# Fixing tip (in STM2)

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# Introduction

STM observation strongly depends on the tip condition.
Therefore, we often fix the tip on a standard sample (mainly Au(111)) before measuring the target sample.

In this document, I briefly summarize how I fix the tip, which part I'm taking care of, and what I'm thinking while fixing the tip.
Note that the tip shape in this document is mostly my guess, because we cannot directly see the tip shape.

# Tip shape

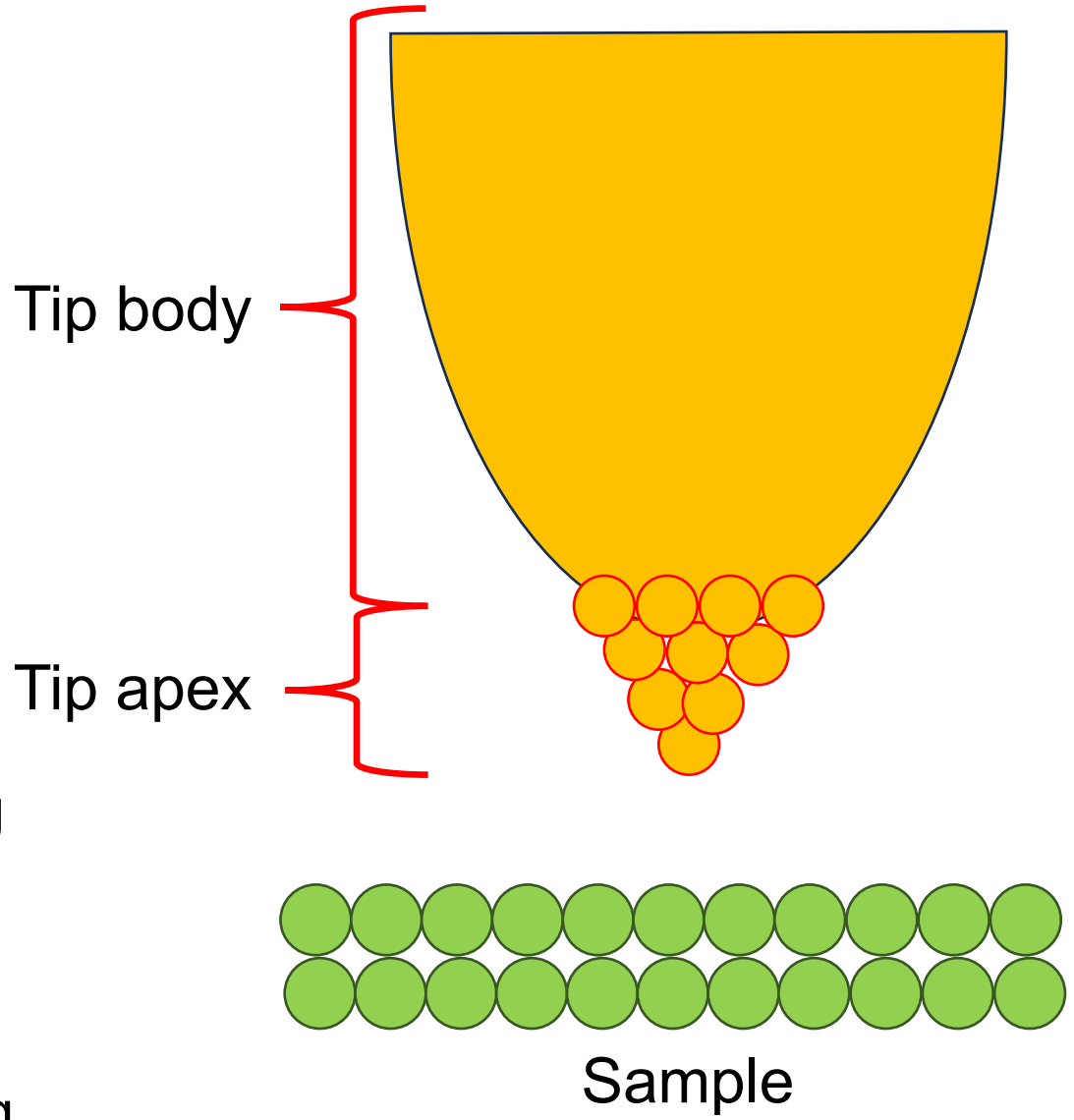
When fixing tip, I'm thinking of two feature of the tip: namely, tip body and apex.

**(i) Tip apex**

At the top of the tip, several atomic layers.
Directly related to the tunneling current.
The atomic arrangement affects the image quality and possibly STS.

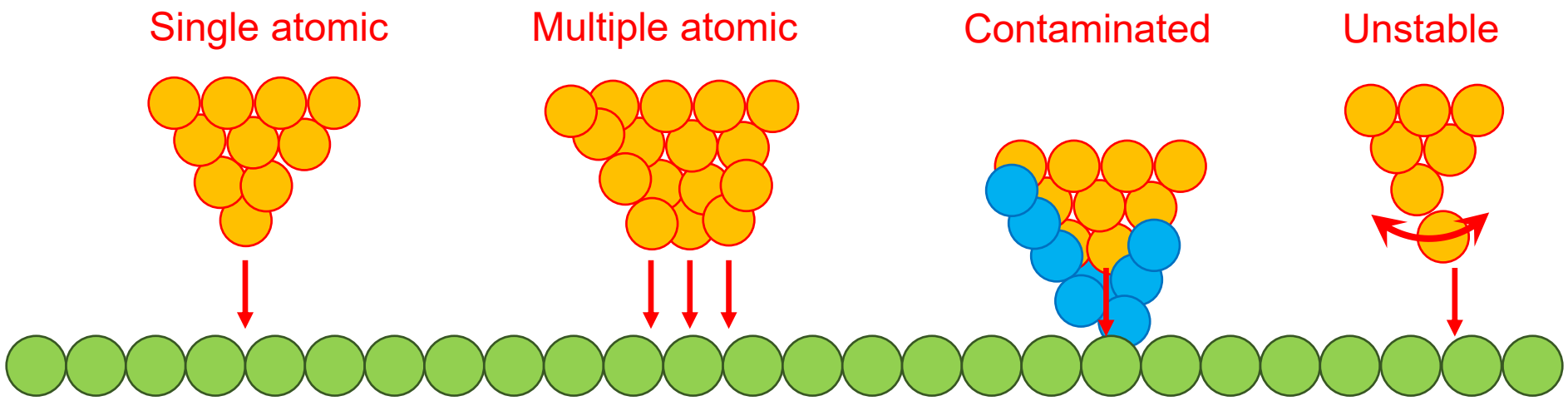
**(ii) Tip body**

The larger scale shape of the tip, supporting the tip apex.
Usually, it does not affect the tunneling current, as this part is far from the sample.
Mainly, it affects the stability of the scanning.



# Effect of tip apex






The tip apex is directly related to the stability and resolution of STM imaging.

(i) **Single atomic**: Ideal condition for STM scan.

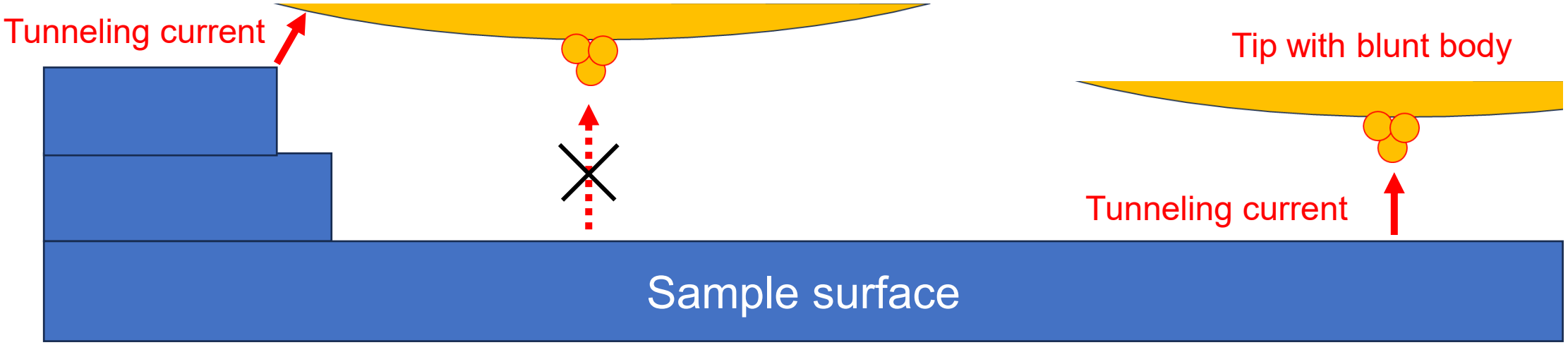
(ii) **Multiple atomic**: Several atoms contribute to the tunneling current, resulting in poor resolution or duplication of surface features.

(iii) **Contaminated**: Impurities covering the tip.
If it is insulating, tip may contact during the scanning and makes the scanning unstable.

(iv) **Unstable**: The atom at the tip apex is mobile, resulting in unstable scanning.

# Effect of body shape ①



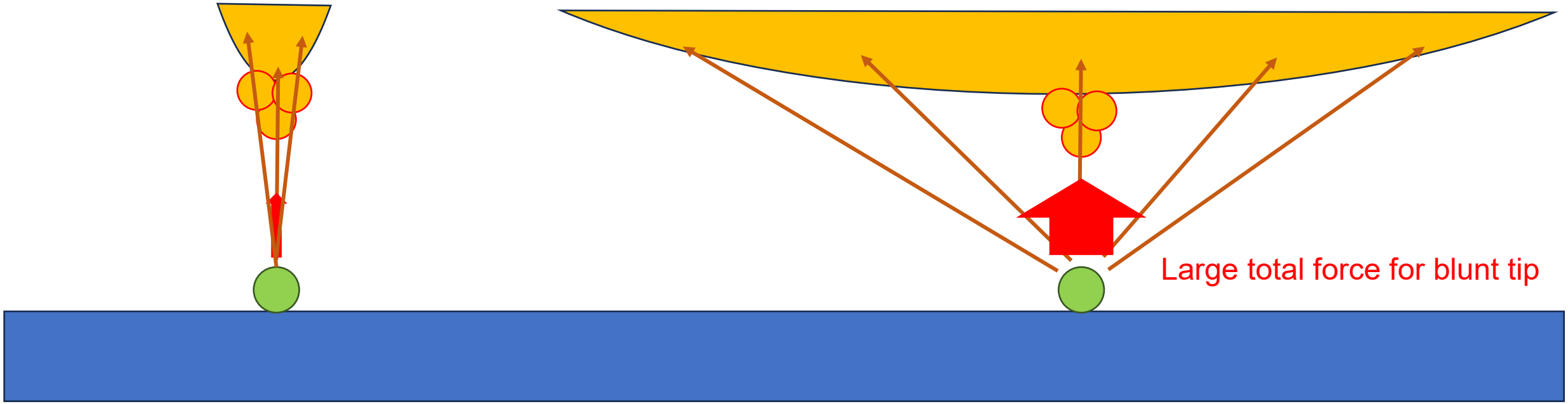



If the sample is flat, only the tip apex contributes to the tunneling current.
However, the side of the tip body can be closer to the sample than the tip apex near some surface structures (such as a step).

Therefore, the blunt tip may result in poor resolution, and the shape of the surface feature becomes blunt, reflecting the blunt tip of the body.

# Effect of body shape ②:



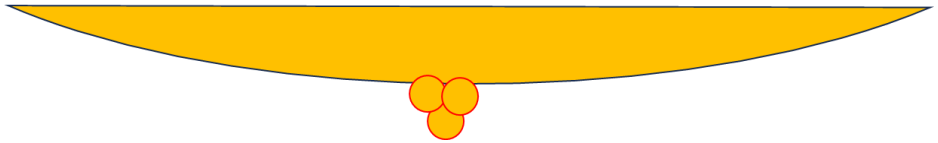



The tunneling current strongly depends on distance, so the tip body **is not** involved in the tunneling.
However, the force has a long-range component, so body shape affects the interaction between the tip and surface atom.

Blunt tip strongly attracts the surface atom, resulting in a higher possibility of picking the atoms from the surface, making scanning unstable and frequent tip condition changes.

# Effect of body shape ③





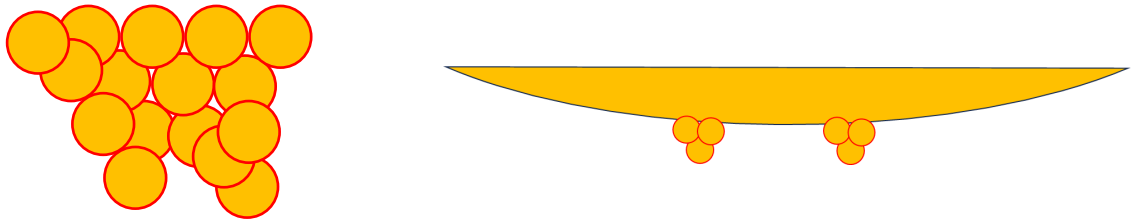
When the tip body is blunt, the position of the tip apex easily changes.
Even a small shock (such as a pulse) may change the position of the tip apex, resulting in the sudden jump of the scanning region.

# Example of bad tip ①: Duplicate steps

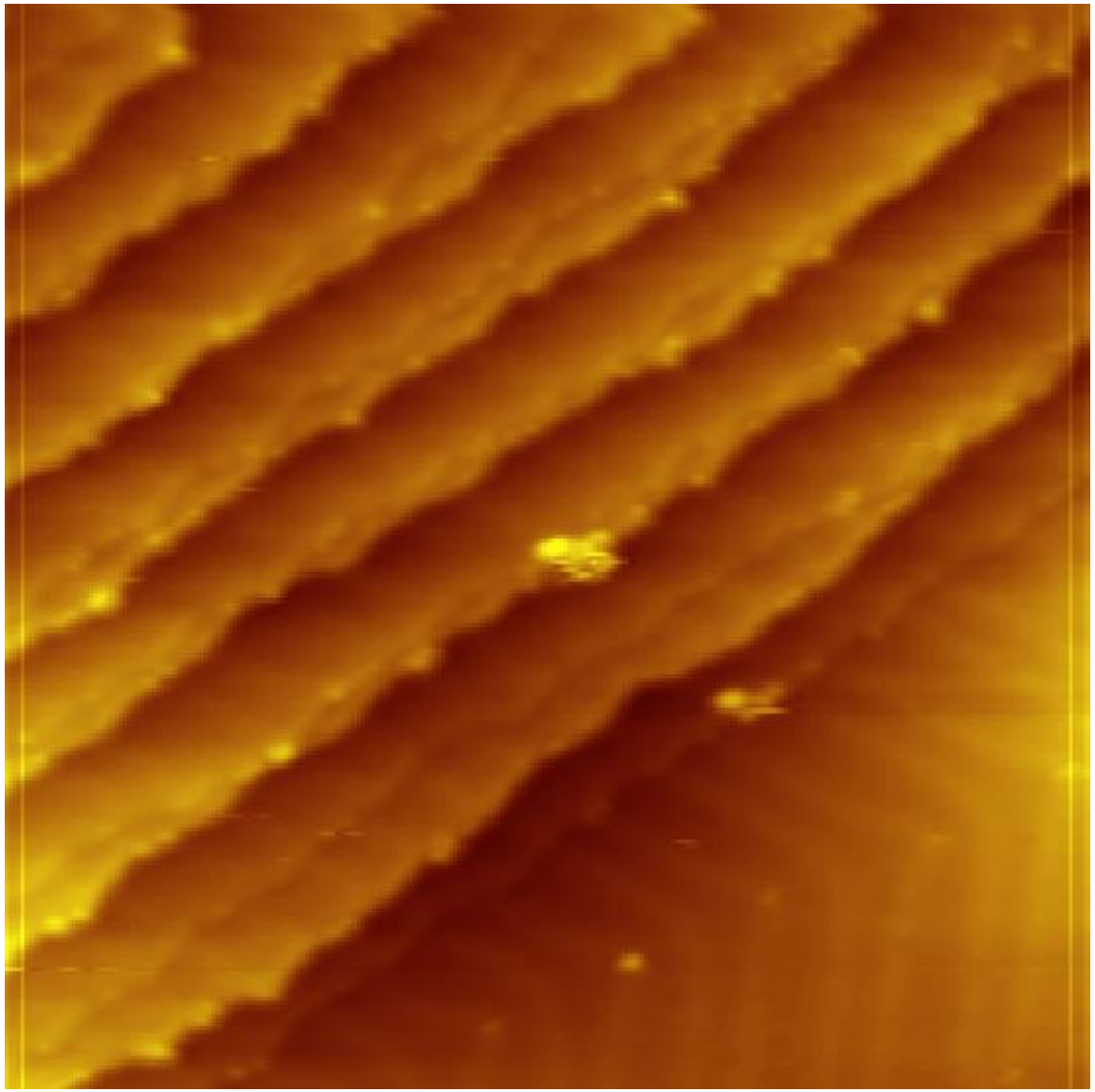


[Characteristics]
- The steps look doubled.
- The step height is lower than usual.

[Origin]
- Double tip apex.
- Possibly blunt tip.
- (If the sample is dirty, impurities may be attached to the steps. In that case, it is not the tip problem.)



Tip shape

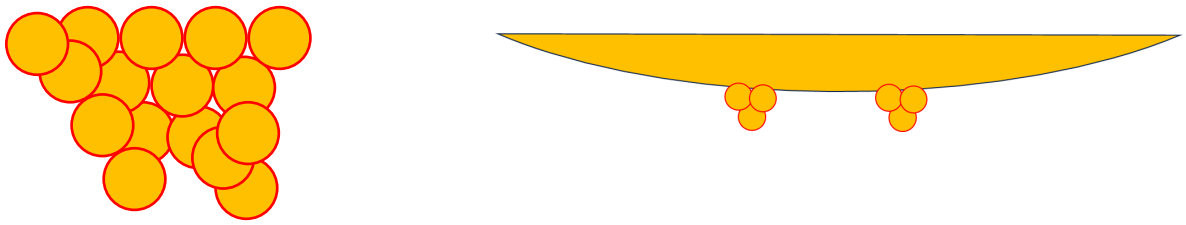


# Example of bad tip ②: Duplicate tip

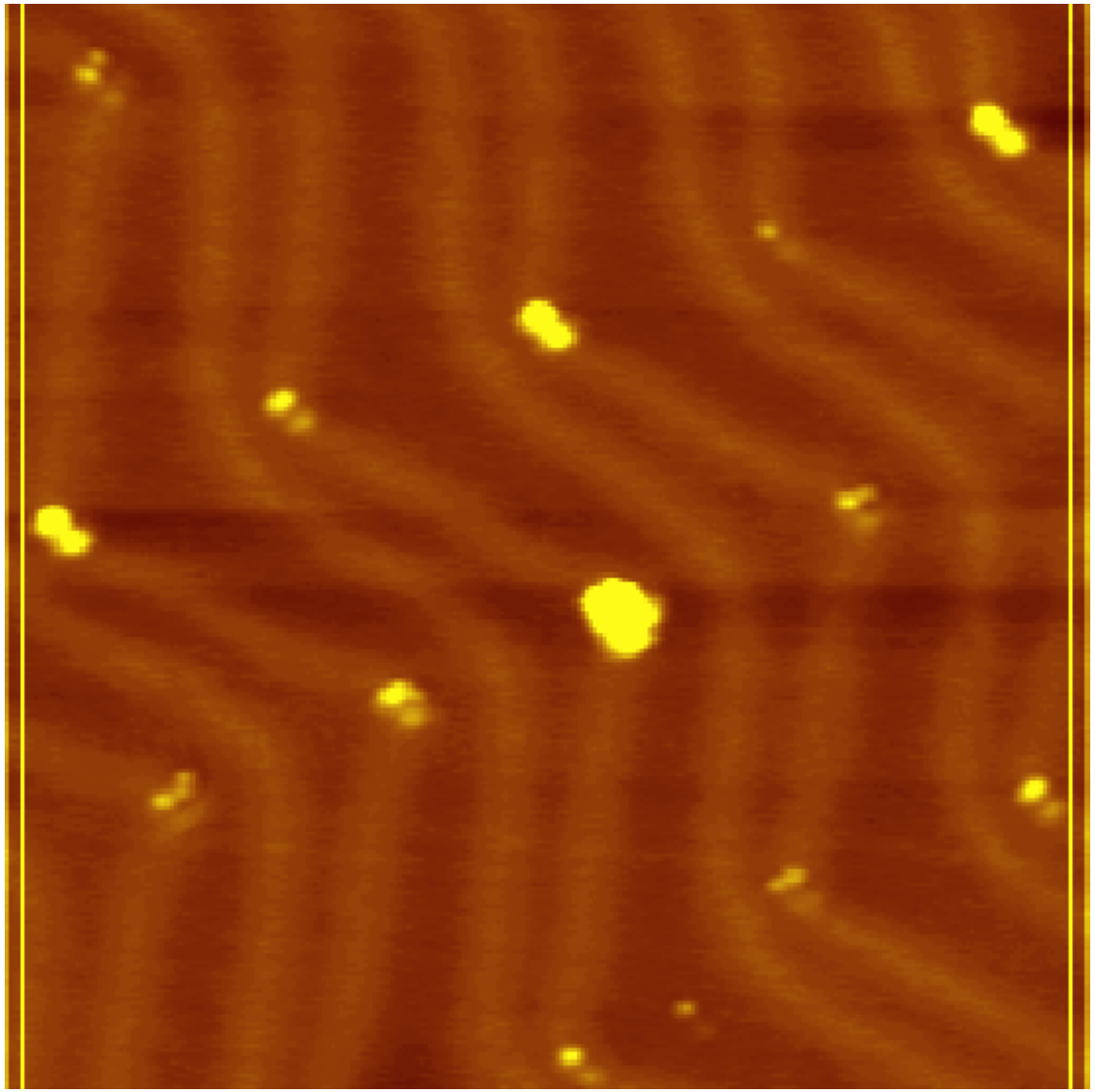


[Characteristics]
- All the Impurities look to form a pair.

[Origin]
- Double (or even multiple) tip apex.
- If the pair is far, the blunt tip.



Tip shape



# Example of bad tip ③: Duplicated herring bone



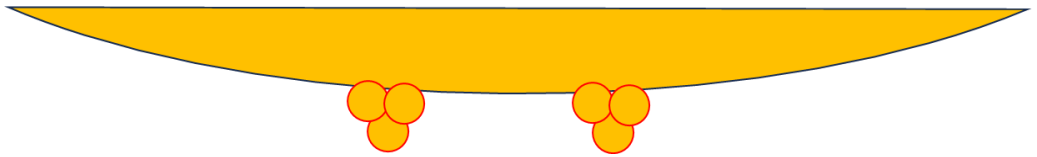
[Characteristics]

・Two herringbone structures overlap.

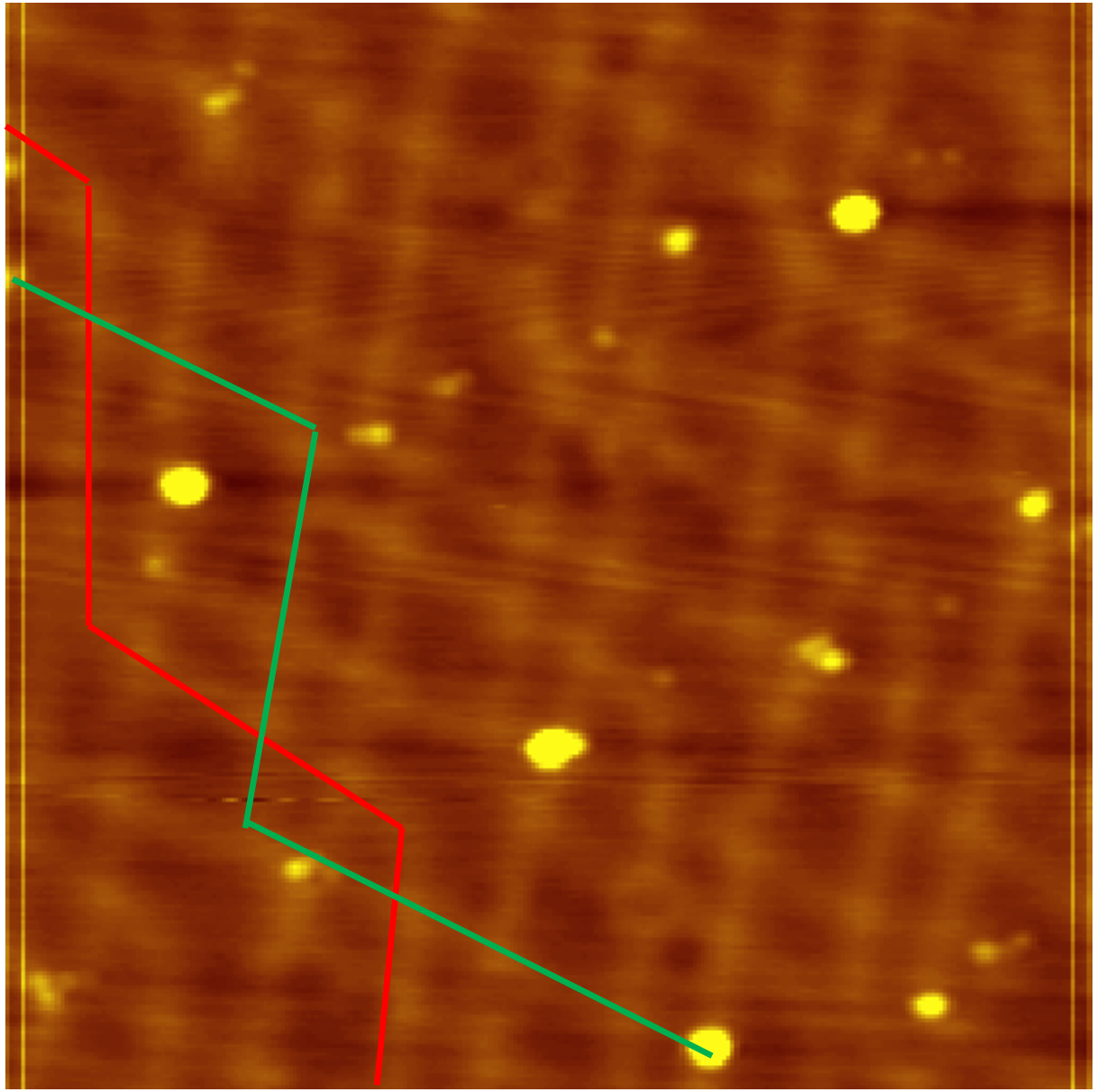
[Origin]

・Double tip, but the two apices are far apart.

・The tip is blunt, especially when the impurities are not doubled.



Tip shape



# Example of bad tip ④: Multiple contact

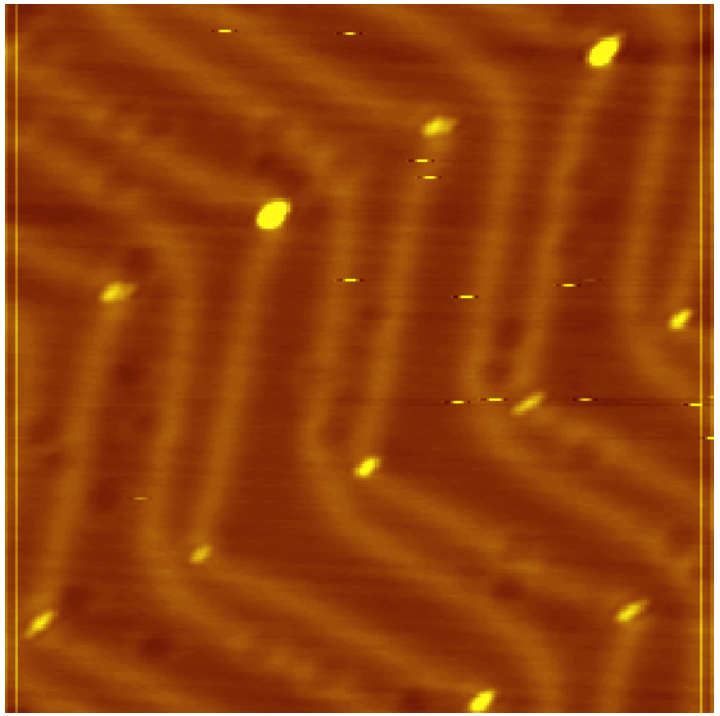


[Characteristics]

・After the small contact of the tip to the sample, multiple contact points appear.

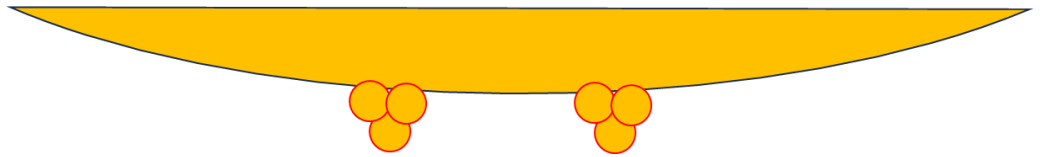
[Origin]

・Blunt tip



Before contact

After contact

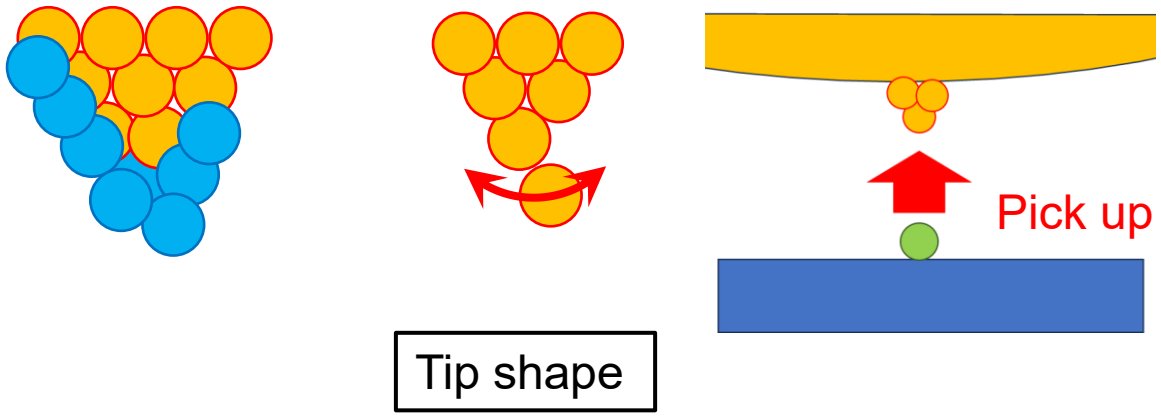


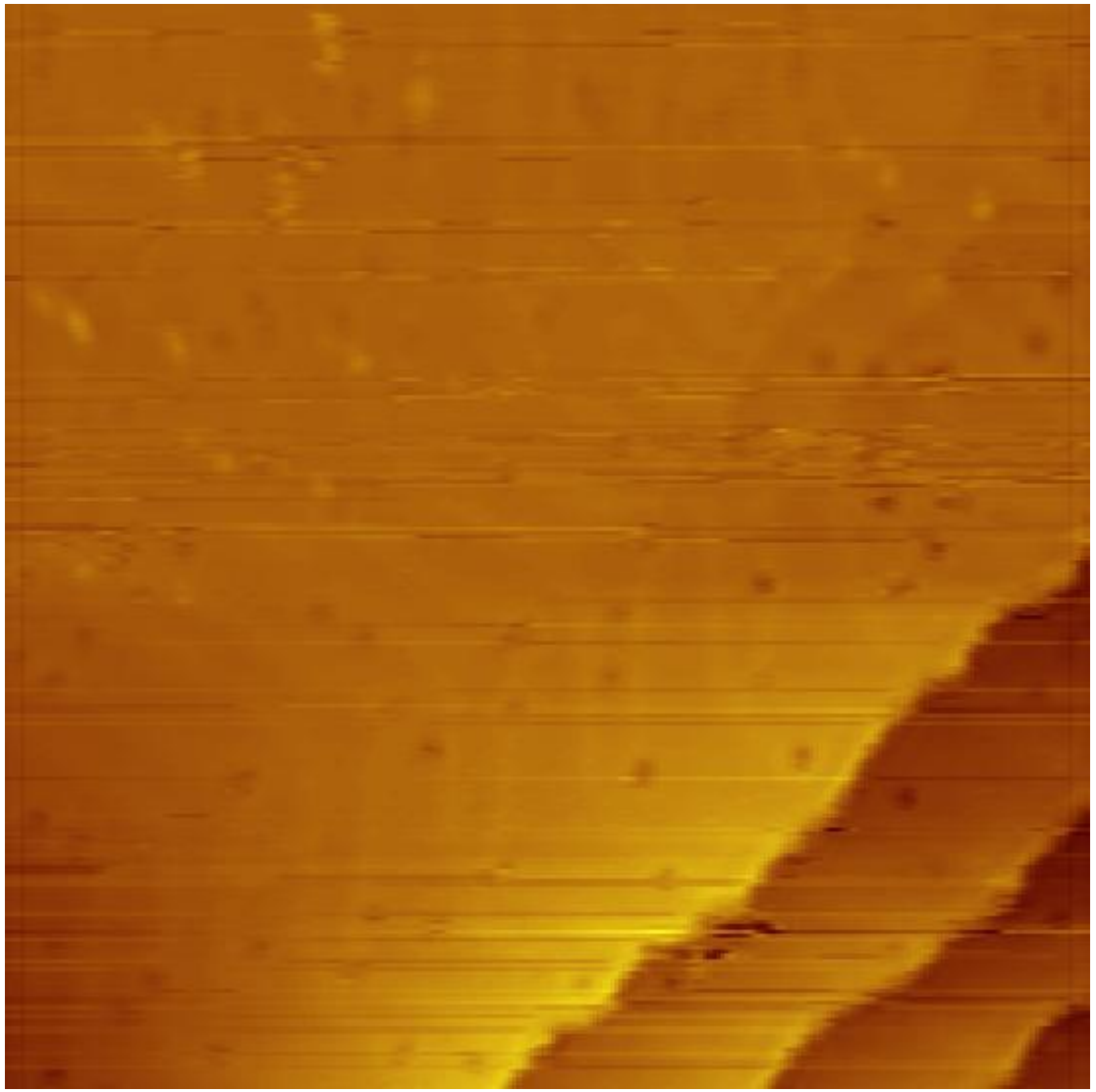
Tip shape

# Example of bad tip ⑤: Horizontal lines

[Characteristics]
・Horizontal lines in the image.

[Origin]
・Unstable tip apex
・Impurities on the tip
・Dirty sample
・If it often happens after a long time of fixing, possibly a blunt tip.



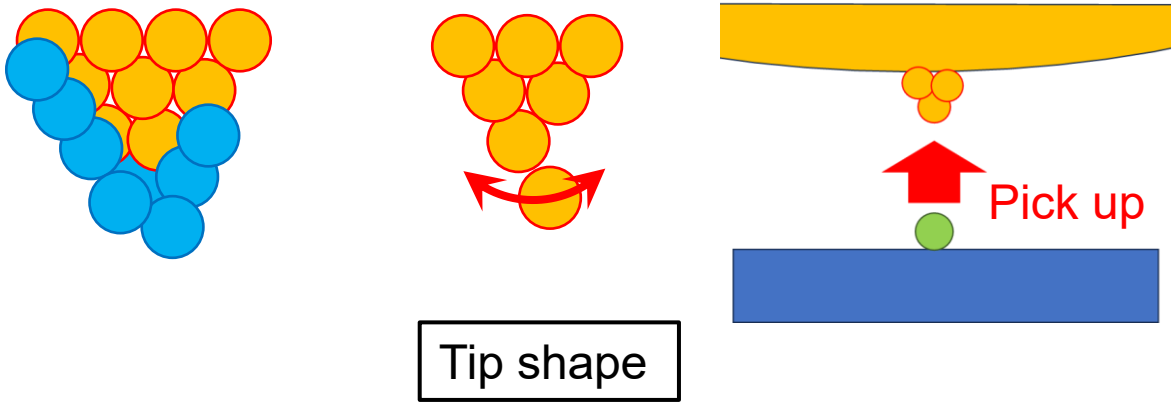



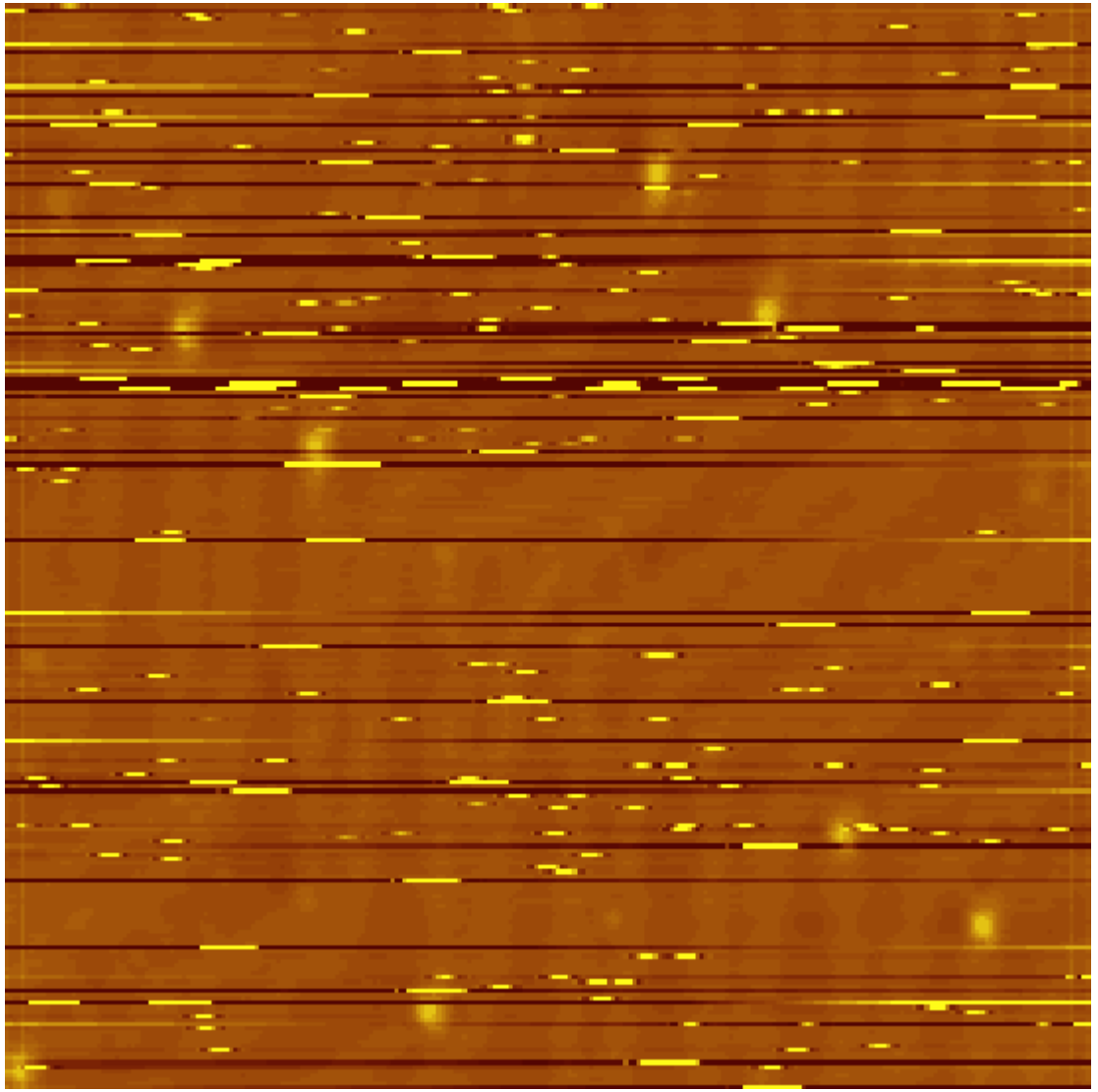
# Example of bad tip ⑥: Spikes



[Characteristics]
・Spikes during the scan

[Origin]
・Unstable tip apex
・Impurities on the tip
・Dirty sample
・If it often happens after a long fixing time, it may be due to a blunt tip.



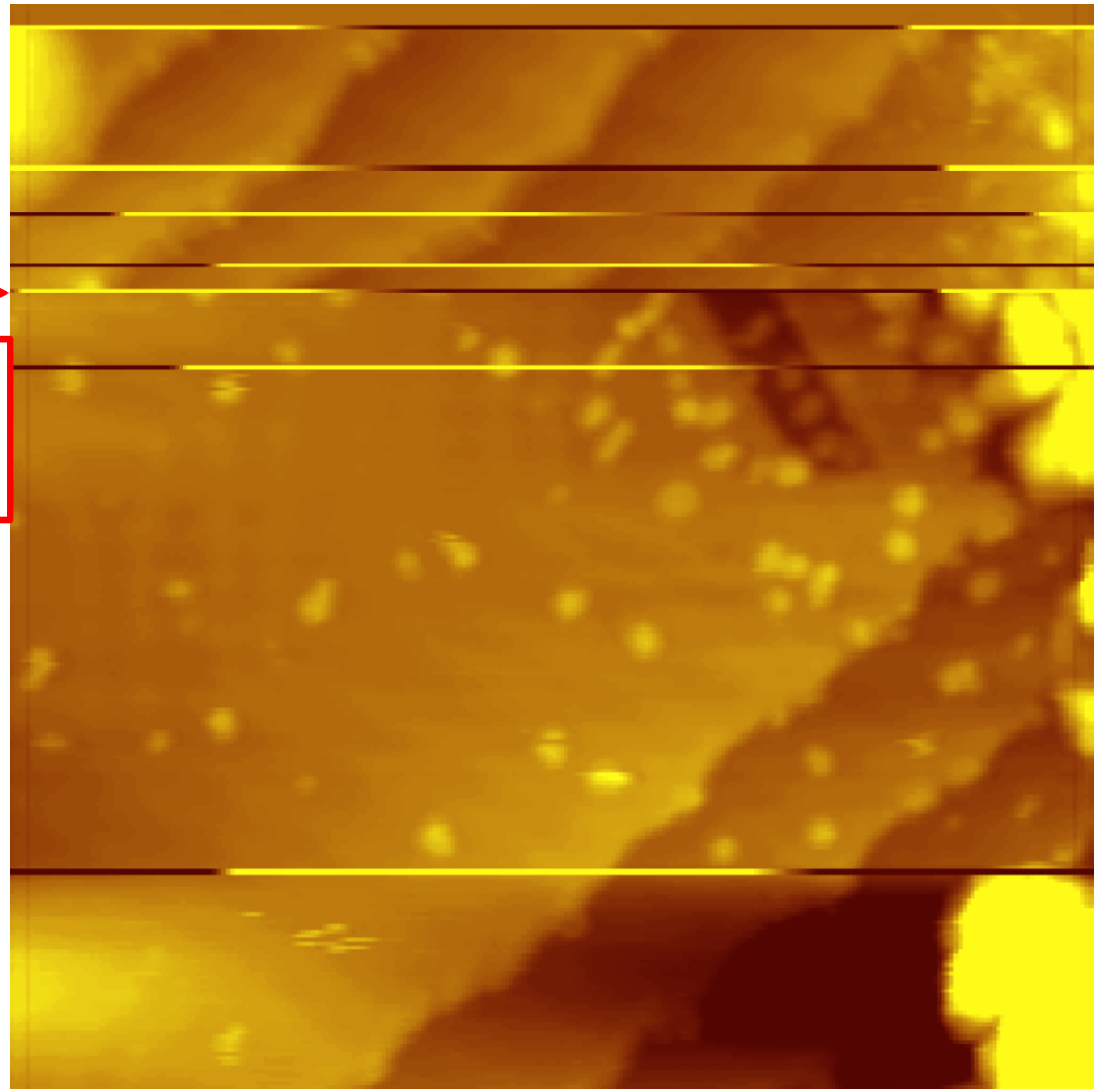



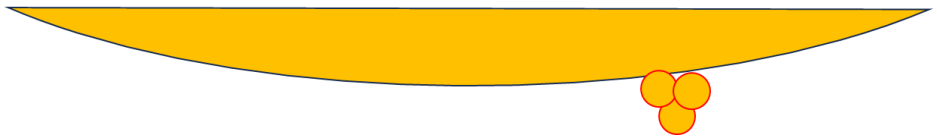
# Example of bad tip ⑦: Jump



[Characteristics]
- Huge jump in scanning region

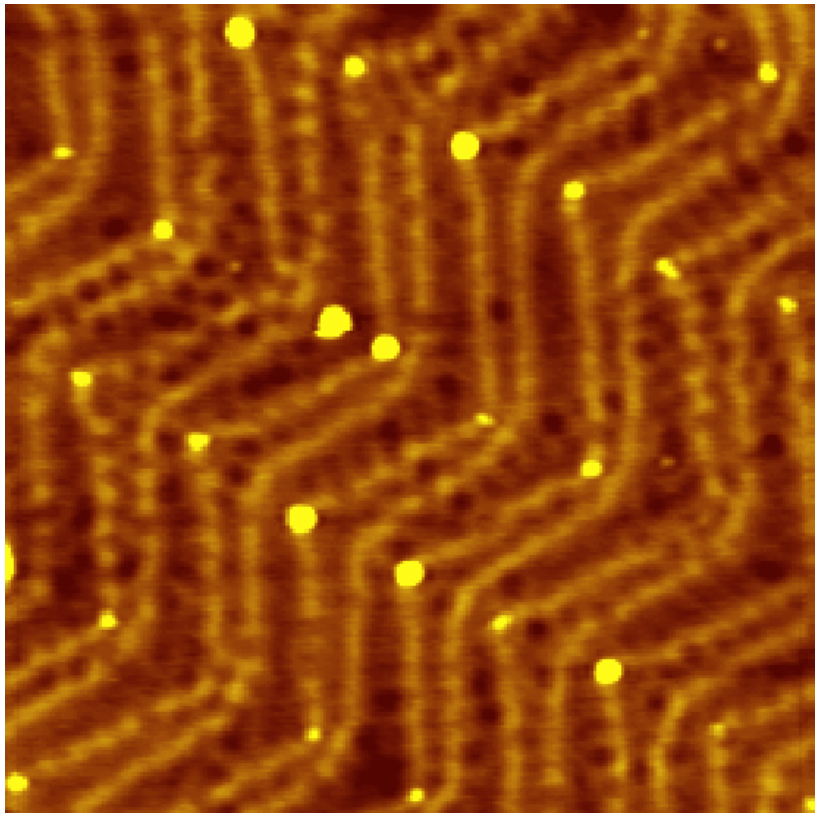
[Origin]
- Large change in tip condition.
- If it often happens, a blunt tip.



Tip shape

# Judgment of good tip



**Must**

① Tip is stable at mild scanning condition(~0.5 V, 0.1 nA)
② No duplication
③ Herringbone is clear
④ Impurities are symmetric, round in shape

**If possible**

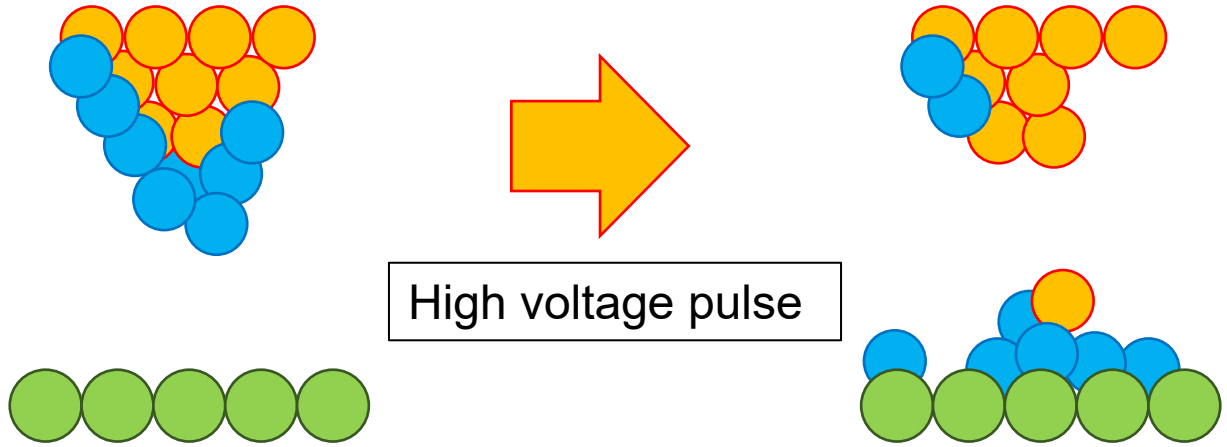
⑤ Tip is stable at hard scanning conditions (~0.1 V, 1.0 nA)
⑥ The tip is kept stable even when applying several pulses.
⑦ Only one contact point after slight contact with the sample

**Optional**

⑧ Clear surface state in STS
⑨ Clear QPI in STS mapping

# Tip fixing methods






**Applying pulse**

Applying a high bias for a short time.
The electric shock removes the atoms from the tip, or even change the tip shape.
(If you want to know the detailed mechanism, search for “field evaporation”)

**[Effects]**

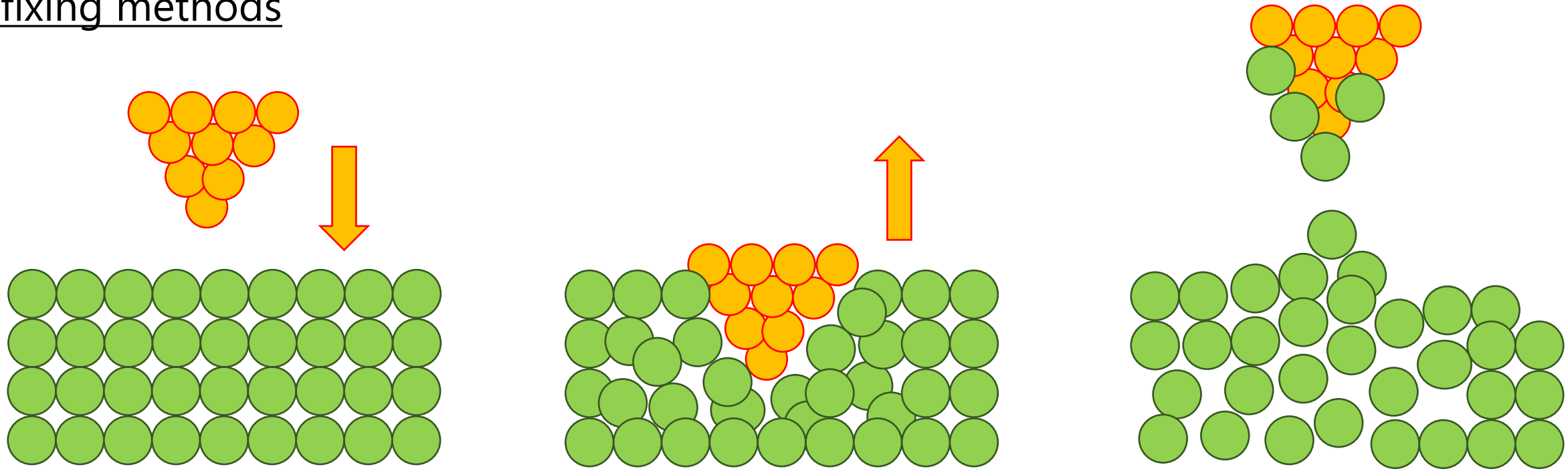
Removing the impurities from the tip
Changing the tip shape

**[Drawbacks]**

Uncontrollable tip shape change
The atoms at the tip apex (not only impurities, but also metals) are removed, so overusing it may lead to the blunt body.

# Tip fixing methods





**Tip contact to the sample and slow lift up**

Intentionally contacting the tip and sample. Then, slowly lifting up.

**[Effects]**

Changing the atomic arrangement of the tip.
Covering the tip with substrate material.
Checking the tip shape.
Slow lifting may extend the tip

**[Drawbacks]**

Possible contamination.

# Tip fixing process (for my case)



The method to fix tip differs depending on the operator. This page introduces my method, but find out your own method.

① Approach on Au(111). Scan the surface and check the image quality. If image quality is not so bad, skip ② and ③.
② Apply pulse with high bias (±8~±10 V) with low scanning bias (0.1 V). Repeat applying a high pulse with changing the region. In the first face, anyway I try to remove all the impurities covering the tip.
③ After using all the region of the first face, change the face.
④ Check image quality on second face. If image quality is not good, fix the tip by applying a pulse (~±6 V), or touching the tip with the sample. If image is good and tip is stable, finish fixing tip.
⑤ If image quality is still bad, repeat ②, then go to next face.
⑥ Third face is the final face. Fix tip by applying a pulse (~±6 V), or touching the tip with the sample.
⑦ Finish fixing tip at the best condition of the tip.
⑧ If we cannot get a good tip in three faces, or we often see the sign of blunt tip body, consider replacing the tip.

# Note for my Tip fixing process



Using high pulse let the tip body blunt, so my method may shorten the lifetime of the tip.
However, removing the impurities on the tip using a low bias pulse is time consuming.

Keeping the good tip condition is not easy, especially at high temperature (> 77 K).
Even we get a good tip, the tip may be easily contaminated and change its condition easily.
Therefore, spending long time in fixing tip may be waste of time, so I try not spending long time in fixing tip.
Instead, spend much more times of trial in observing the target sample.

If the measurement is performed at low temperature (~4 K) and spectroscopic measurement is necessary, I much carefully fix tip.