

Preliminary Study on the Fretting Wear Behavior of Multi-Layer Coatings for Accident Tolerant Fuel Cladding

Young-Ho Lee*, Jung-Hwan Park, Dong-Jun Park, Yang-Il Jung, Sung-Chan Yoo, Hyun-Gil Kim

Advanced 3D Printing Technology Development Division, Korea Atomic Energy Research Institute

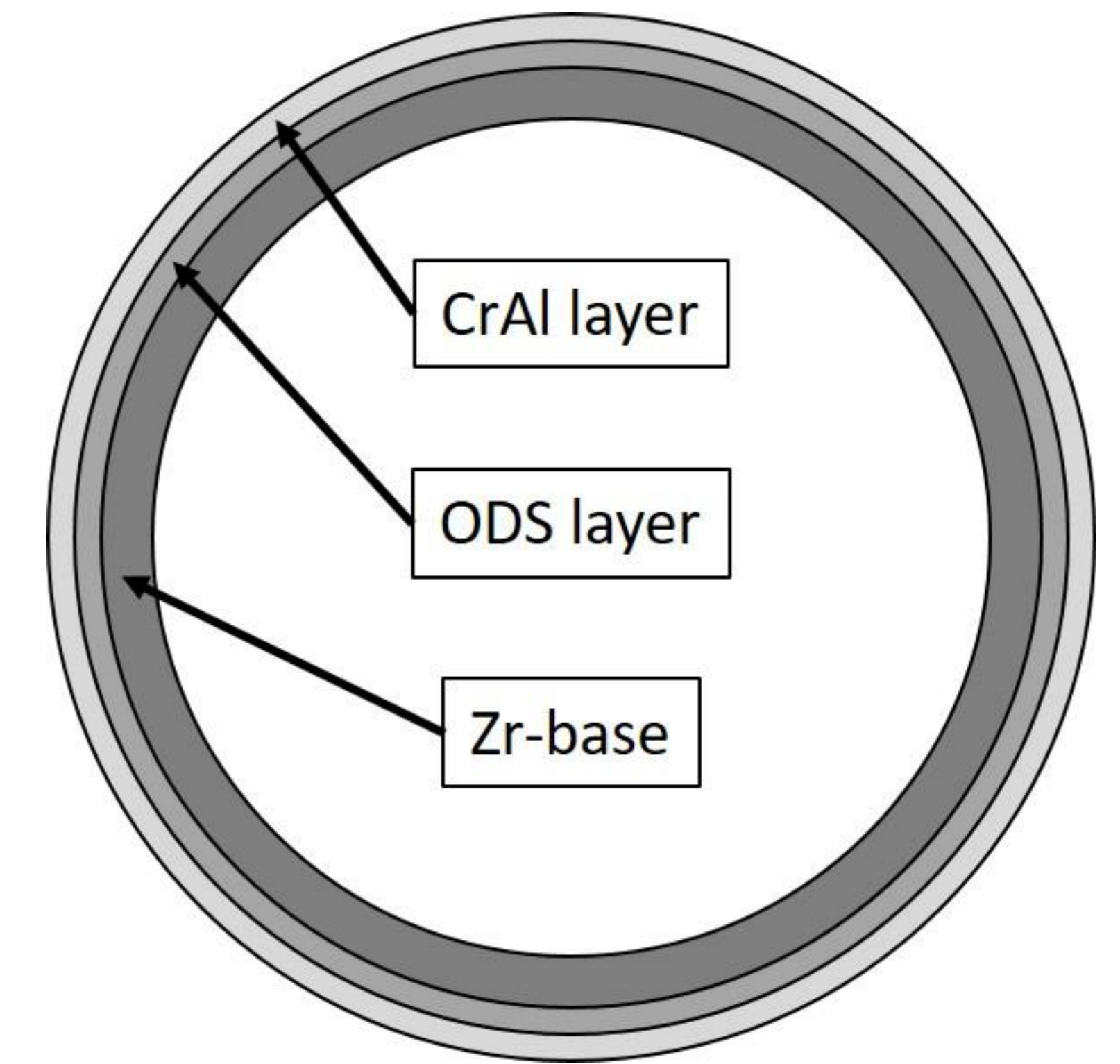
Introduction

Multi-layer coating for Accident-Tolerant Fuel cladding

- Base materials: Conventional Zr-based fuel cladding
- Inner surface: Improving mechanical strength (Oxide Dispersion Strengthened, ODS)
- Outer surface: Corrosion resistance in high temperature steam (CrAl alloy)

Different interfacial strength between CrAl-coated Zr and CrAl-coated ODS Zr cladding

- The same CrAl coating method on different base materials (Zr Alloy vs ODS-treated Zr Alloy)
- The same CrAl coating thickness: $\sim 20 \mu\text{m}$
- To evaluate compatibility of conventional Zr-base spacer grid without shape and materials modification



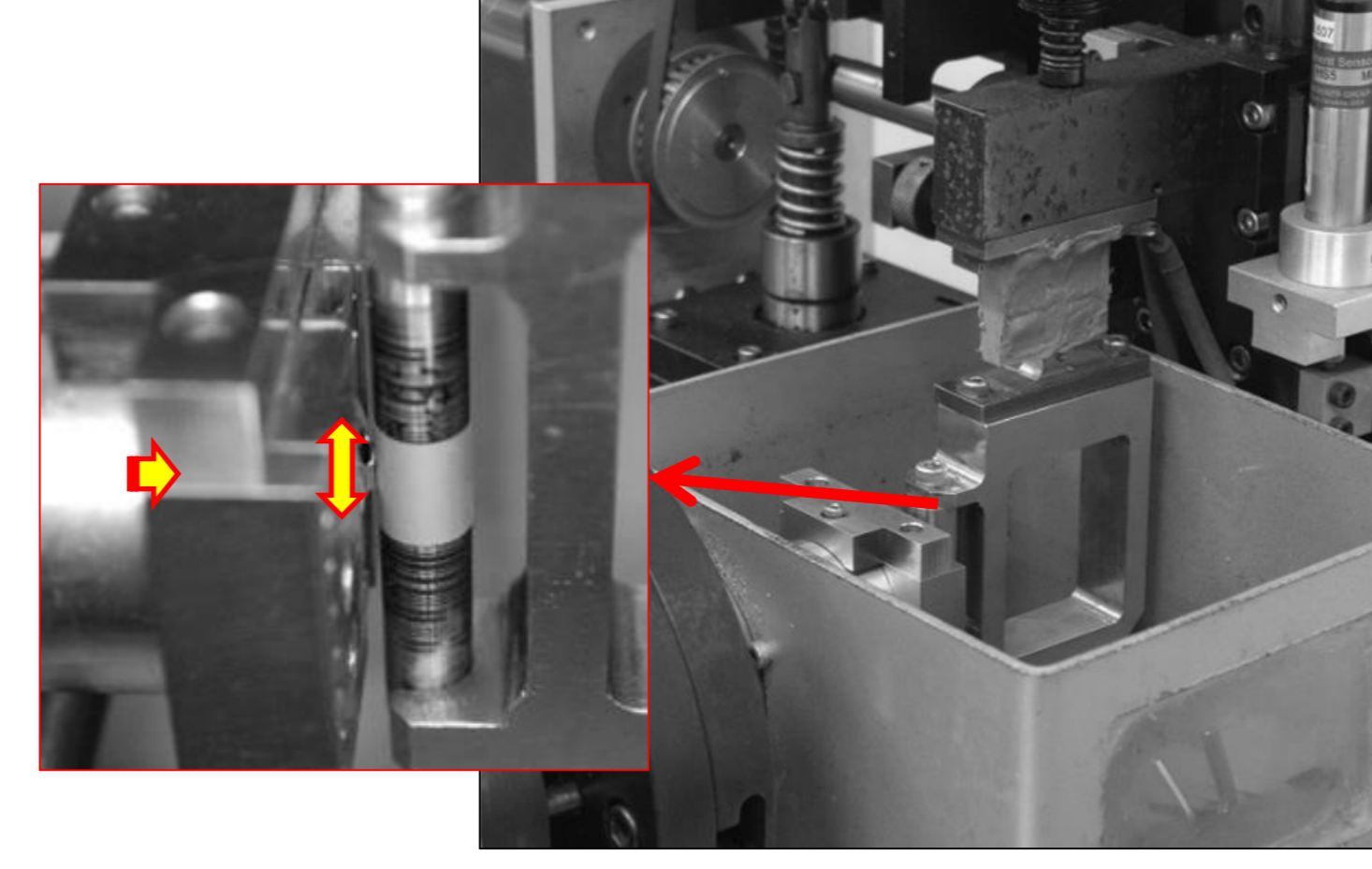
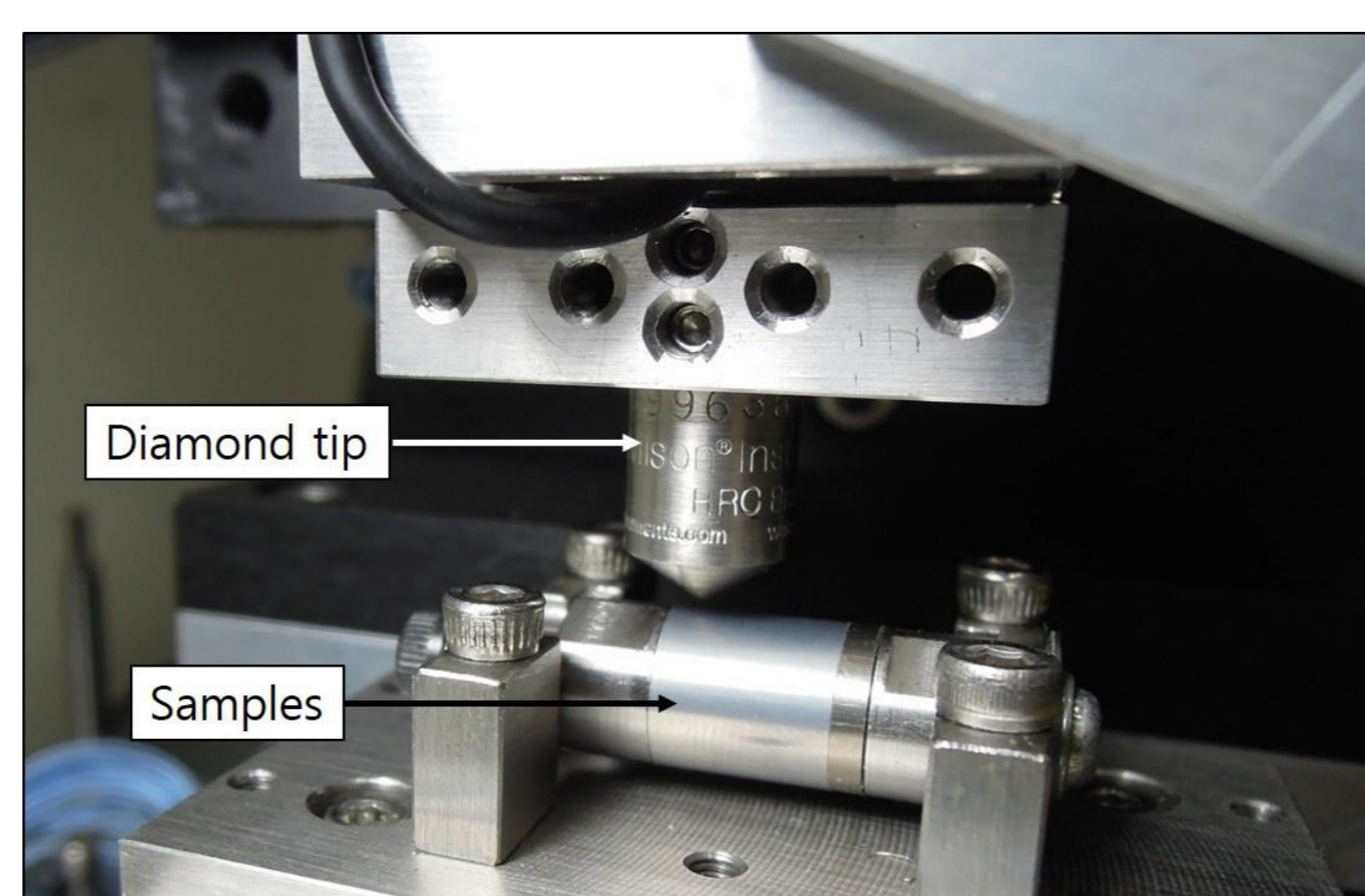
Multi-layer coating concept

❖ In this study, the tribological properties of CrAl-coated ODS Zr alloys deposited by an Arc Ion Plating (AIP) and Sputtering (SP) method were experimentally evaluated.

Experiments

Fretting wear test condition

- Normal force: 10 N
 - Relative slip amplitude: $100 \mu\text{m}$
 - Frequency: 30 Hz
 - Number of cycles: $10^5 \sim 10^6$
 - Room temperature water
 - Repeat.: more than 3 times
- ❖ Coated cladding against Zr-based grid specimen (As-received)

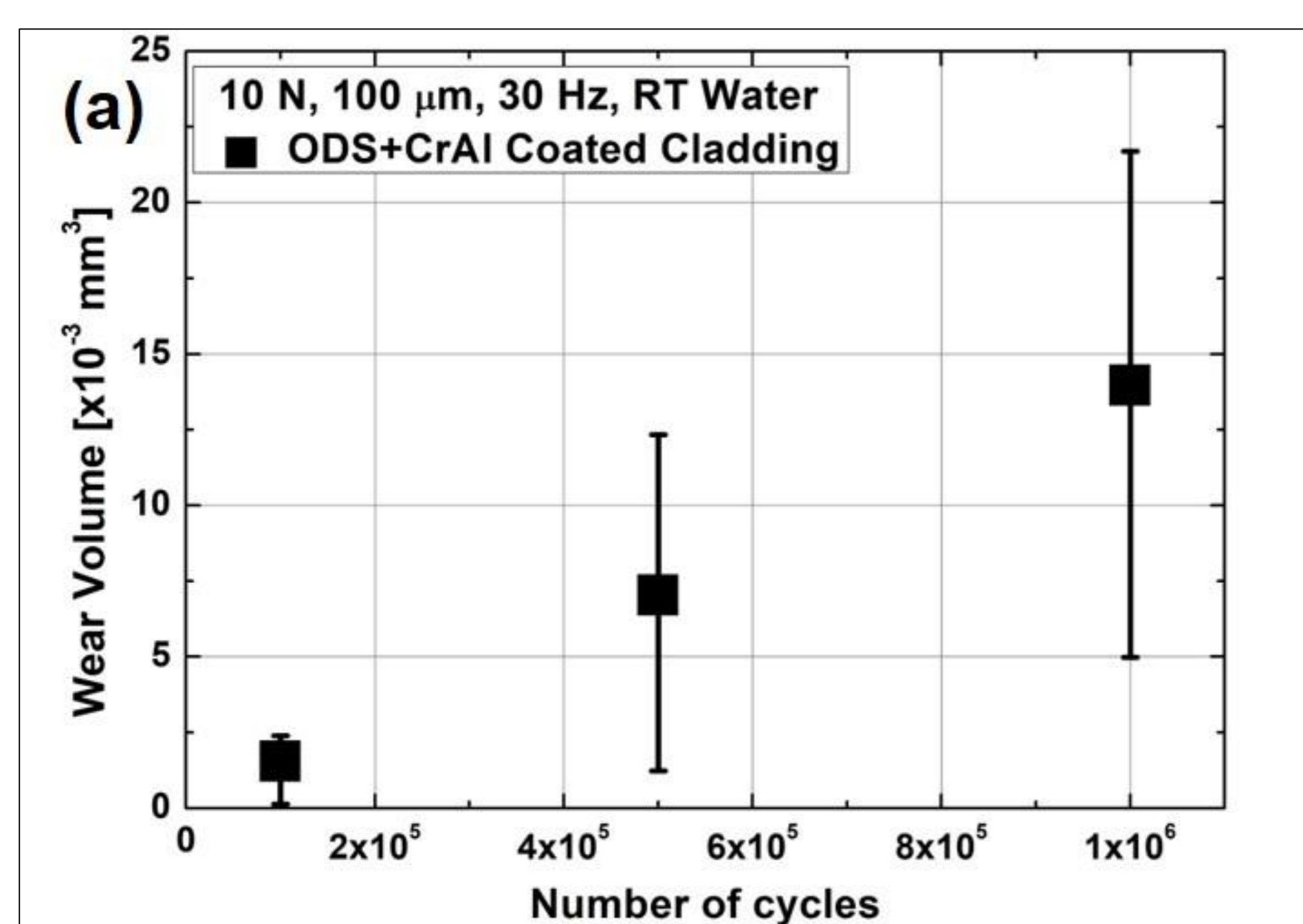


Scratch and Indentation test

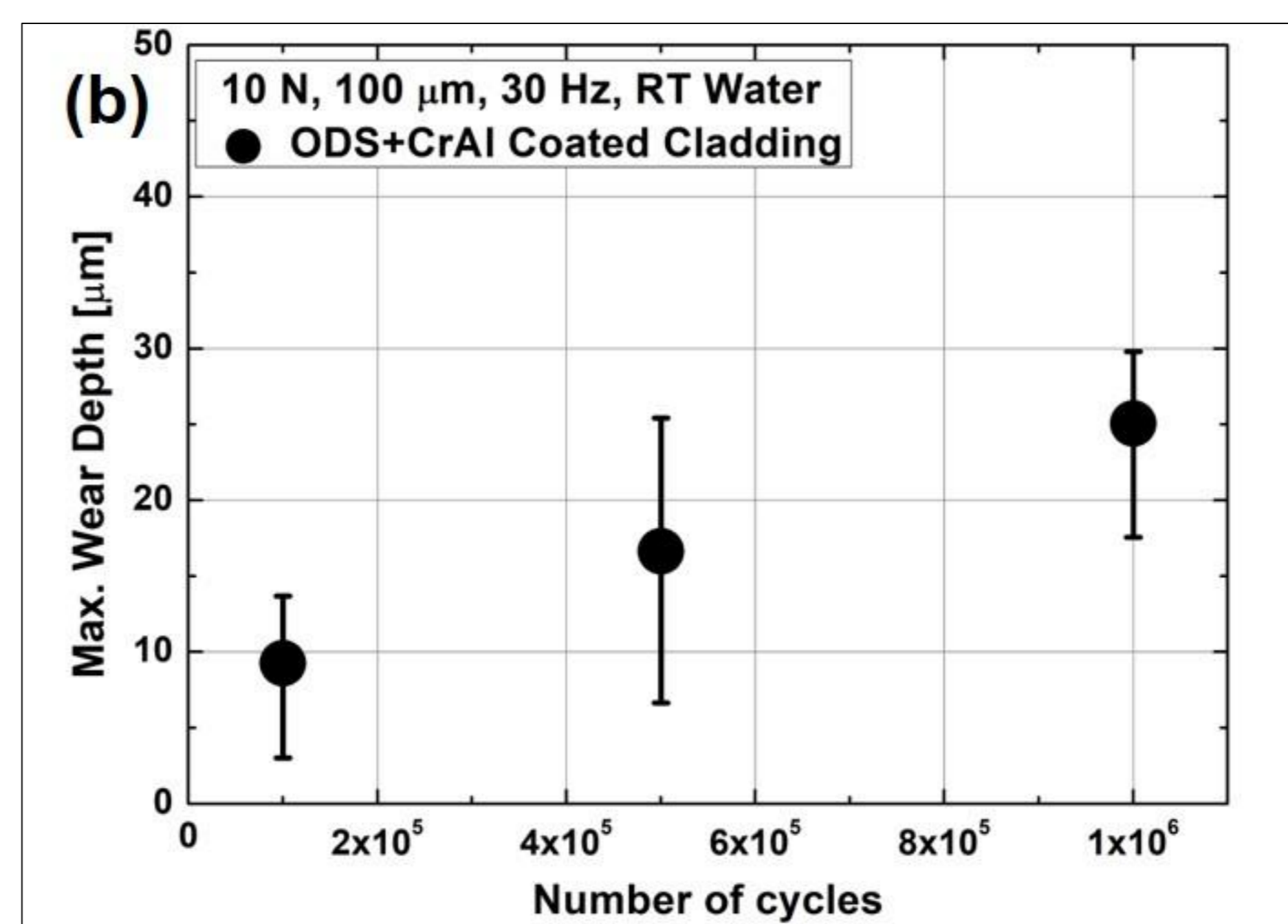
Fretting Wear test

Wear measurement system

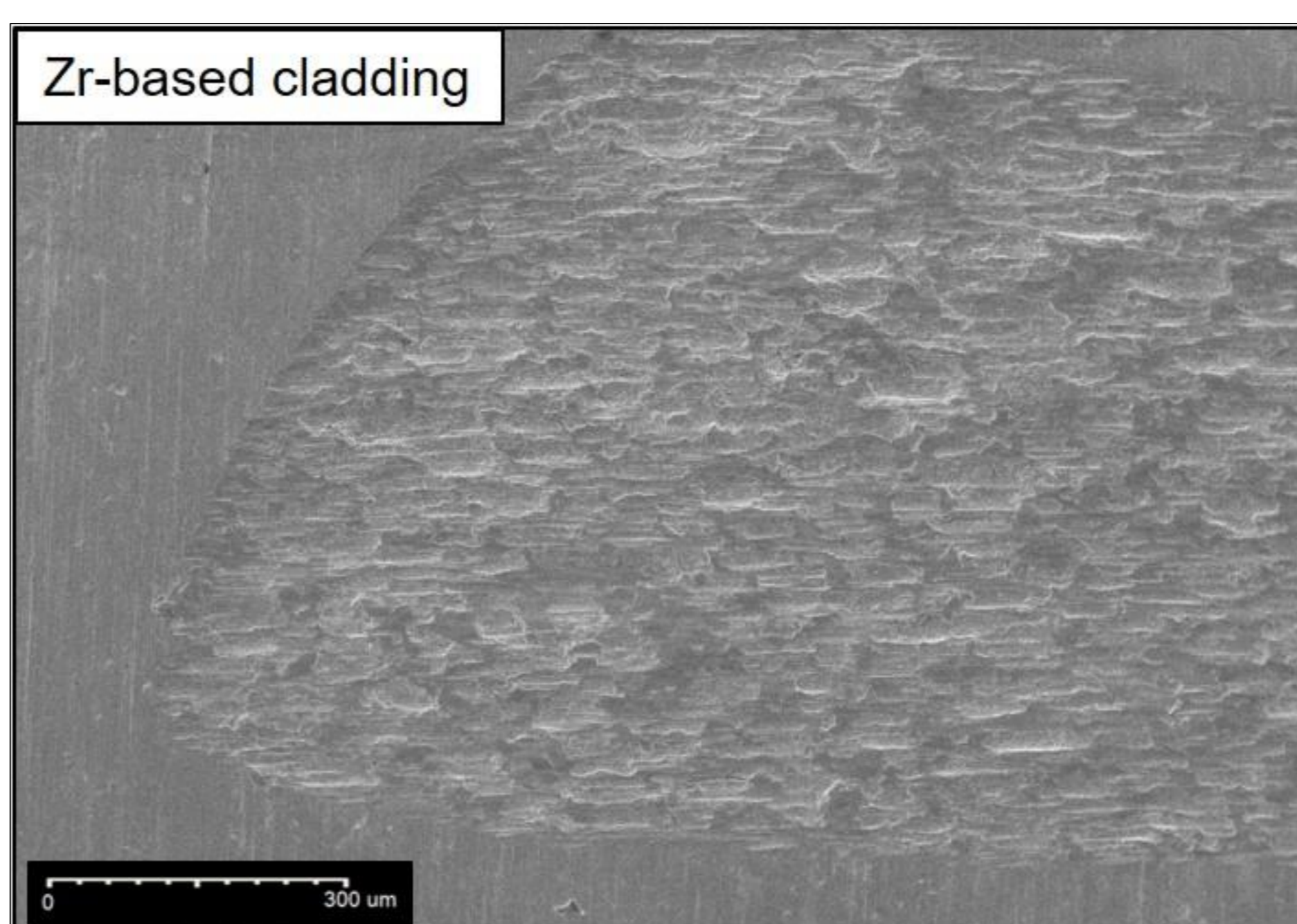
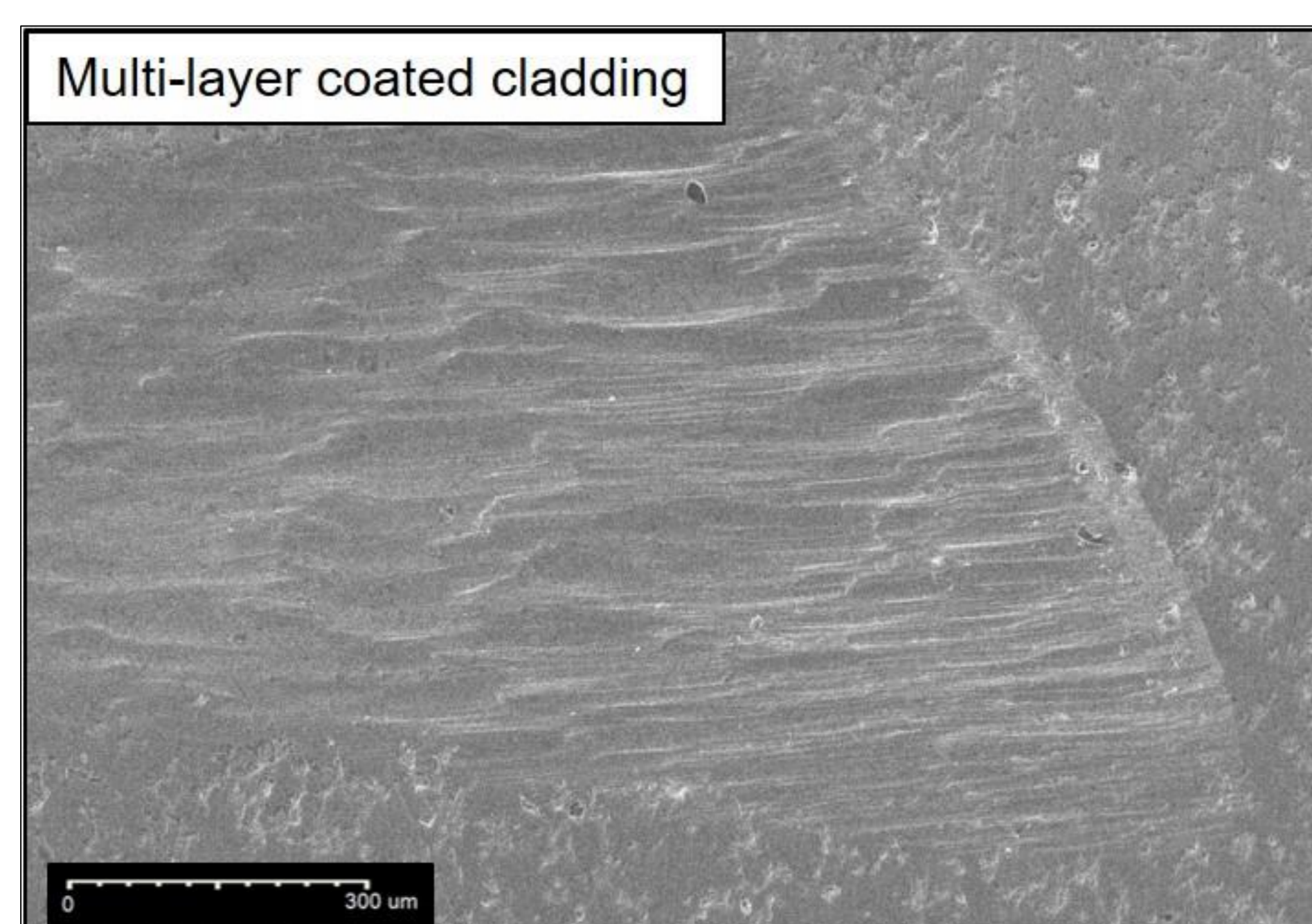
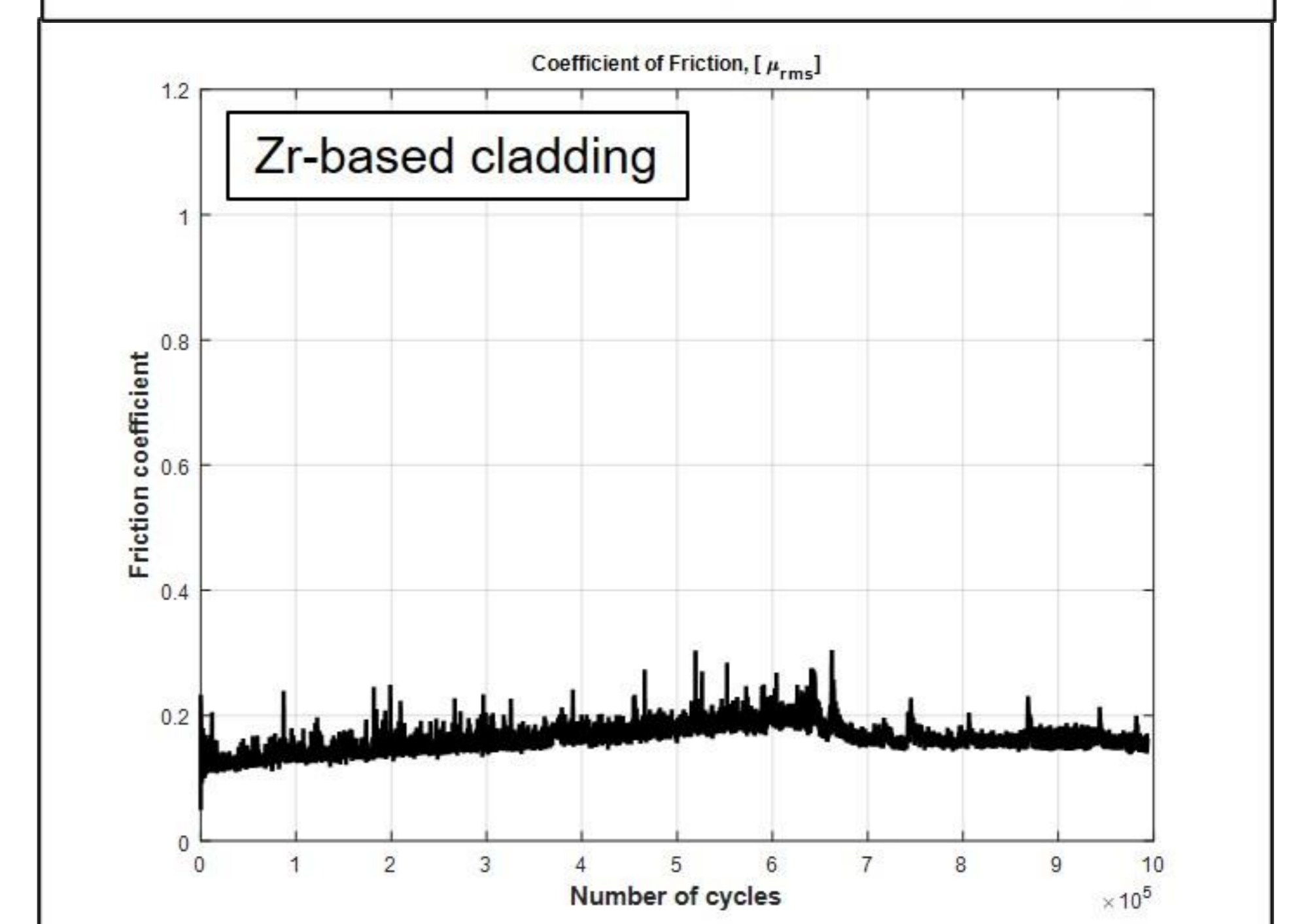
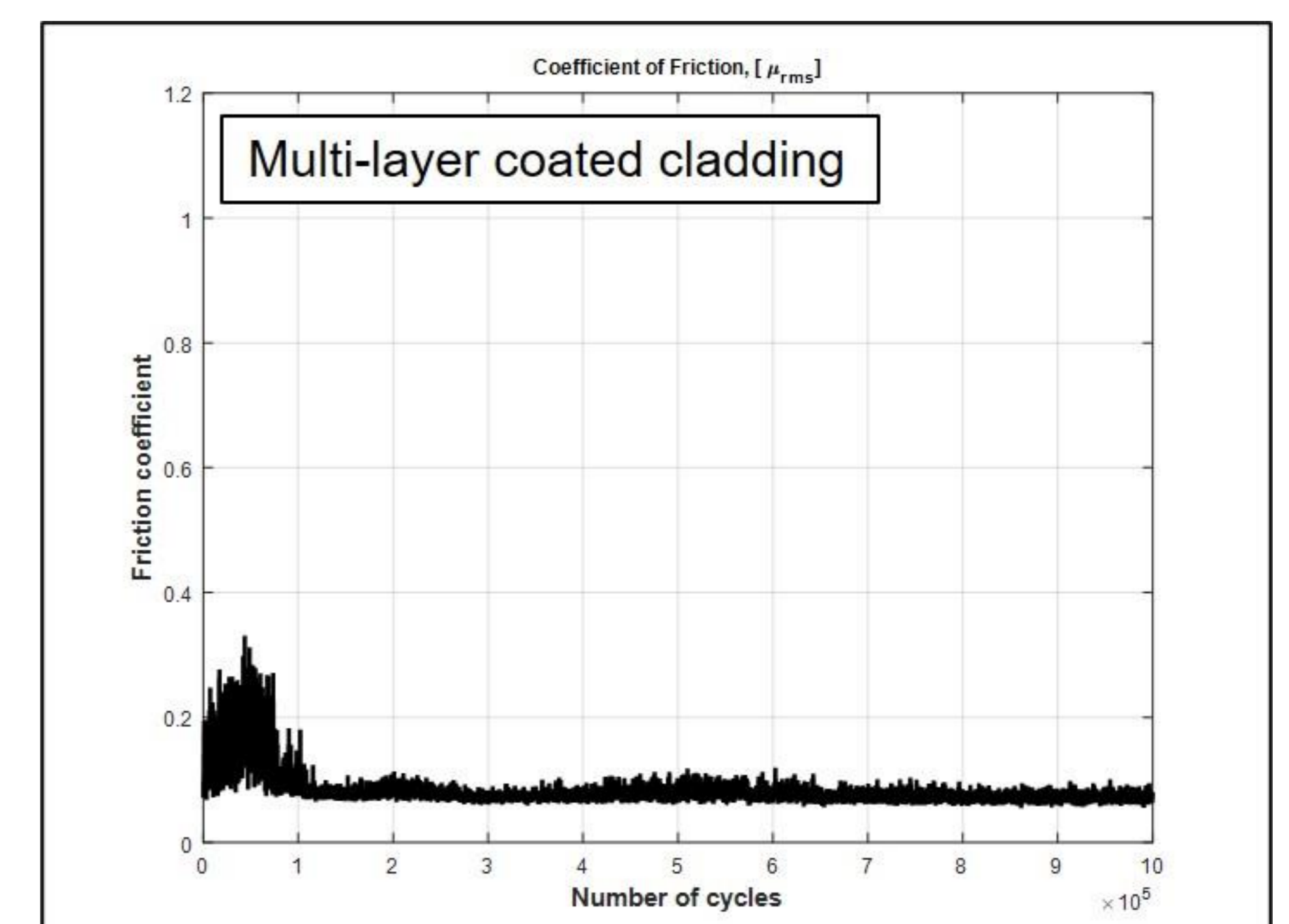
Results & Discussion



Coating failure mechanism by indentation tests



Frictional behaviors of CrAl coating layer by different coating methods



Average wear depth for considering localized failure by mechanical contacts

Summary of wear test results: (Left) Wear volume, (Right) Maximum wear depth

Summary

In this study, the reliability of the CrAl coating layer formed on the outer surface of ODS-treated Zr was experimentally evaluated and compared with uncoated Zr cladding by testing scratch and fretting wear tests.

- Based on the results of the scratch tests, there is no significant difference of the scratching behaviors between single CrAl coating and multi-layer coating.
- The multi-layer coated cladding shows smooth worn surface without fractured layers, which indicates that fretting wear mechanism can be affected by the formation of severe plastic deformation layer.
- The formation of multi-layer coatings can improve the oxidation resistance as well as excellent mechanical properties.

