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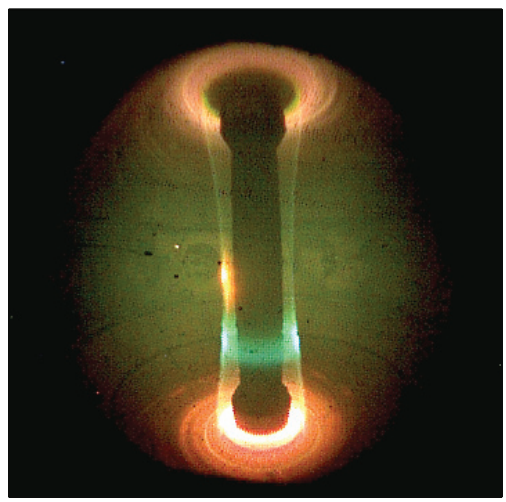
Elements Duke It Out to Penetrate Hot Plasma

Scientists get a better understanding of why some atoms get into the core of their magnetic fusion experiments more easily than do others.

PROVIDENCE—Scientists at the Department of Energy's Princeton Plasma Physics Laboratory used fast cameras that take up to 100,000 frames per second and computer codes to understand how impurities are produced and can penetrate the core of the hot ionized gas known as plasma during magnetic fusion experiments in the National Spherical Torus Experiment (NSTX).



Photo/video of the interior of the NSTX fusion experiment showing light emitted by the hydrogen, carbon, and lithium atoms in the cooler edge regions of the plasma near where it contacts interior surfaces.

Impurities can cool the plasma so their accumulation has to be avoided in order to heat the plasma to at least 100 million degrees Celsius. These temperatures are needed in order for the fuel ions to collide into each other at a high speed and fuse together to create magnetic fusion. To understand the sources of impurities, scientists placed high-speed cameras viewing the interior of NSTX during fusion experiments, along with spectrometers that capture the unique light wave produced by the atoms. They were then able to trace what happens when plasma hits the walls of the vessel that holds the plasma inside a magnetic field. In NSTX, in particular, the walls of the tokamak are made of graphite and are sprayed with a coating of lithium before each plasma experiment. When the plasma hits the walls of the tokamak, it causes lithium and carbon atoms to bounce off the walls and potentially penetrate the core plasma.

"The idea was to start looking at all the processes that cause impurities to be released at the wall and eventually penetrate the plasma," explained Filippo Scotti, a scientist on the project.

The researchers found were numerous carbon atoms in the plasma core but very few lithium atoms, despite the layer of lithium on top of the graphite. The lithium erodes fairly quickly from the tokamak walls, exposing the graphite beneath it, but travels only a short distance before bouncing back to the tokamak floor (called divertor). The lithium ions are then “trapped” more efficiently than carbon in the divertor region. The carbon atoms can escape more easily, travel along the magnetic lines that contain the plasma and then penetrate in the plasma core.

Scientists not only used fast camera and spectrometers, they also used computer codes to explain how these processes work, leading to the identification of other processes which limit the penetration of lithium ions in the core. In particular, the few lithium ions that make it to the core are dispersed by collisions on carbon ions which have higher charge, thereby leading to lower accumulation.

Understanding the processes that generate and transport impurities into the plasma could help scientists find ways to further improve plasma performance. They could investigate using other materials to replace the graphite used in the tokamak, for example, or they could investigate other plasma configurations that would reduce the number of atoms that hit the tokamak walls and floor. In particular this work also highlights the potential of lithium as a material for a reactor first wall thanks to the very low core penetration of lithium ions.

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Abstract:

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