desorption by a Thompson velocity distribution, a good agreement with the experiment was found.

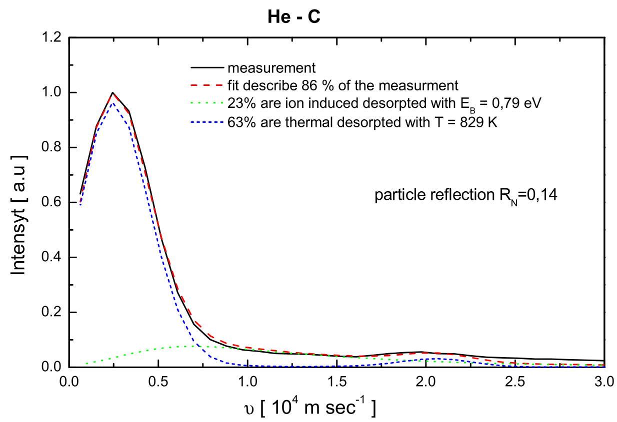

Figure 4: Fit of the measured spectrum

The fit parameters are the amplitude of thermal and ion induced desorption and the surface temperature T_S as well as the surface binding energy E_B. The determination of T_S shows a good agreement with the temperature T_T measured by a thermocouple (fig. 5a)). With the assumption that the recycling of the particles is equal to one, the remaining part in the velocity distribution describes the particle reflection. The integral over this part is associated with the particle reflection coefficient R_N. Fig.5 b) shows a comparison of experimental values with the numerically calculated ones, which were calculated with the Monte Carlo code TRIM[2]. The energy of He II was calculated from T_e[3]. The calculation of R_N for W shows an overestimation. The reason for this may lie in the coating of the W-limiter with carbon during the discharge.

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[3]P.Lindner, *Untersuchung der Freisetzungsmechanismen von Helium und Neon an Kohlenstoff und Wolfram in TEXTOR-94, thesis at Heinrich-Heine-Universität Düsseldorf* (1998), Jül-3560 (1998)

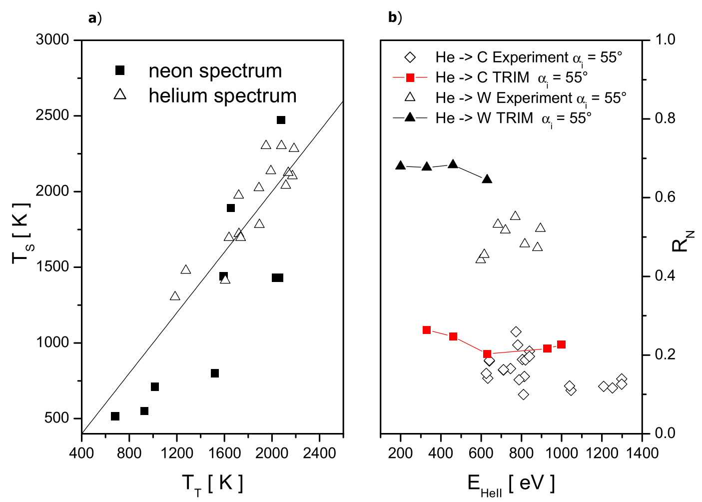

Figure 5: a) Limiter surface temperature b) particle reflection coefficient for different E_{HeII} with an ion incident angle of $\alpha_i = 55°$