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Impurity Induced Micro-Electromagnetic Instabilities in Toroidal Plasmas

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Impurities are inevitable in nature and laboratory plasmas. The instabilities in presence of impurities, which is defined as the third particle species beside the main ions and electrons, have been long standing subjects in space and fusion plasmas because of their crucial roles in particle and energy transports and confinement [1]. In particular, even a small quantity of impurity greatly enhances the radiation losses of energy and induces damage of in-vessel components of devices in fusion plasmas. I addition, the effects of impurities on low-frequency electrostatic drift instabilities such as ion temperature gradient (ITG) driven modes [2-4] and trapped electron modes (TEMs) [5-7] have been investigated. Micro-electromagnetic instabilities and their effects on plasma confinement were observed in the pedestal region of H-mode plasmas on HL-2A tokamak [8]. New micro-electromagnetic instabilities are found in magnetically confined toroidal plasmas with two ion species (main and impurity ions) from gyrokinetic simulations. The instabilities are induced by impurity ion density gradient and finite β (plasma pressure/magnetic pressure) effect even in the absence of ion temperature gradient. The requirements of dual critical impurity density gradients (one positive and one negative), finite impurity concentration and plasma β are identified for the instabilities to occur. The instabilities are demonstrated as kinetic shear Alfvén type and kinetic ballooning type, respectively, and are unstable in the first and second stable regimes of the ideal MHD ballooning modes and may have significant influence on plasma confinement.

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