Tokamak edge physics and plasma-surface interaction

Richard A. Pitts
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Centre de Recherches en Physique des Plasmas
Association EURATOM-Confédération Suisse, CH-1015 Lausanne, Switzerland

In any closed system, conditions at the boundary are critical in determining the subsequent evolution of the system. Tokamaks are no different and the issues of particle and heat exhaust and plasma-surface interaction play an extremely important role in the performance of modern devices. Their influence will be significantly enhanced in future burning plasmas, such as the International Tokamak Experimental Reactor (ITER), where the upscale from the largest device currently in operation, JET, is an order of magnitude in plasma duration, at least 2 orders in fuel throughput and stored energy and about 4 orders in terms of divertor particle fluence. In ITER, plasma-facing components must satisfy the multiple demands of damage resistance due to high transient heat loads (such as those due to Edge Localised Modes and disruptions), material lifetime as a result of plasma and neutral erosion and the very low permitted levels of tritium retention in surfaces imposed by nuclear licensing regulations. The amount of T-retention is determined by surface implantation and co-deposition, when eroded material traps the recycling fuel. At any given location, most importantly in the divertor itself, this eroded material may originate from local plasma-surface interaction or through migration from a distant source via transport in the boundary plasma.

This tutorial will aim to provide a simplified overview of the essential physics governing heat and particle transport and divertor function in tokamaks, with emphasis on those aspects of particular relevance to ITER-scale devices and where possible using illustrations from research results on present machines, notably JET. It will also address the key issue of plasma-surface interaction, discussing the questions of first wall material choice, dust generation, tritium retention and material lifetime.