A Novel Coating to Avoid Corrosion Effect and Vibration Coupling Between Eutectic Gallium-Indium Alloy and Heat Sink Metal for X-Ray Optics Cooling

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Abstract

Although the vibration decoupling method based on eutectic gallium-indium (EGaIn) alloy performs excellent in suppressing parasitic vibration caused by the cooling medium and pipes of X-ray optics,[1,2,3] the corrosion of EGaIn alloy to the heat sink metal still results in the solidification and the vibration decoupling failure.[4,5] A novel anti-corrosion coating based on tungsten(W) is proposed. Through the analysis of the microstructure and the chemical composition after heating for 36 hours at 250°C, there is no obvious evidence that W is corroded which is more effective than the widely used coating of nickle(Ni). And the W coating by using magnetron sputtering has been implemented for feasibility validation. Its corrosion resistance mechanism has also been analyzed.

X-Ray Optics Cooling Based On EGaIn Alloy

The bulge connected with the cooling pipe is immersed into the grove which is machined on the mirror and filled with EGaIn alloy. The vibration is cut off and suppressed. At the same time, the heat on the mirror transfers to the bulge connected with the pipe through EGaIn alloy. It can suppress the vibration and cool the optics . It has the advantages of vibration decoupling and no clamping stress. But Cu as a conventional heat sink material, has poor corrosion resistance for the EGaIn. A compound of $CuGa_2$ is easily generated at room temperature.[6,7,8]

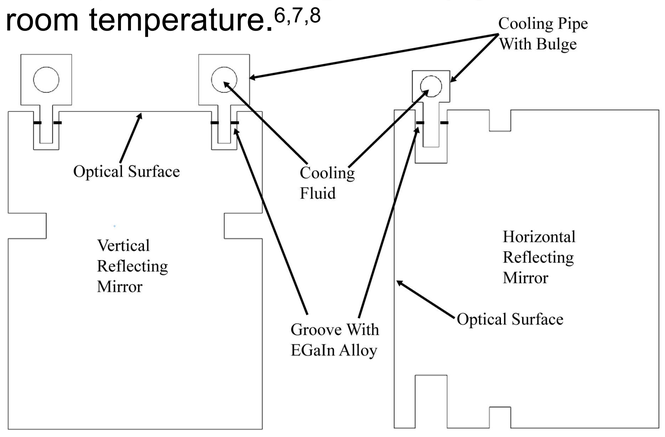

FIG. 1. Vibration decouplincg cooling.

The reaction will reduce gallium in EGaIn alloy which will cause the increasing of melting point of the alloy from 15.5°C(In: 24.5wt%, Ga: 75.5wt%).The alloy will be solidified if the melting point exceeds operating temperature (about 22℃) , which results in a rigid connection and vibration decoupling failure. Ni coating is applied to arrest corrosion, but the alloy still cures into paste after a period of time to leading to the interface stiffening and the parasitic vibration effect.

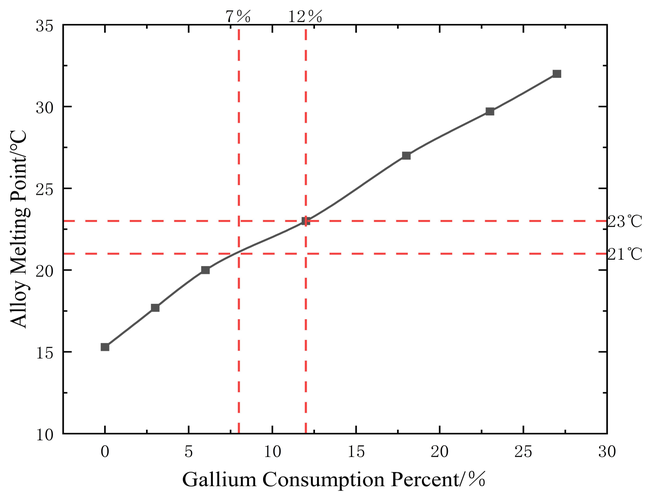

FIG. 2. Melting point curve of the alloy.

Experiment

- **Six settings**
- **Five coatings**
  - **W**
  - Mo
  - TiAlCrN
  - **Ni**
  - **Cu**
- **Two analytical methods**
  - **Microstructure**
    - Optical microscope (OM)
    - Scanning electron microscope (SEM)
  - **Phase composition**
    - X-ray diffraction (XRD)

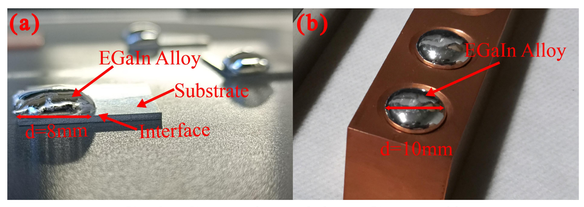

FIG. 3. Sample with EGaIn alloy.
(a)substrate sample (b)coating sample

TABLE I. Experimental settings.

Group	Condition
Group 1	150°C-6h
Group 2	200°C-6h
Group 3	250°C-6h
Group 4	250°C-12h
Group 5	250°C-18h
Group 6	250°C-36h

Results And Analysis

Figure 4 is the cross-sectional corrosion observation view of the substrate in different conditions(Cu, Ni, W).

- **Cu:** Adhesion→ Serious pit → Serious void layer
- **Ni:** Nothing → Slight pit → Slight void layer
- **W: No obvious pit or adhesion**

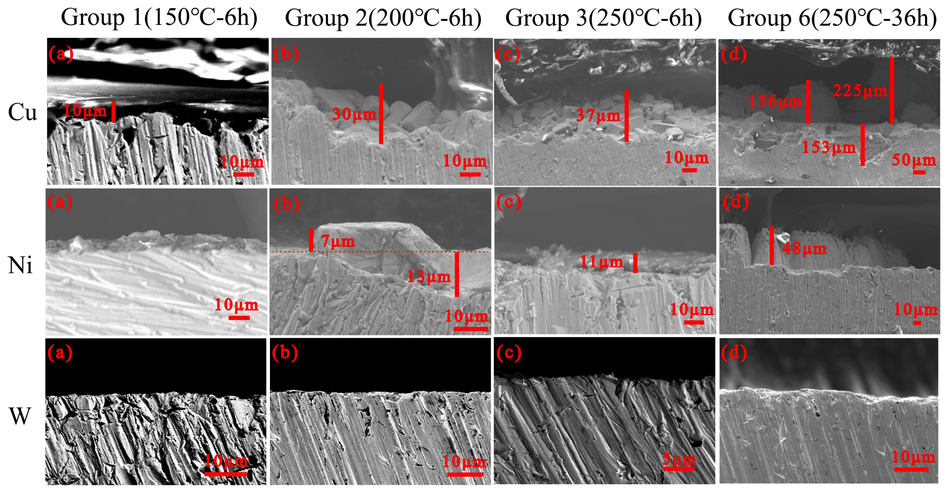

FIG. 4. Corrosiocn observation.

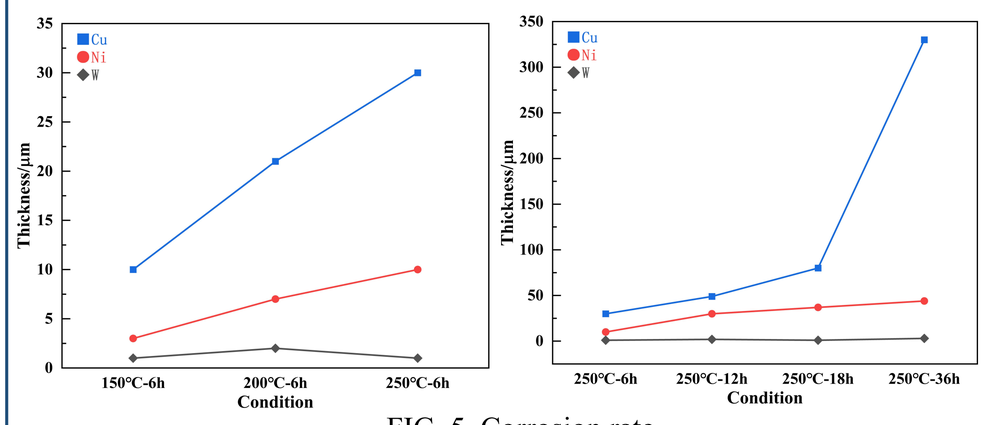

FIG. 5. Corrosion rate.

- **Cu:** $CuGa_2$(Cu is coverd)
- **Ni:** $NiGa_5$, $NiGa_4$, Ni_3Ga_7
- **W: No new phase**

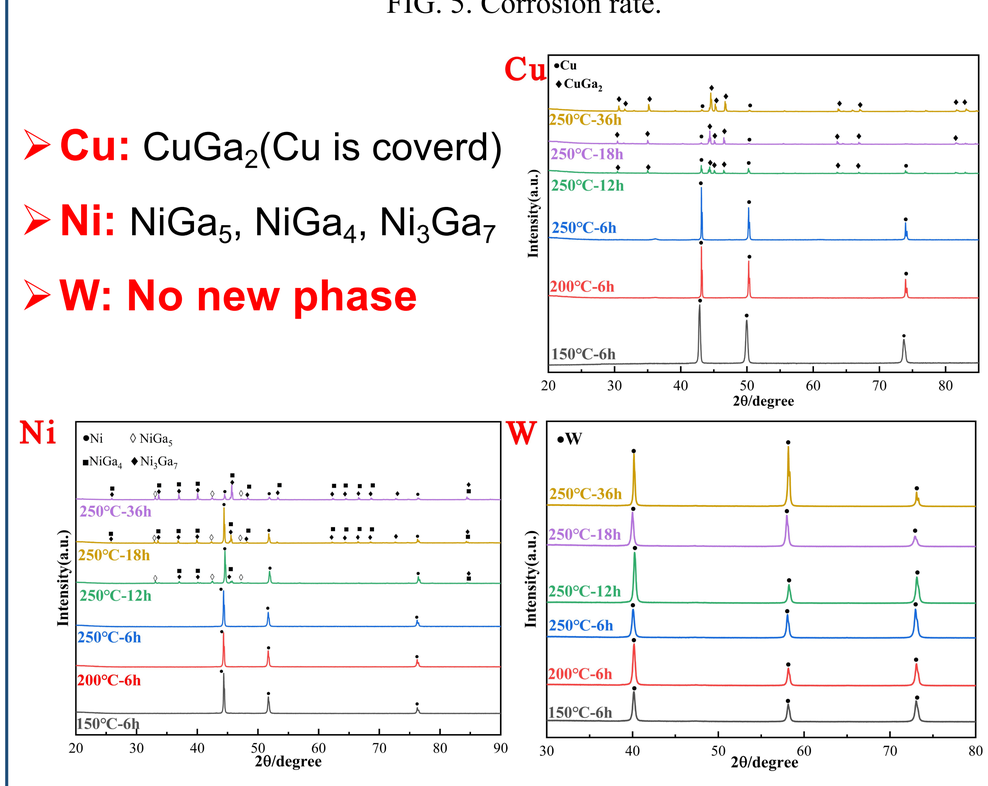

FIG. 6. The XRD results

Validation And Fabrication Of The Proposal Coating

- **Prepared by magnetron sputtering**
- **Ten months**

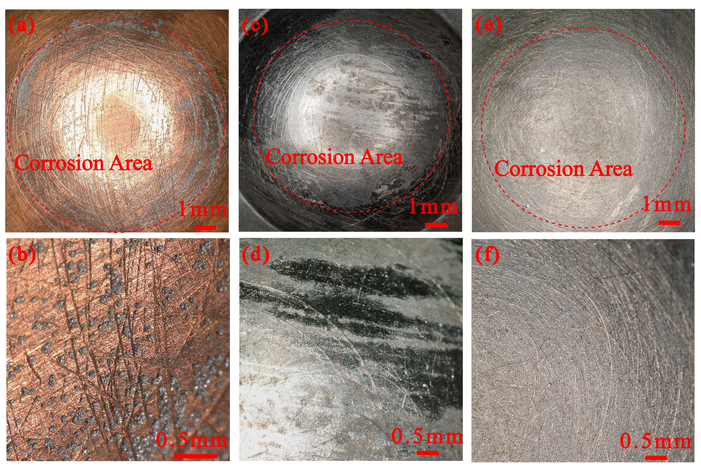

FIG. 7. Sample with EGaIn alloy.
(a)substrate sample (b)coating sample

The result is consistent with experiments.

Conclusion And Discussion

- Vibration decoupling failure mechanism is described.
- W is validated as a better coating for vibration decoupling from microstructure and phase composition.
- The feasibility of W coating prepared by magnetron sputtering is implemented.
- The corrosion resistance mechanism can be further analyzed in order to explore a better method.
- The vibration decoupling after coating optimization can be further compared and analyzed by FEA.

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