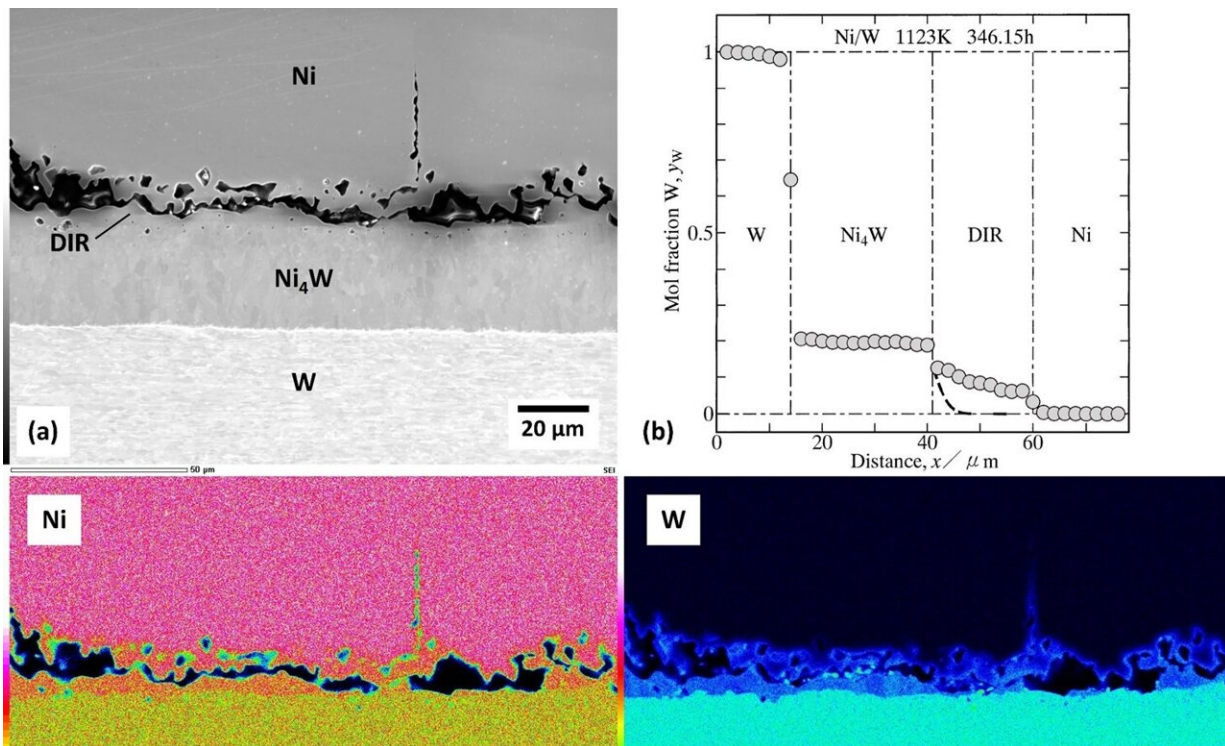


Exploring interface phenomena for more durable and effective nickel–tungsten alloys

May 14 2024



The interdiffusion of Ni and W results in the formation of Ni₄W as an intermetallic layer. At the interface between the Ni₄W layer and Ni phase, Kirkendall voids are observed. Credit: Minh Oh

Alloying is a key process in creating new materials. By combining metals with desirable traits, scientists can produce alloys with suitable properties. For example, stainless steel, formed by combining iron with

chromium, nickel, and other elements in smaller quantities is highly resistant to corrosion.

A class of alloy of particular interest for [military applications](#) is the nickel–tungsten alloys (Ni–W). These alloys possess high durability, making them useful as coatings. As Ni and W have different properties, their joining interface forms unique layers where [intermetallic compounds](#) (IMCs) and [diffusion](#) induced recrystallization (DIR) regions are formed through processes such as diffusion and interfacial reactions.

These regions exhibit significantly different mechanical, thermal, and chemical behaviors compared to the rest of the alloy. Therefore, understanding the properties of these interfaces is an important aspect of designing alloys with suitable properties.

Now, researchers led by Assistant Professor Minho Oh from Tokyo Institute of Technology and including Professor Hee-Soo Kim, currently at Chosun University, South Korea, have revealed how various phases, including IMCs, are formed within a Ni–W alloy. [Their findings published](#) in the *Journal of Alloys and Compounds* can prove valuable in developing Ni–W alloys that last longer and are more effective as coatings.


"Insights from studies of IMCs and intermediate layers formed by diffusion at the Ni/W interface have the potential to significantly improve the effectiveness and longevity of important materials in various fields," says Oh.

To examine the Ni/W interface, the researchers sandwiched a W sheet between two Ni plates. They then heated the sample at 1123 K for 112 hours to encourage diffusion, followed by annealing at the same temperature for 234.15 hours.


Subsequently, the researchers analyzed the morphology and chemical compositions of the interface using experimental techniques. They analyzed the concentrations of Ni and W in each phase of the material's cross-section, as well as the grain sizes of the regions formed at the interface.

Exploring Interface Regions and Kirkendall Void Formation Mechanisms in Nickel-Tungsten Alloys

Nickel-tungsten (Ni-W) alloys are highly durable, making them useful as a coating material for specialized equipment and weaponry

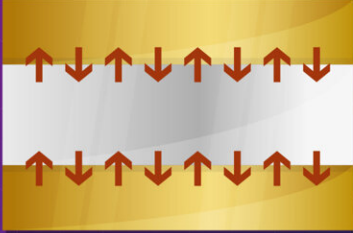


Understanding the properties of Ni/W interfaces is crucial for improving alloy performance



Formation of the diffusion-induced recrystallization (DIR) region

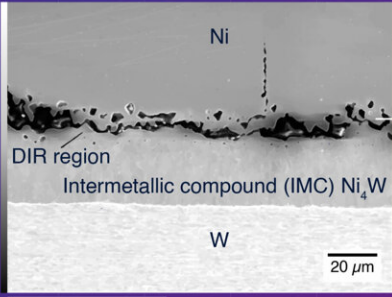
Annealed diffusion couple Ni-W sample




Ni plate
W sheet
Ni plate

✓ Diffusion of Ni and W


Polycrystalline layer formation at Ni/W interface




Ni
Kirkendall voids
DIR region
Intermetallic compound (IMC) Ni₄W
W
50 μm
20 μm



Formation of IMC and DIR region as polycrystalline layers



Formation of Kirkendall vacancies at the DIR/Ni interface



Grain boundary diffusion of W observed in the DIR region

The formation of Kirkendall vacancies depends on the difference between the nickel and tungsten diffusivities

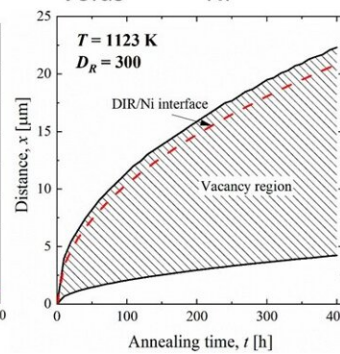
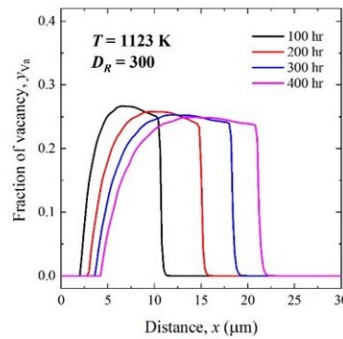
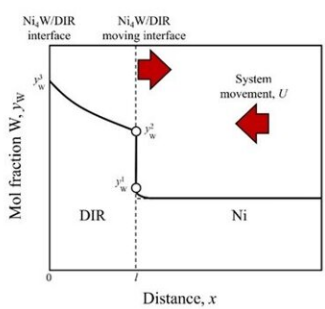
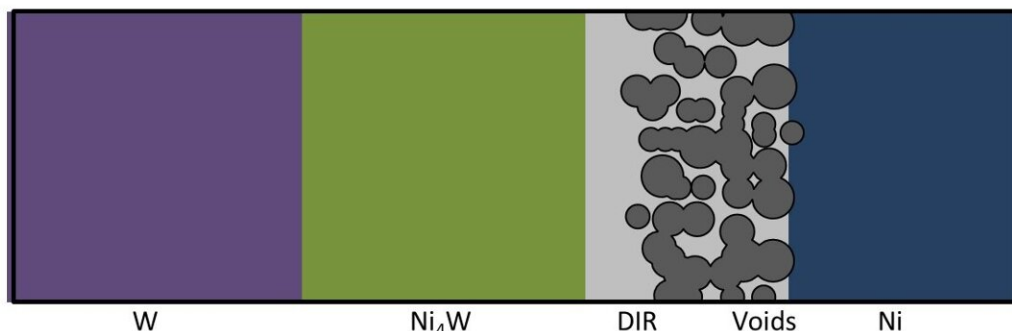
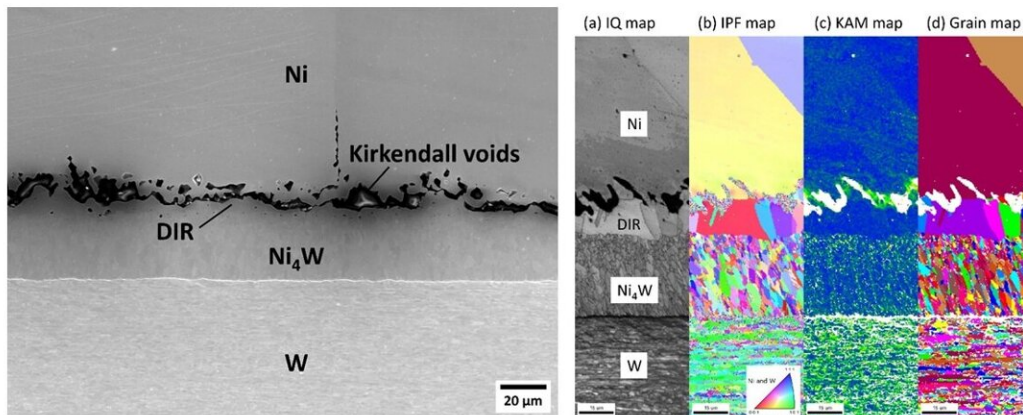
Understanding Kirkendall effect in Ni(W) diffusion-induced recrystallization region
 Oh et al. (2024) | *Journal of Alloys and Compounds* | 10.1016/j.jallcom.2024.174556



The formation of Kirkendall vacancies depends on the difference between the

nickel and tungsten diffusivities. Credit: Minh Oh, Tokyo Institute of Technology

Understanding Kirkendall effect in Ni(W) Diffusion-Induced Recrystallization Region



In the DIC region, W atoms diffuse into the Ni matrix via grain boundary diffusion. Credit: Minh Oh

Additionally, the researchers developed a diffusion model that accounted for the diffusion rates of Ni and W in both the bulk metal and different interface regions to explain the formation of these interface regions.

Their analysis revealed that the interdiffusion of Ni and W results in an IMC layer of Ni_4W , which grows bidirectionally towards Ni and W plates. The W atoms continue to move into the Ni matrix, forming a diffusion-induced recrystallized region (DIR) between the Ni matrix and the IMC layer. Notably, both the Ni_4W IMC and the DIR region exhibit a polycrystalline structure.

The DIR region is not an individual phase but a solid-solution region within the Ni phase. It is characterized by the presence of elongated columnar-shaped grains that facilitate grain boundary diffusion of W atoms.

In the DIR region, the imbalance in the diffusion rates of Ni and W causes irregular-shaped voids known as Kirkendall voids to form near the interface between Ni and DIR in the DIR region. Notably, the interfaces consisting of the DIR region, IMC, and voids influence the strength and thermal properties of the material.

"These findings not only advance our comprehension of the DIR region resulting from IMC formation and diffusion at the Ni/W [interface](#) but also offer crucial insights into the phenomenon of Kirkendall void generation and the mechanism of defect formation within the DIR region of the metal system," says Oh.

"This integrated approach enhances our understanding of thermodynamics and kinetics in the Ni–W diffusion couple, advancing knowledge crucial for high-temperature materials science."

More information: Minho Oh et al, Understanding Kirkendall effect in Ni(W) diffusion-induced recrystallization region, *Journal of Alloys and Compounds* (2024). [DOI: 10.1016/j.jallcom.2024.174556](https://doi.org/10.1016/j.jallcom.2024.174556)

Provided by Tokyo Institute of Technology

Citation: Exploring interface phenomena for more durable and effective nickel–tungsten alloys (2024, May 14) retrieved 20 June 2024 from <https://phys.org/news/2024-05-exploring-interface-phenomena-durable-effective.html>

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