Radiation strengthens NiCr alloys

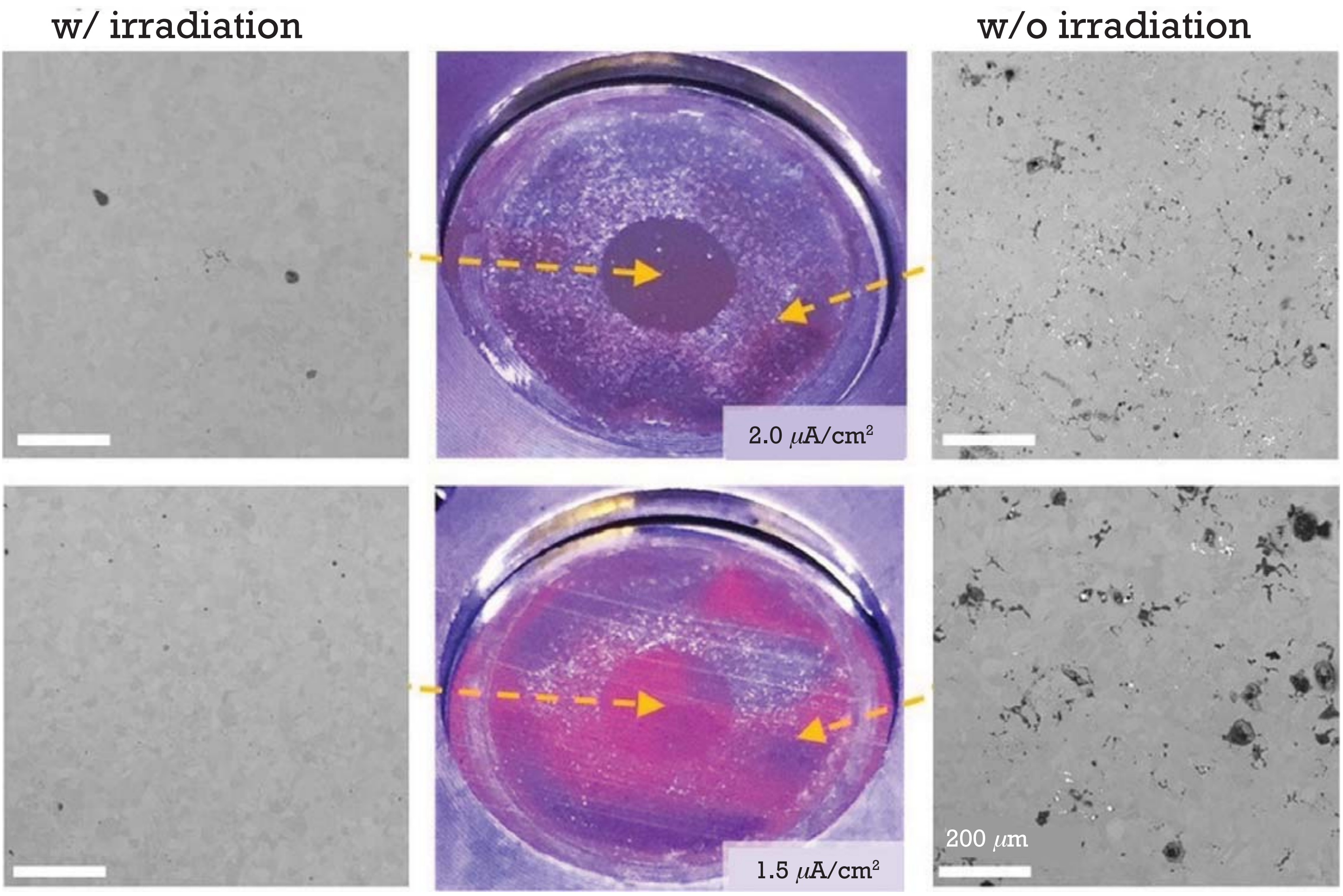
Researchers at Massachusetts Institute of Technology (MIT) have discovered that exposure to proton irradiation can strengthen and extend certain alloys' lifetime, including nickel-chromium.

Text & image by MIT

The most damaging effect of radiation is its tendency to degrade any material exposed to it. This encourages rapid deterioration and often results in the need to replace key parts in high-radiation environments, such as nuclear reactors.
But new research proffered by MIT researchers shows that, for certain alloys that could be used in fission or fusion reactors, the opposite reaction can occur: instead of speeding up the material's degradation, radiation actually improves its resistance, potentially doubling the material's useful lifetime.

An accidental discovery

In a full report published by the journal Nature Communications, the findings signify an opportunity for some new, cutting-edge reactor designs, including molten-salt-cooled fission reactors, and new fusion reactors such as the ARC design under development by MIT and Commonwealth Fusion Systems.
Michael Short, MIT professor of nuclear science and engineering and one of the researchers on the team, implies it was a surprise result as they had been looking to investigate the opposite effect. Initially, they wanted to determine how much radiation increases the corrosion rate in certain alloys of nickel and chromium that may be used as cladding for nuclear fuel assemblies.
MIT's news office reports that experiments were difficult to carry



Optical and scanning electron microscope images showing irradiated and unirradiated zones of a nickel-chromium alloy. The left side shows examples of foils with irradiation; instead of degrading the material as it almost always does, the radiation actually makes it stronger by reducing the rate of corrosion. Image courtesy of the researchers
[source: www.news.mit.edu]

out because of how impossible it was to measure temperatures directly at the interface between the molten salt, used as a coolant, and the metal alloy surface. It was, therefore, necessary to figure out the conditions indirectly by surrounding the material with a battery of sensors. "Right from the start, though, the tests showed signs of the opposite effect — corrosion, the main cause of materials failure in the harsh environment of a reactor vessel, seemed to be reduced rather than accelerated when it was bathed in radiation, in this case a high flux of protons".

Radiation activates self-healing mechanism

The same article explains that the team simulated a reactor environment in the experiment which involved the use of molten sodium, lithium, and potassium salt as a coolant for both the nuclear fuel rods in a fission reactor and the vacuum vessel surrounding an incredibly hot swirling plasma in a future fusion reactor.

"Where the hot molten salt is in contact with the metal, corrosion can take place rapidly, but with these nickel-chromium alloys they found that the corrosion took twice as long to develop when the material was bathed in radiation from a proton accelerator, producing a radiation environment similar to what would be found in the proposed reactors".

The impact of being able to more accurately predict the usable lifetime of critical reactor components is that this could reduce the need for early replacement of parts.

Careful analysis of images of the affected alloy surfaces, after irradiating the metal in contact with molten salt at 650 degrees Celsius - a typical operating temperature for salt in such reactors - helped to reveal the mechanism causing the unexpected effect. "The radiation tends to create more tiny defects in the structure of the alloy, and these defects allow atoms of the metal to diffuse more easily, flowing in to quickly fill the voids that get created by the corrosive salt. In effect, the radiation damage promotes a sort of self-healing mechanism within the metal".

Discovery opens up possibilities

The discovery could be relevant for a variety of proposed new designs for reactors that could be safer and more efficient than existing designs. Several designs for salt-cooled fission reactors have been proposed, including one by a team led by Charles Forsberg, a principal research scientist in MIT's Department of Nuclear Science and Engineering. The findings could also be useful for several proposed designs for new kinds of fusion reactors being actively pursued by startup companies, which hold the potential for providing electricity with no greenhouse gas emissions and far less radioactive waste.

"It's not particular to any one design," MIT news office reports Short as saying. "It helps everybody."

The research team included K. Woller, P. Stahle and G. Q. Zheng at MIT, and Y. Yang and A. M. Minor at Lawrence Berkeley National Laboratory. The full report is available via Nature Communications.

To read the original news article, see: www.news.mit.edu