DOI: 10.34854/ICPAF.52.2025.1.1.005

FROM TOKAMAK-1972 TO ITS TOGA UPGRADE TOWARD LI WALL FUSION

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The tokamaks remained fundamentally unchanged since 1972, when Shafranov and Artsimovich [1] introduced tokamaks with a non-circular cross-section. While numerous modifications — such as spherical tokamaks, X-point super-divertors, and negative triangularity — have contributed to incremental improvements, none has addressed the core issue of tokamak fusion: uncontrolled plasma edge cooling caused by recycling. Despite G. McCracken's 1969 proposal [2] to suppress recycling by a lithium (Li) layer for plasma pumping, further exploration was stalled due to concerns about the feasibility of helium ash removal in a low-recycling regime of deuterium-tritium (DT) plasmas.

McCracken's concept was revived (L. Zakharov & S. Krasheninnikov, 1998, see also [3]) enhancing it by proposing direct plasma core fueling via neutral beam injection (NBI). This Li Wall Fusion (LiWF) concept faced resistance due to two entrenched dogmas: (a) lithium is incompatible with burning plasma due to tritium absorption, and (b) NBI core fueling is infeasible. The first dogma lacks scientific basis, while the second applies only to high-recycling regimes. Unlike conventional materials, liquid lithium layers are unaffected by secondary atoms arising from charge exchange.

Recently, the TOGA design was submitted as a Provisional Patent Application to the US Patent and Trademark Office. Toga embodies the driving idea that the tokamak plasma should face only lithium. This approach reduces plasma edge cooling to 10–20%, significantly enhancing plasma performance while lowering external heating requirements. Importantly, toga eliminates Plasma Surface Interactions (PSI), as known at present, thus offering a predictable pathway to disruption-free operation. The Li-doping effect on NBI capture, recently demonstrated in the Lithium Tokamak Experiment (LTX), enables middle-sized tokamaks to high-energy hydrogen NBIs, paving the way to simulate the 120–180 keV D/T NBIs needed for burning plasma.

The primary research goal of the Toga LiWF regime is to confirm the stability of the plasma edge, leveraging insights from limited low-recycling experiments to date. Beyond plasma physics, the broader challenge lies in defining the role of tokamak fusion in energy systems, particularly for fusion-assisted nuclear energy. Given the relatively low power density of fusion compared to fission, collaboration with Fast Breeder Reactor (FBR) technology is essential to address the global energy challenge and reduce reliance on fossil fuels.

This presented report details the TOGA concept and its implications for magnetic fusion within the constraints imposed by the ongoing patent application process.

Литература

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