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Plasma diagnostics of charge breeder ECR ion sources

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Electron Cyclotron Resonance (ECR) ion source charge breeding (CB) technique was invented in the 1990s in the context of Isotope Separation On Line facilities development for the study of atomic nuclei far from stability. ECR CB allows the 1+ beam injection on the source axis at the higher magnetic mirror side. After the capture of the injected ions into the support plasma, they are multi-ionised and extracted in the same way as the support gas atoms and ions. Therefore, the plasma must simultaneously favour the 1+ capture, multi-ionisation and release of the injected ion species in order to enhance the CB efficiency while keeping the process time short and impurity contamination of the extracted beams low. In the 2010s, the "Enhanced Multi-Ionization of Short-Lived Isotopes at Eurisol"project funded by the European Research Activities NETwork for Nuclear Physics Infrastructures initiated a collaboration between several laboratories to improve the CB performances in view of the large-scale EURISOL nuclear physics project. Here we present a comprehensive description of the plasma diagnostics studies conducted by the collaboration with the LPSC ECR CB in parallel to its development towards improved CB efficiencies. Analysing the uncaptured fraction of the injected beam passing through the CB allowed estimating the limits of the electron density and ion-ion collision frequencies in the ion source plasma. Experiments in pulsed mode 1+ injection were conducted to study the CB time, estimate plasma parameters and timescales, e.g. plasma electron density and temperature, ionization, charge exchange and ion confinement times. Finally, to refine the capture model, comparative measurements with different injected species into the CB demonstrated that the plasma potential plays a key role for 1+ ions slowing down. These studies together with the source improvements resulted in a significant enhancement of the performances and a better understanding of the CB process.

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