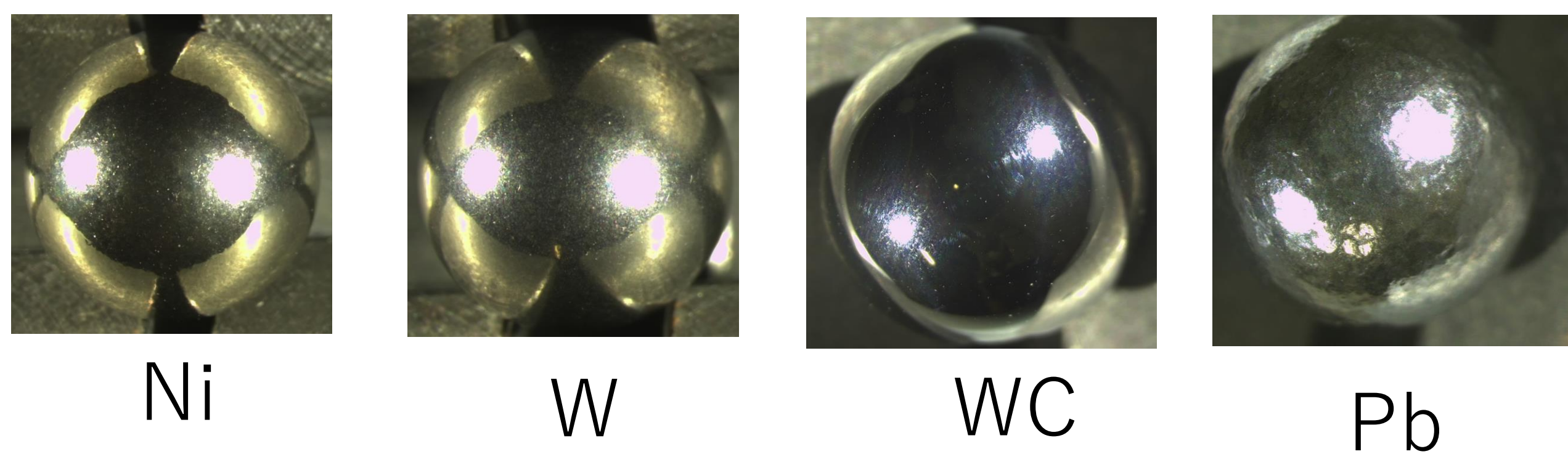


# Ease of bouncing objects

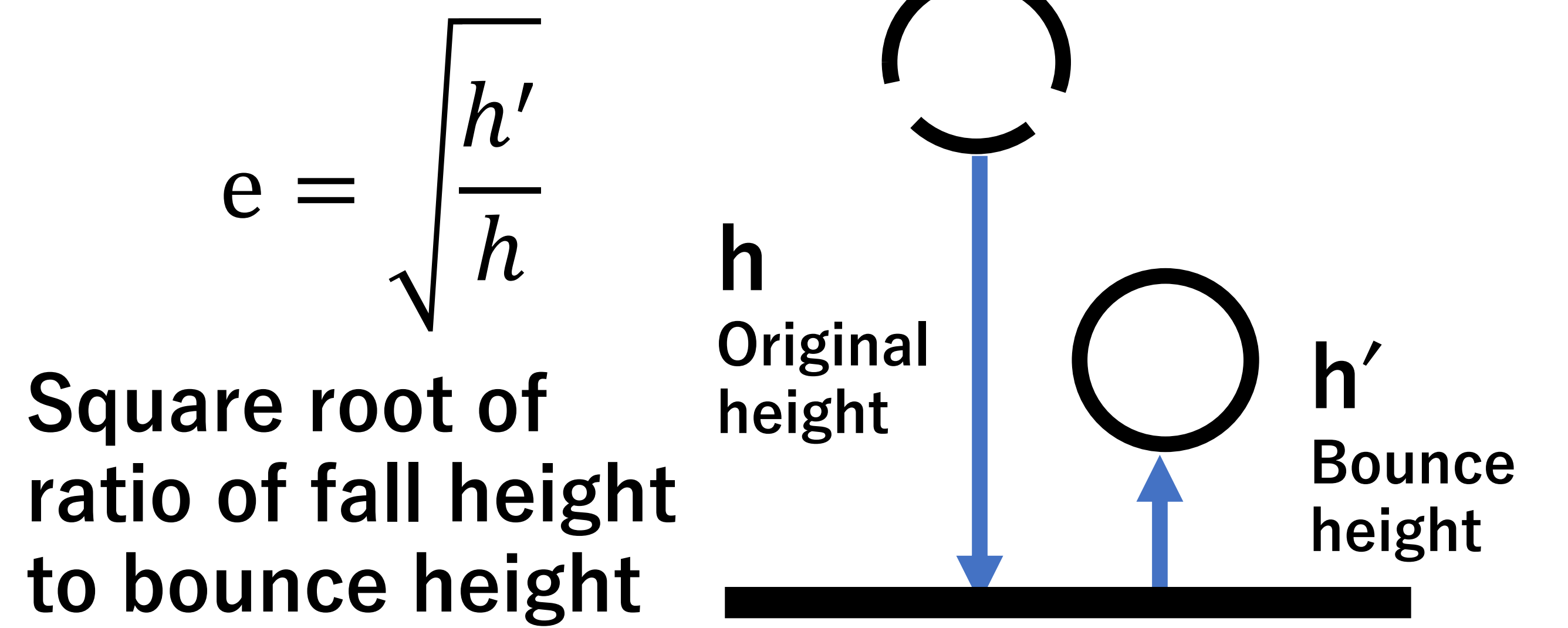
**Hypothesis: The ease with which an object bounces back (coefficient of repulsion) may be related to its hardness.**

## 1.Type of balls used

- Aluminum (Al)
- Titanium (Ti)
- Chrome steel (Cr)
- Stainless steel (SUS)
- Nickel (Ni)
- Copper (Cu)
- Brass
- Tungsten (W)
- Tungsten carbide (WC)
- Lead (Pb)



## 2.How to obtain the repulsion factor“e” (Pliability)



## 3. Research Flow

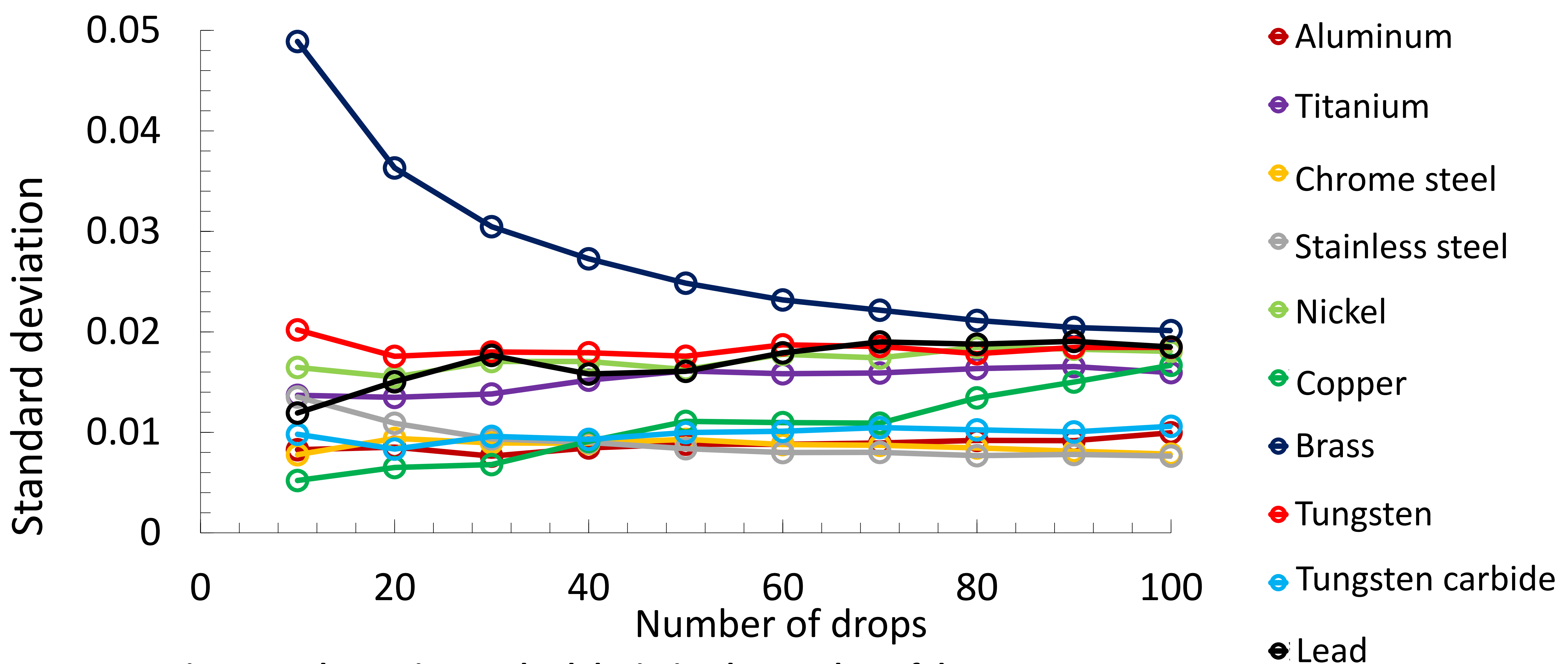
- ① Drop a 50cm-high metal ball and measure the bounce height.
- ② Repulsion factor is calculated from the ratio of dropped height.
- ③ Hardness of each metal ball is measured with a Vickers tester.
- ④ Repulsion factors are calculated for coefficient of resilience and hardness values.
- ⑤ Consideration of whether there is a correlation between coefficient of rebound and Vickers hardness



**Figure 1**  
Experimental environment

## 4. Determining the number of drops

Standard deviation (variation of data) per number of drops



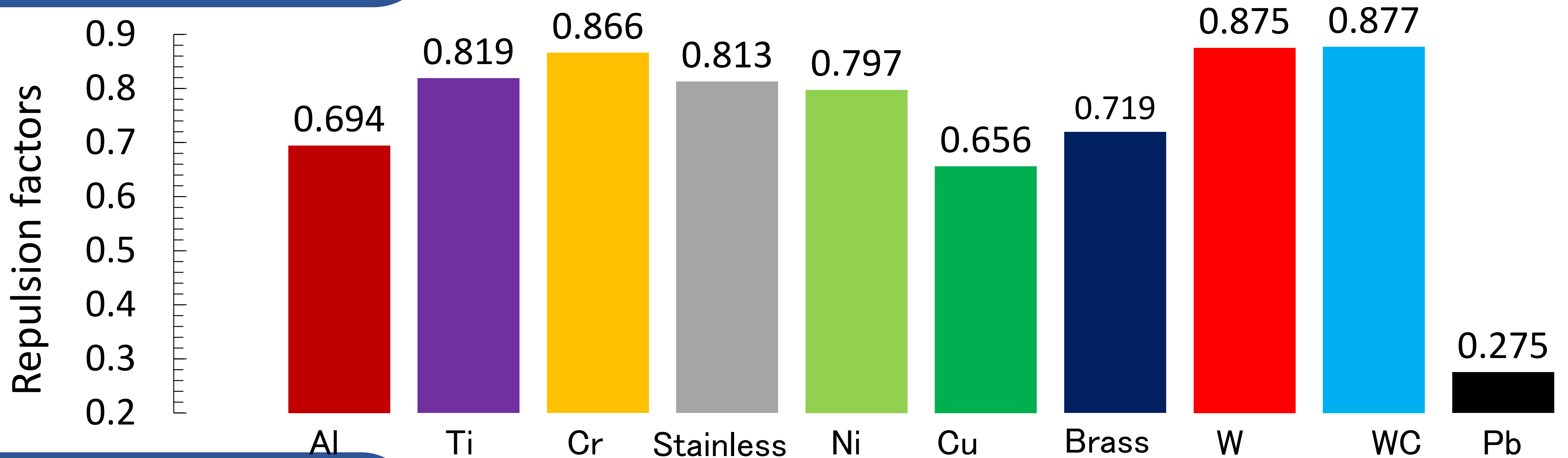
**Figure 2: Change in standard deviation by number of drops**

→Analysis with 100 data points for which the standard deviation was estimated to have converged.



## 5. Experimental results

Average coefficient of repulsion obtained from 100 drop tests.



## 6. Hardness test

Figure 3: Experimental results

→ Different materials have different Pliability

Vickers hardness test\* performed in Mori Laboratory, Mechanical Engineering and Robotics Course (n=5)

\*Hardness is measured by the size of the indentation made by pressing a diamond indenter

Table 1 Results of hardness test

Test ball	Hardness HV	Test ball	Hardness HV
Aluminum	88	Copper	102
Titanium	231	Brass	146
Chrome steel	735	Tungsten	330
Stainless steel	248	Tungsten carbide	235
Nickel	242	Lead	6

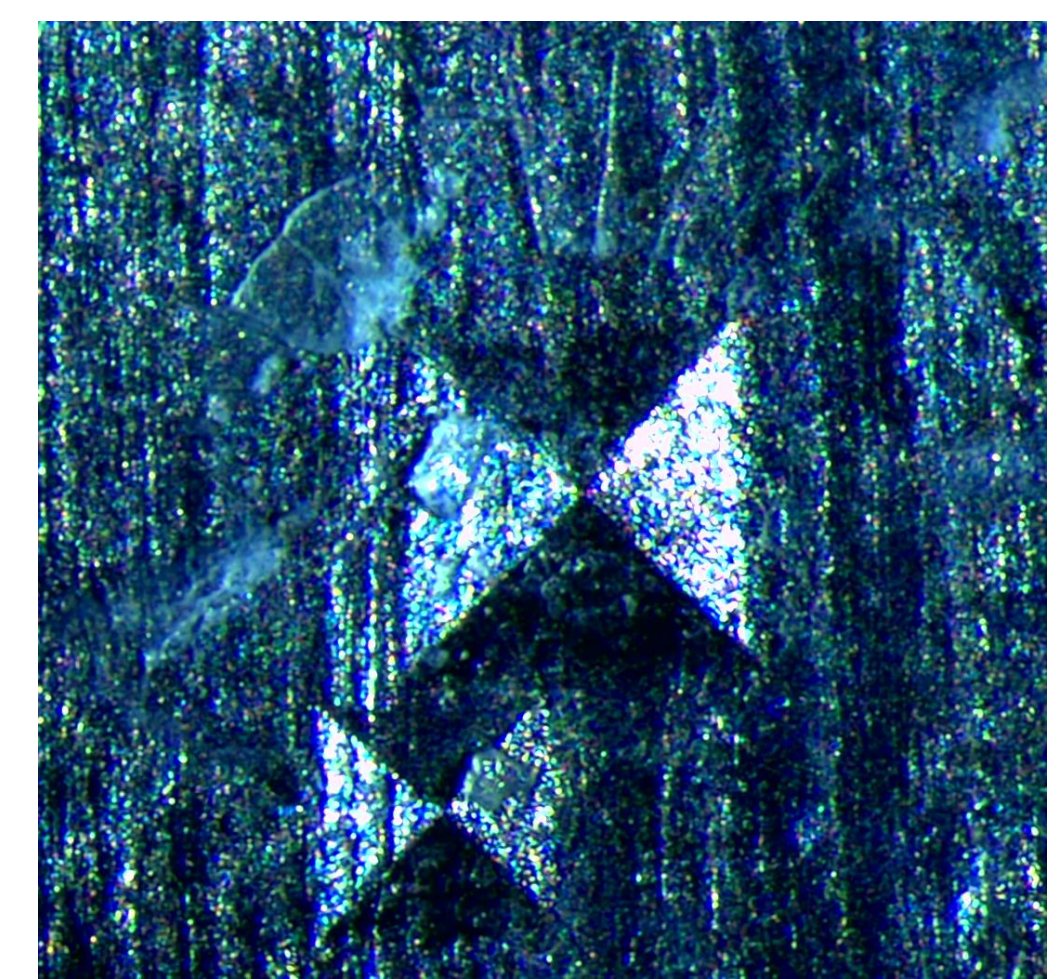


Figure 4 Indentation of hardness test

## 7. Relationship between repulsion factor and Hardness

→ Hardness varies depending on the material

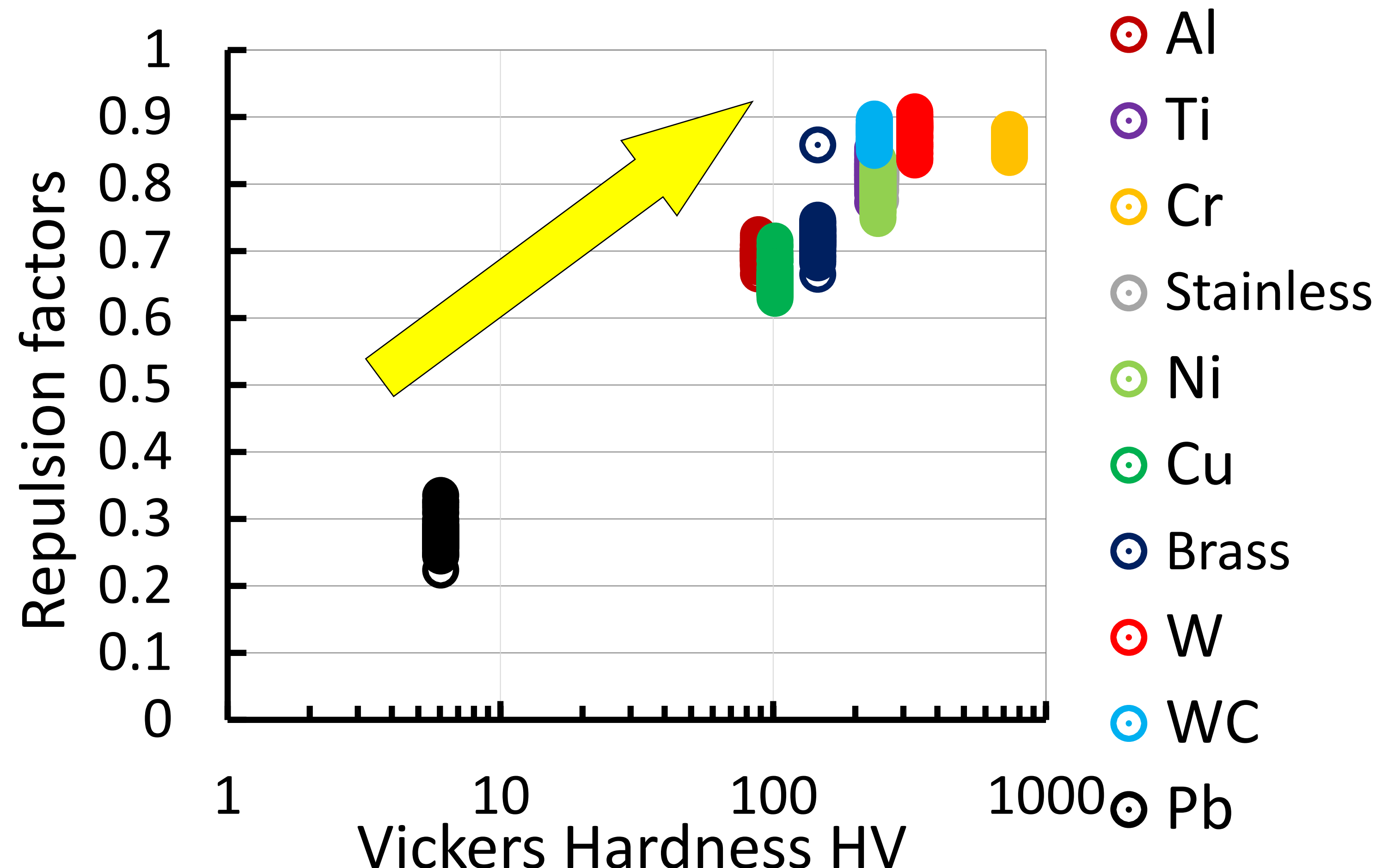


Figure 5 Relationship between coefficient of rebound and Vickers hardness (one logarithm)

Statistical Test for Correlation between repulsion factor and Hardness  
correlation between repulsion factor and Hardness

Null hypothesis : **No correlation between repulsion factor and Hardness**  
Authorization : **Pearson's product rate correlation coefficient of The T-test (one-tailed) for uncorrelated**  
**Reject null hypothesis when correlation coefficient < statistic**

• Correlation coefficient → **0.624**

• The statistic  $T$  → **25.2**

$$T = \frac{|r|\sqrt{n-2}}{\sqrt{1-r^2}} = \frac{0.624 \times \sqrt{1000-2}}{\sqrt{1-0.624^2}} = 25.2$$

$$0.624 < 25.2$$

The null hypothesis is rejected and the correlation between the two is not zero.

## 8. Conclusion

**Repulsion factors is positively correlated with hardness**

## 9. Future Outlook

Identify parameters besides hardness that correlate with the repulsion factors, and propose an experimental formula for determining the repulsion factors.