Unique characteristics of the novel carbonaceous film with high electrical conductivity and ultra high hardness for semiconductor test probes

Teruyuki Kitagawa, Ph.D.
Nomura Plating, Co., Ltd.
JAPAN

IEEE SW Test Workshop
Semiconductor Wafer Test Workshop
June 10 - 13, 2012 | San Diego, California

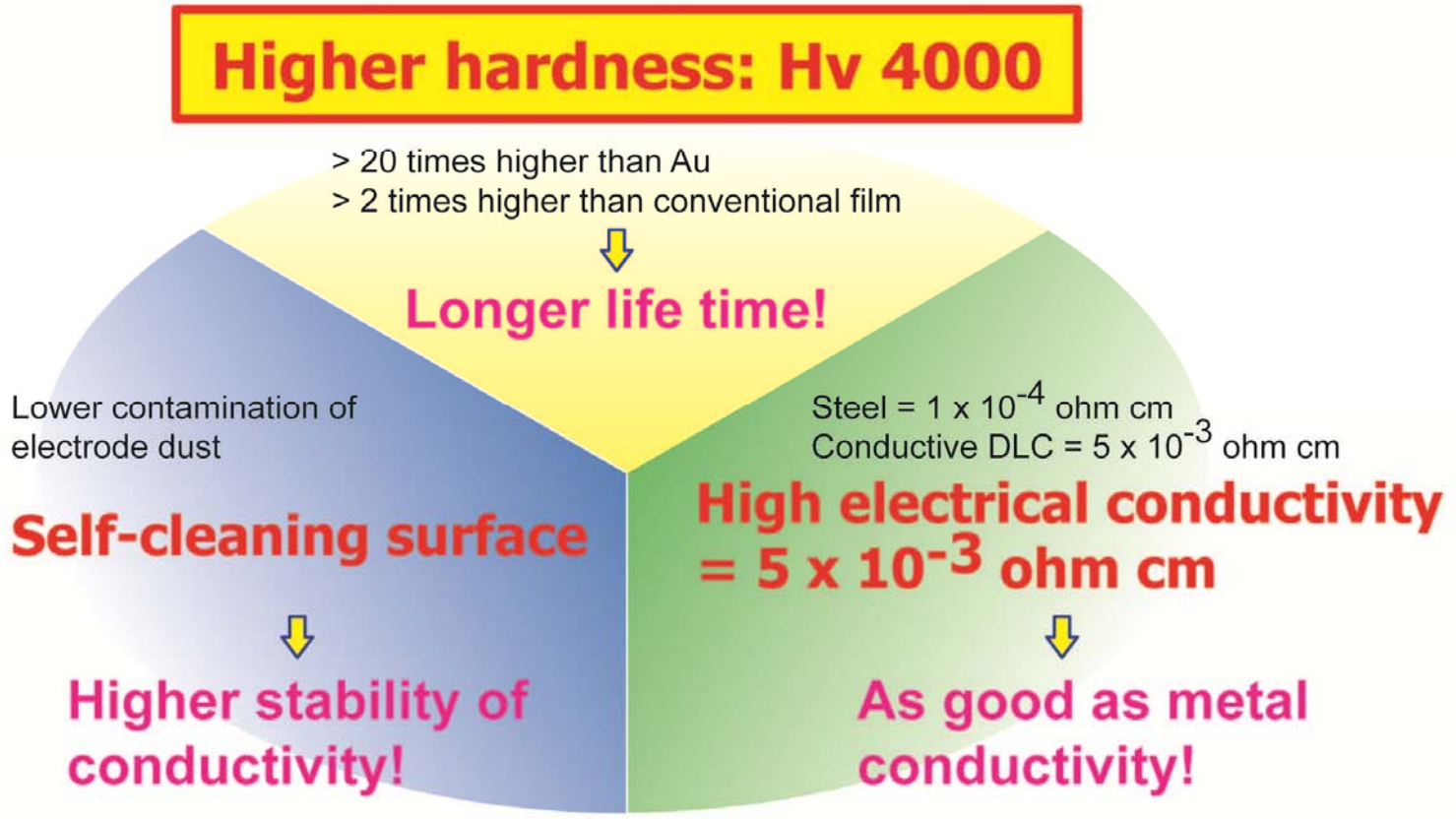
Outline

1. **What is the carbonaceous film?**
   - Introduction
2. **Can the film actually be used productively in the industry?**
   - Industrial issue
3. **Why does this film have these characteristics?**
   - Discussion
4. **Are there any care points of practical use?**
   - Care points of practical use
5. **Conclusion**

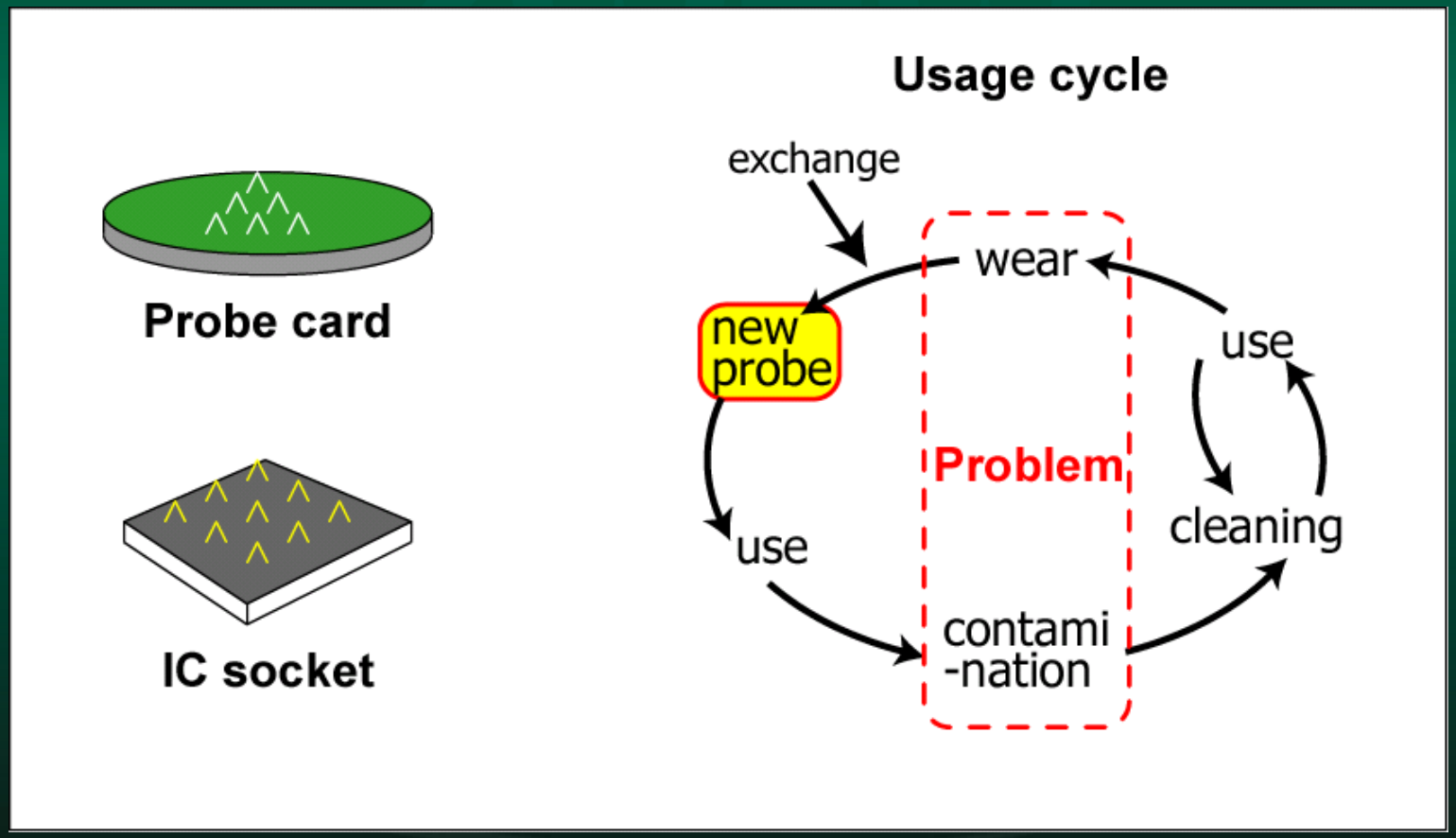
Introduction

1. WHAT IS THE CARBONACEOUS FILM?

The carbonaceous film has 3 outstanding properties.



Industry needs a probe surface with wear-resistance, and electrical stability.



Problem -> Solution

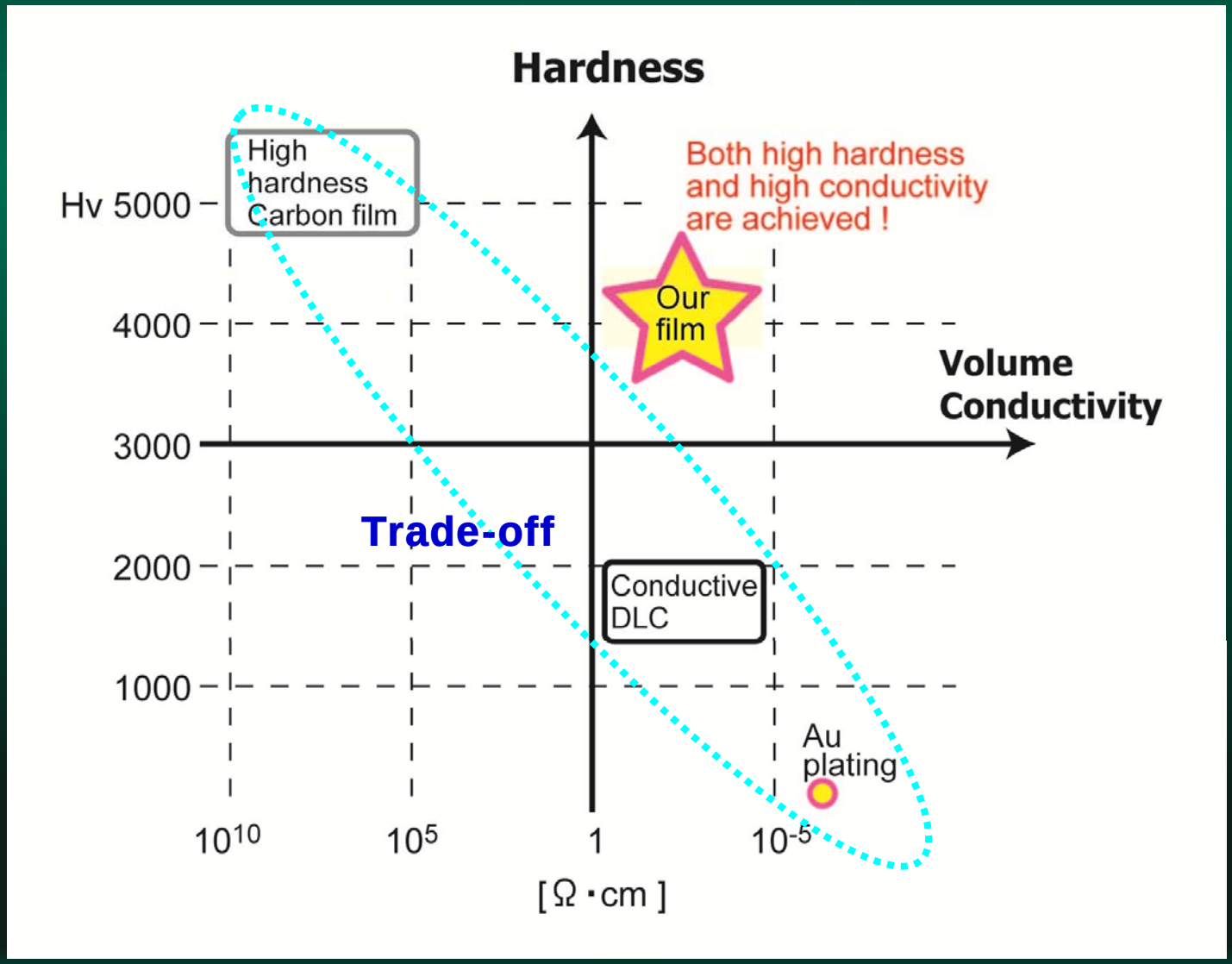
- Wear -> High hardness (wear-resistance)
- Contamination (decrease of electrical stability) -> Self-cleaning surface

The film has the potential as future surface treatment for probes.

Surface Treatment	Hardness	Self-cleaning surface	Electrical Conductivity
Au Plating	X (< Hv 250)	X	○
Palladium Alloy Plating	△ (Hv 350~400)	X	○
Rhodium Plating	△ (Hv 800~900)	X	○
Conductive DLC (Diamond-Like Carbon)	△ (Hv 1000~2000)	△	△
Our film	○ (Hv 4000)	○	△

[Key]
○ = very effective
△ = somewhat effective
X = ineffective

The film has an advantage compared with prior treatment.



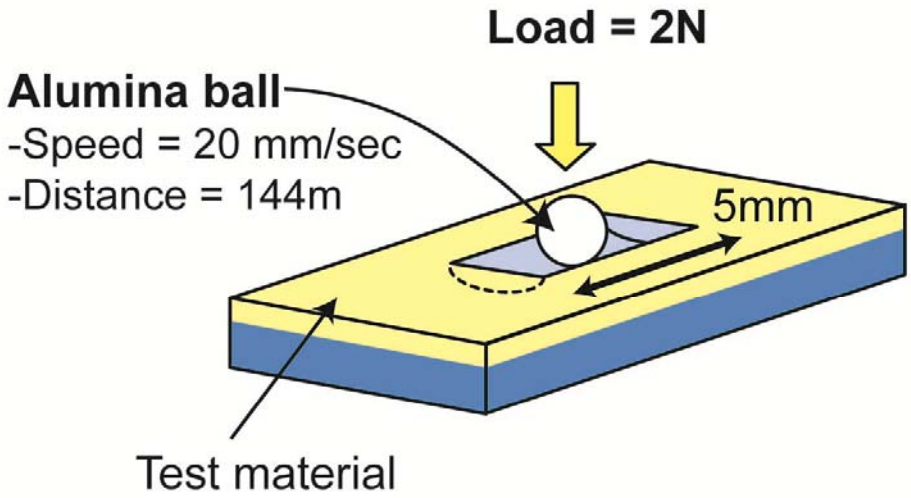
Industrial issue

2. CAN THE FILM ACTUALLY BE USED PRODUCTIVELY IN THE INDUSTRY?

Yes, it can. Why?

- **Because, the film has 3 points for customer appeal.**
  - (a) Higher wear-resistance
  - (b) High electrical & more stable conductivity
  - (c) Self cleaning surface

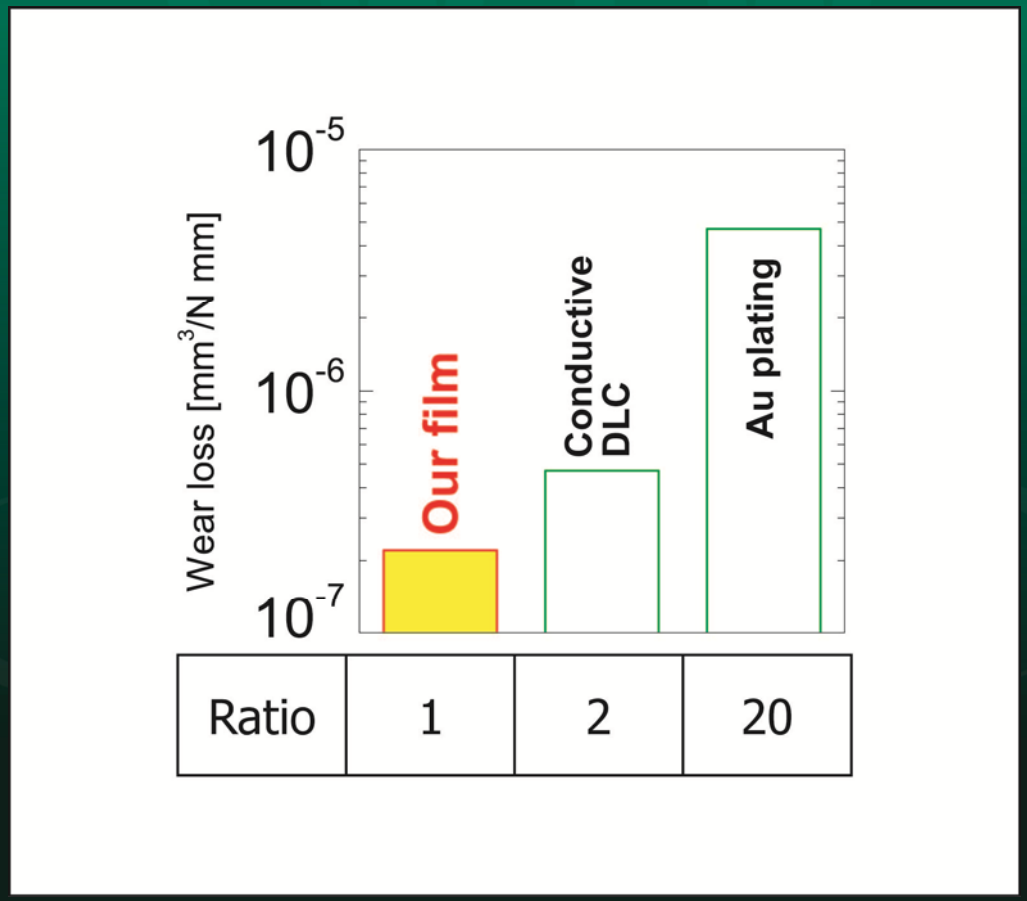
(a-1-1) The method of wear-loss test



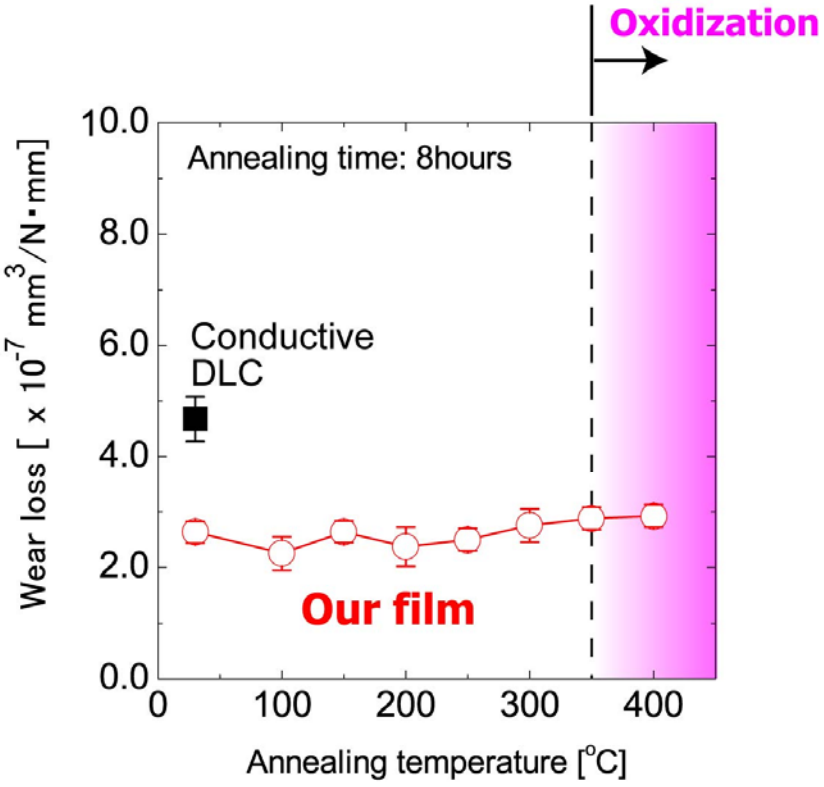
Schematic diagram of wear-loss test

(a-1-2) The higher wear-resistance is obtained compared with alternative materials.

- **Our film has the minimum wear-loss after friction test.**

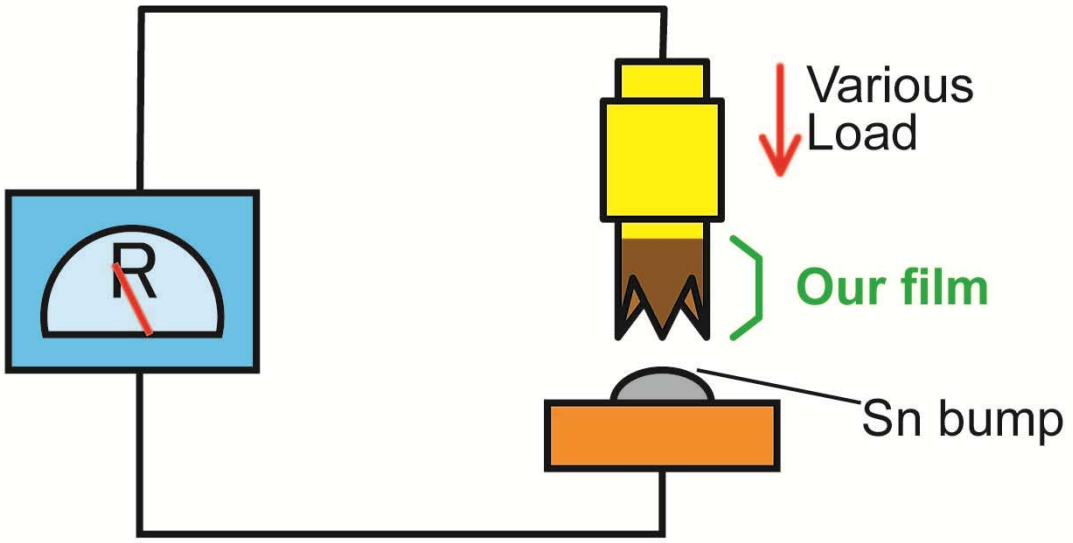


(a-2) The higher wear-resistance is maintained up to 350 °C.



Annealing temperature dependence on wear loss for 8 hours.

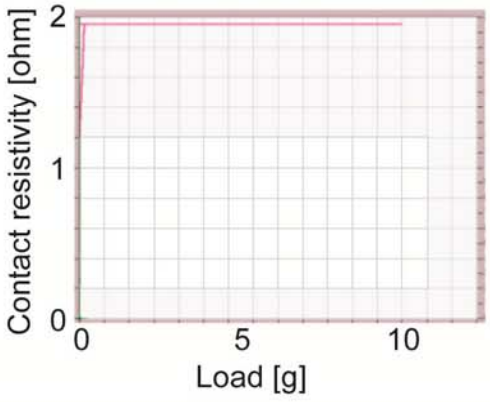
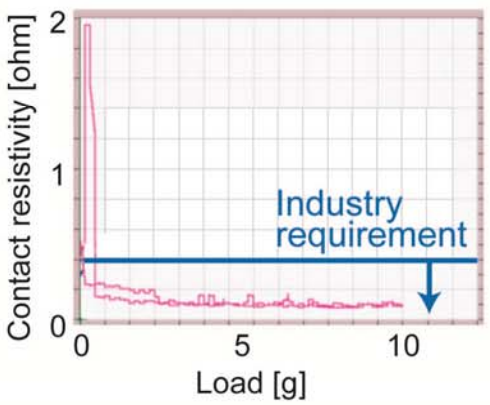
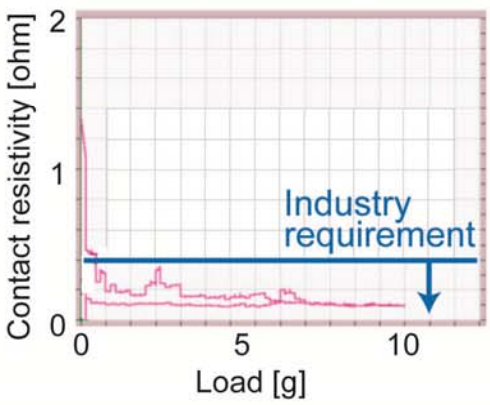
(b-1-1) Method of contact resistivity measurement of the film.



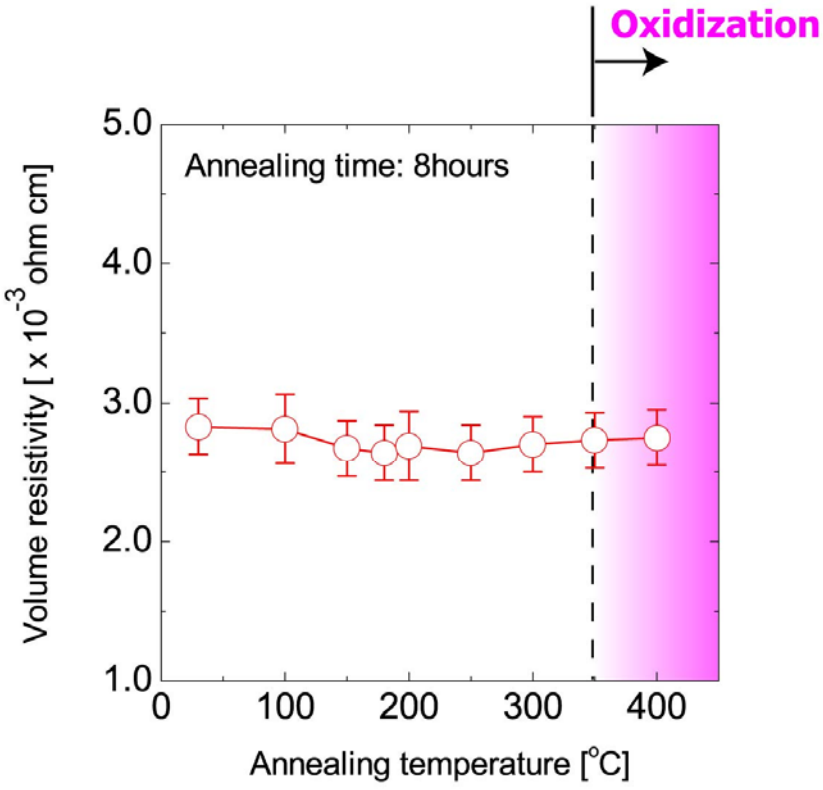
Schematic diagram of contact resistivity measurement

(b-1-2)
High electrical conductivity is obtained at low load.

– Contact resistivity below 200m ohm is obtained with 10gf Load.

	Our film@2011	Our film@2012	Au plating
Contact resistivity with 10gf	> 2 ohm	0.12 ohm	0.10 ohm
Load vs. Contact resistivity			

(b-2) High electrical conductivity is maintained up to 350 °C.



Annealing temperature dependence on volume resistivity for 8 hours

"From experimental results of touchdowns with Sn bump"

1) Conductive DLC

-> Increase in resistivity above 100 °C, because of the oxidization of the metal component in the film.

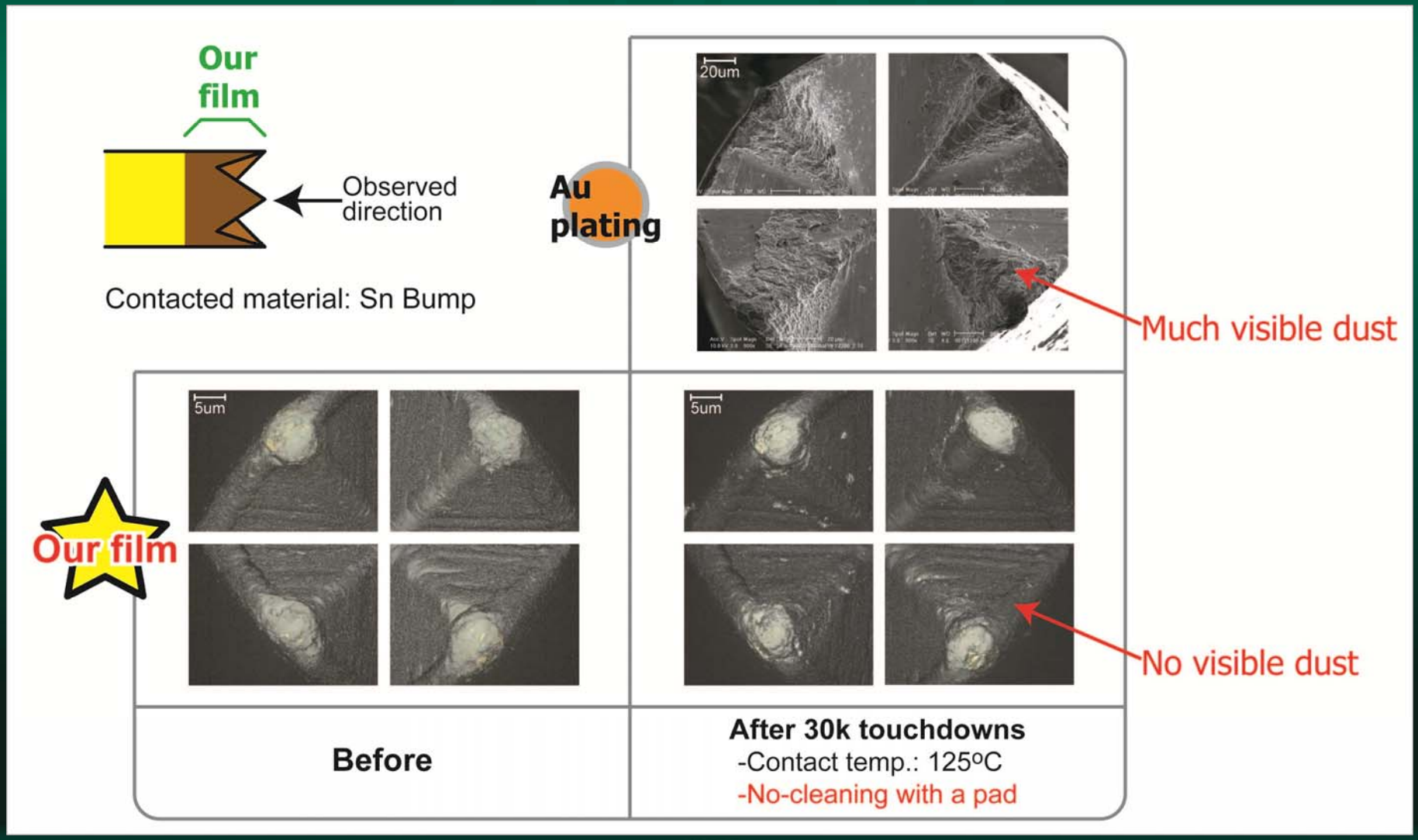
2) Au, Palladium plating

-> Increase in resistivity above 100 °C, because of the contamination on the probe surface.

3) Our film

-> Stable resistivity above 100 °C.

(c) Self-cleaning surface is maintained, after 30k touchdowns.



Discussion

3. WHY DOES THIS FILM HAVE THESE CHARACTERISTICS?

- (a) Higher wear-resistance
- (b) High electrical & more stable conductivity
- (c) Self cleaning surface

(a) Higher wear-resistance is obtained with structural stability of the carbonaceous film.

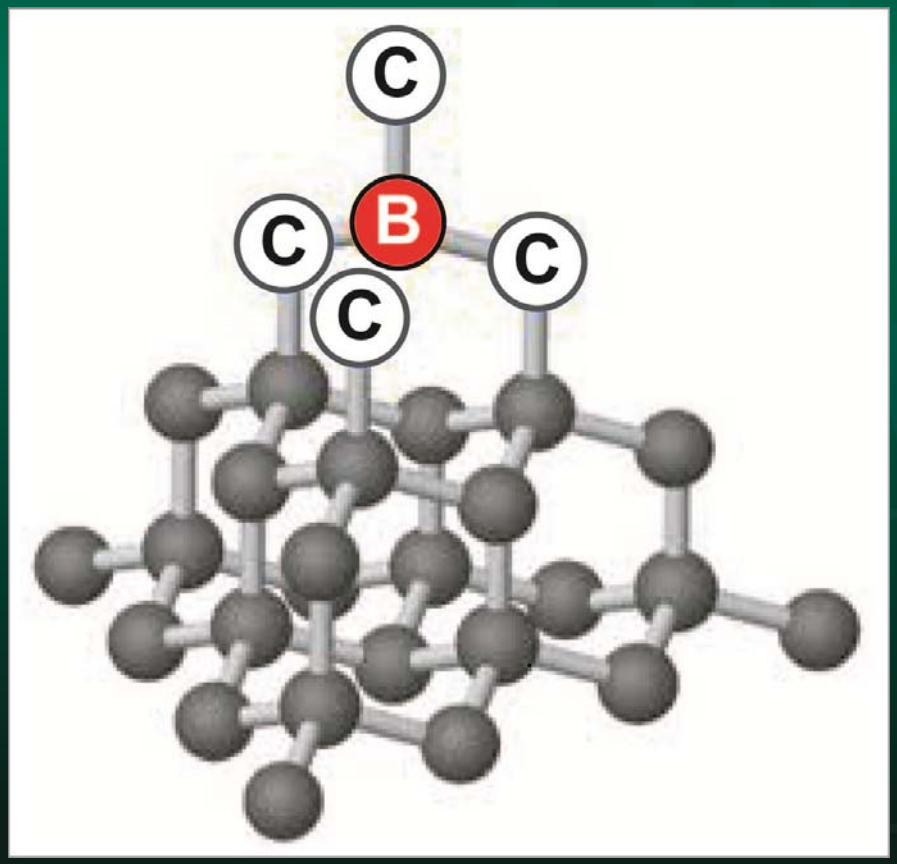
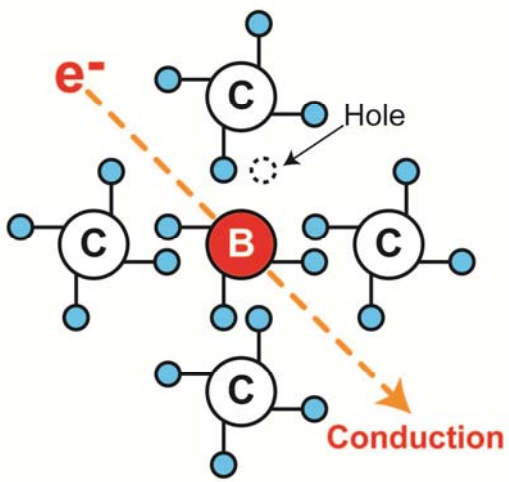
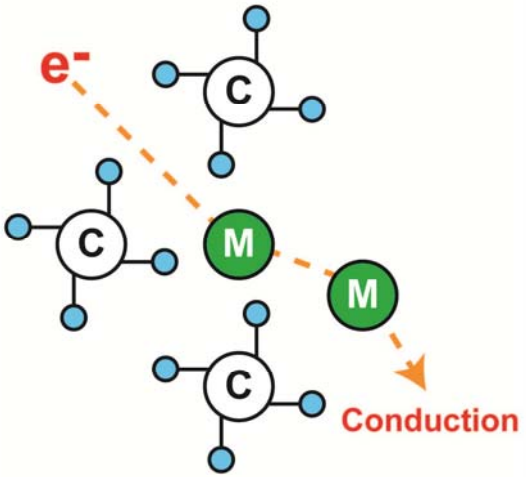


Image of the film structure

- **The structural stability is caused by 3 reasons.**
  - (1) Base material is carbon.
  - (2) The structure consists of diamond-like bonding.
  - (3) Boron, which is doped for the conduction, is less than 1%.

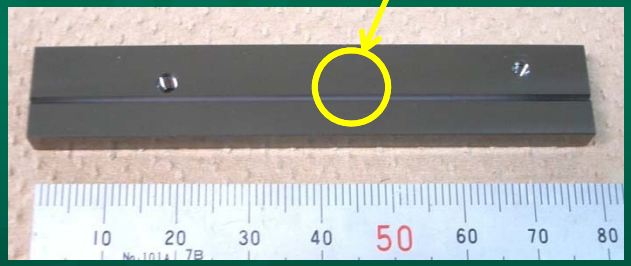
(b) High electrical & more stable conductivity is given by low content of Boron.

	Our film	Conductive DLC
Conduction model		
Principle of conduction	p-type conduction of covalent bond	Metal conduction
Contents of the element	B < 1 atomic%	Metal < 20~40 atomic%
Stability against the oxidization	Stable up to 350°C	Unstable above 100°C

(c) Self-cleaning surface is obtained by lower surface free energy of the film.

Example of surface free energy

Lower contamination of Sn



Picture: Parts feeder for MLCC deposited with the carbonaceous film. (Multi-Layer Ceramic Condenser)

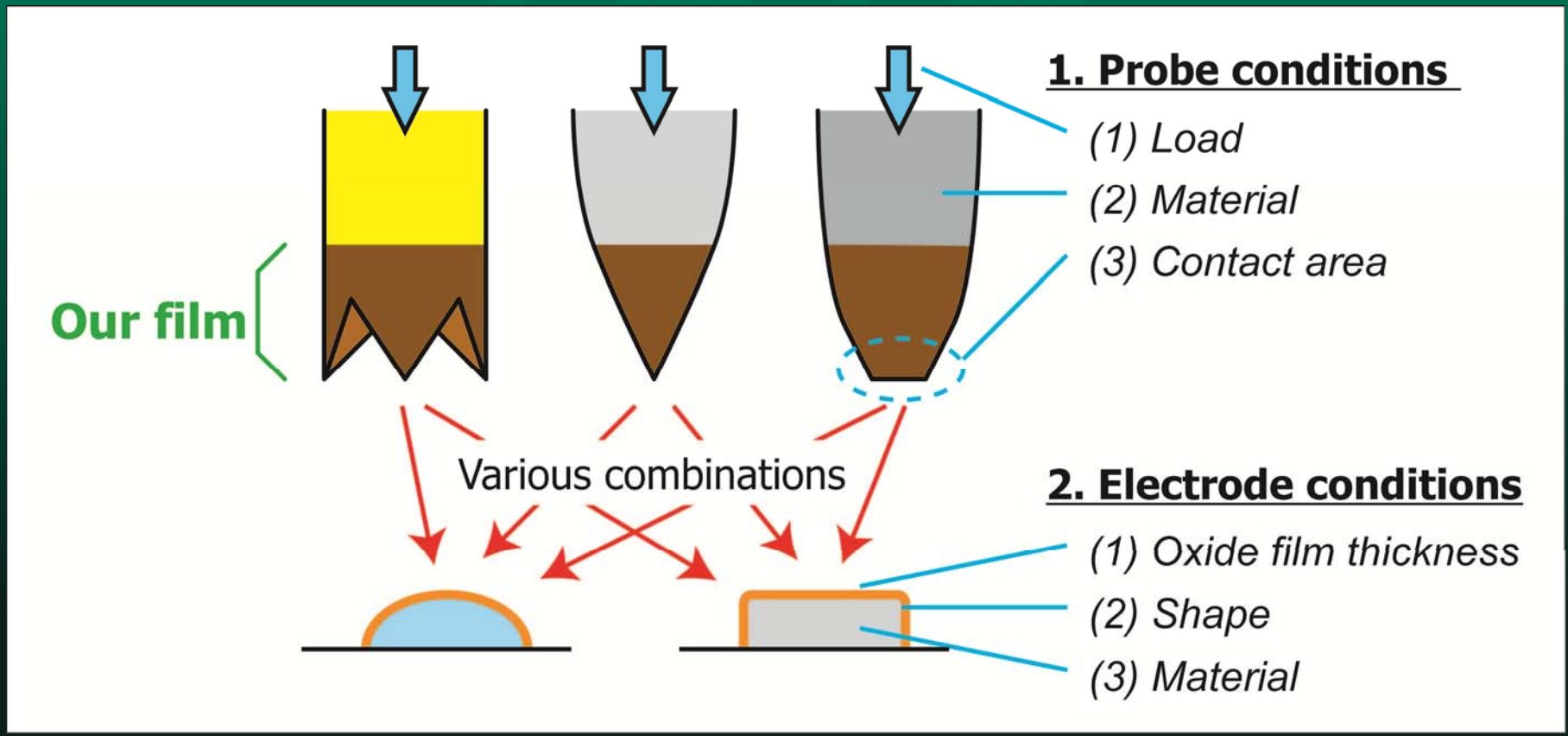
- **Why does this film have lower surface free energy?**
  - A characteristic of carbon with >99% purity
  - Higher bonding strength

Care points of practical use

4. ARE THERE ANY CARE POINTS OF PRACTICAL USE?

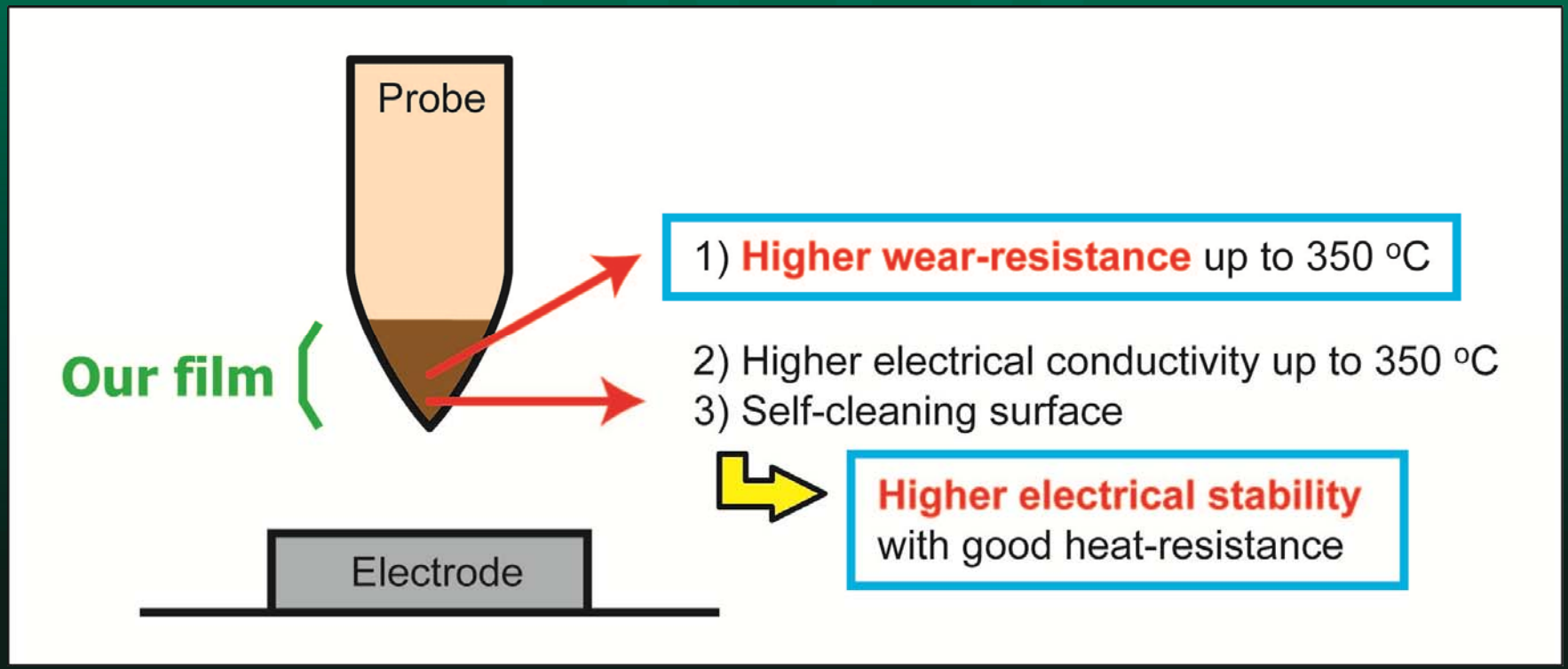
Yes, there is a care point of practical use.

- **The evaluation of the film under each condition of probe user is necessary, before practical use.**



5. CONCLUSION

- **A practical use of the film will be further progressed, owing to the capability for longer life and better measurement reliability of probes.**



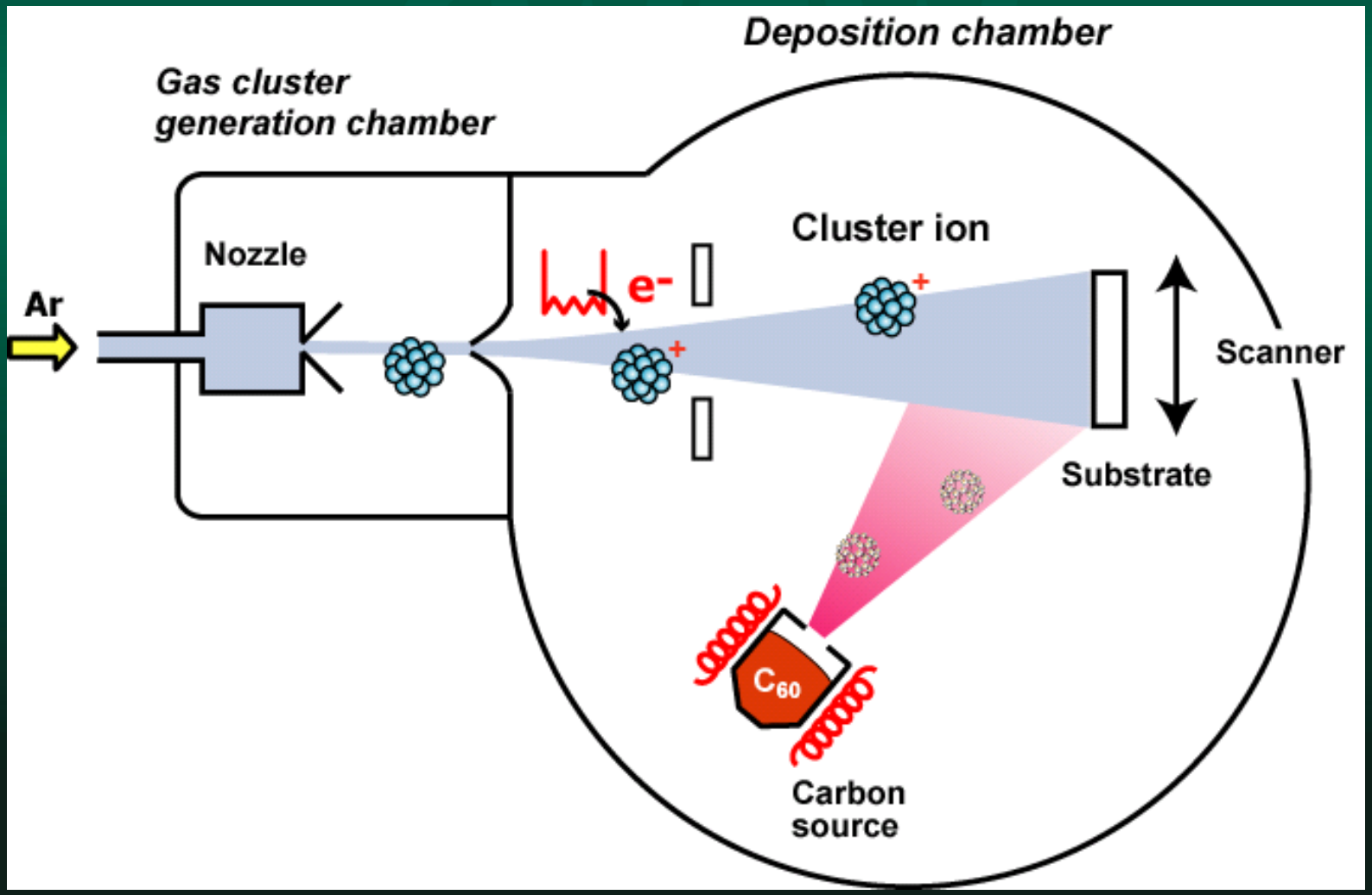
- **Contact**
  - We exhibit the SWTW Expo.
  - Booth No.3

Acknowledgement

– We are deeply grateful to K. Takizawa, S. Ono, and Y. Kawahata at JC Electronics Corporation.

- **for Q&A session**

Gas cluster ion beam process.



High density bombardment effect of cluster ion is effective in depositing higher hardness film.