Evaluation of wear properties and durability by DLC film

○Kengo Sakurai [1], Kazushige Namiki[2] , Hideki Nakamori[3], Masanori Hiratsuka[3], Kenji Hirakuri[1]

[1]Tokyo Denki University, [2]Namiki-Mi Co. Ltd, [3]Nanotec Co. Ltd

E-mail address : 17kmj18@ms.dendai.ac.jp

Medical devices

Examples of medical devices

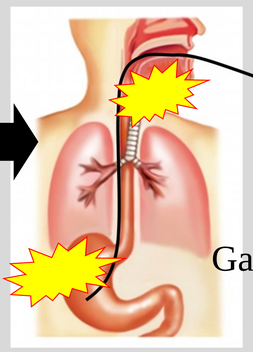
Gastroscopy

Catheter

Main materials of current medical devices

⇒Metal such as stainless-steel (SUS) and titanium

However…



Problems

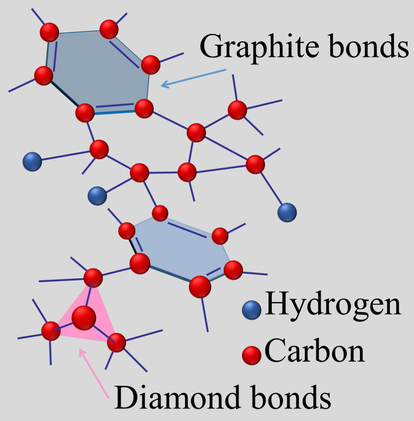
① Due to acidic solution (stomach acid)
⇒Deterioration of medical devices
⇒Elution of allergic substances
② Due to sterilization treatment
⇒Deterioration of medical devices
③ Due to the friction
⇒Aching pain, discomfort by high friction

Surface modification of metal material is required!

https://www.bing.com/images/search?q=%e3%82%ab%e3%83%86%e3%83%bc%e3%83%86%e3%83%ab&FORM=HDRSC2

Diamond-like carbon (DLC)

Amorphous carbon thin film with both graphite and diamond structure



Structural model of DLC

< Characteristic >

✔Low friction
✔Chemical stability
✔Biocompatibility
✔Gas barrier

Chain

HDD

https://www.bing.com/images/search?q=HDD&qs=n&form=QBIRMH&sp=-1&pq=hdd&sc=8-3&sk=&cvid=EAE931E6EDD64DF1864912EEA2524E84

Aims of this research

In order to modify the surface of the metal materials, DLC was coated on the SUS substrate.

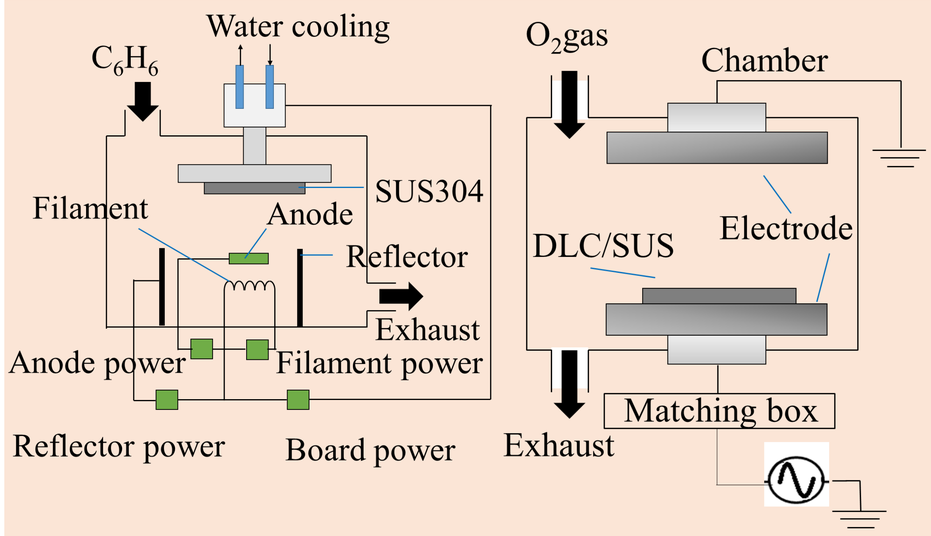
① Acid tolerance and sterilization test

② Reduction of friction

★Durability of DLC coating against sterilization and acidic solution
- Raman spectroscopy, Scanning Electron Microscope, etc…

★Wear properties of DLC coating
- Ball-on disc test (ISO / DIS 18535 standard reference) etc…

Method of DLC coating



Ionized deposition system

RF plasma system for surface treatment

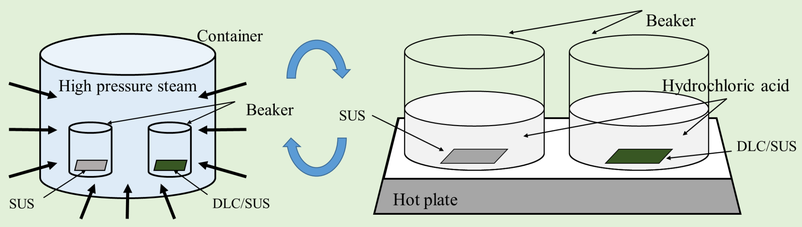
Deposition condition of DLC coating

Substrate	SUS304
Source	C_6H_6
Pressure	0.2 [Pa]
Filament current	30 [A]
Substrate voltage	2 [kV]

Treatment condition of O_2 plasma

Sample	DLC/SUS
Source gas	O_2
Pressure	10 [Pa]
Supply power	200 [W]
Treatment time	2 [min]

Sterilization test



Sterilization condition

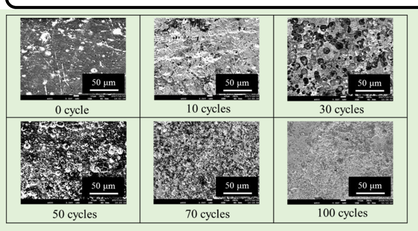
Time	15 [min]
Temperature	126 [℃]

Immersion condition with acidic solution

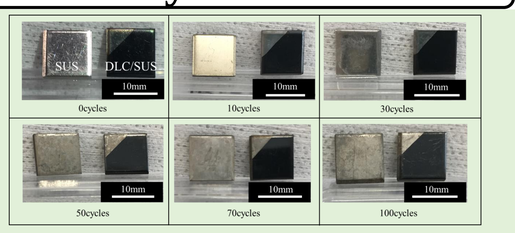
Time	30 [min]
Acid concentration	pH=1.023 (22.1℃)
Temperature	70±5[℃]

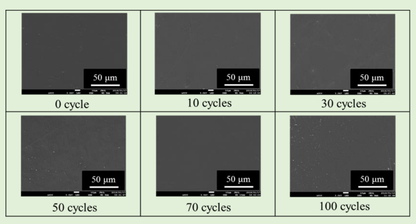
1 cycle:
High pressure steam sterilization and next immersion test with acidic solution
★ Analyzation substrate in each cycle ⇒ Total 100 cycles

Structure analysis

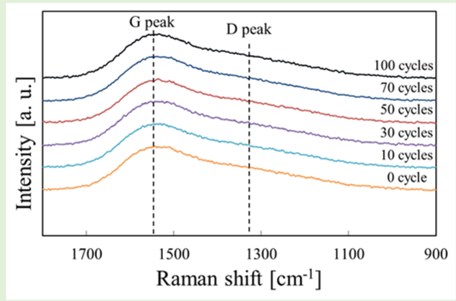


Surface condition of SUS



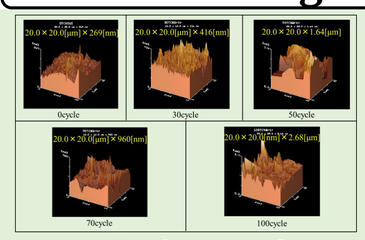


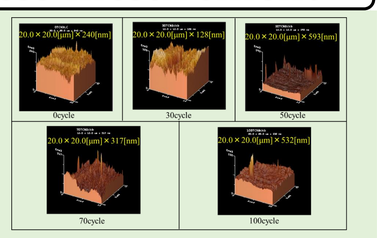
Surface condition of DLC/SUS



Raman spectra of each sample

Surface roughness mesurement





Surface roughness of SUS and DLC/SUS

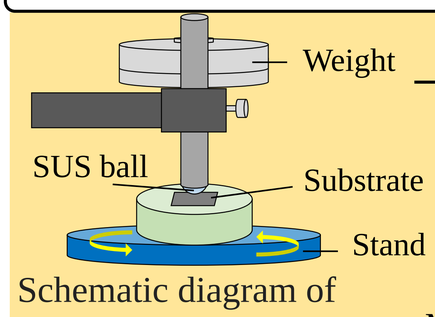
Mean roughness of each sample

Cycle	SUS	DLC/SUS
	Mean roughness（Ra）[nm]	
0	10.4	5.76
30	24.7	7.11
50	106.0	8.53
70	71.3	8.40
100	47.5	8.36

DLC has durability against sterilization and acidic solution.

The Ra value of the DLC coating was extremely low.
⇒ It was found that the DLC makes flat.

Wear property of DLC coating



Schematic diagram of ball-on disc test schematic

Ball-on disc test condition

Object	SUS ball φ=6 [mm]
Load	3 [N]
Rotational speed	7960 [rpm]
Running time	50 [m]
Measurement time	17 [min]

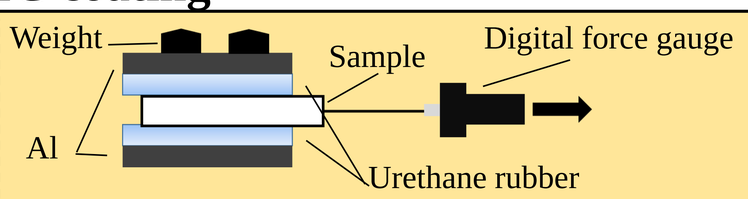
Friction coefficient of each sample

Sample	Friction coefficient
SUS	Dry:0.529
	Wet:0.556
DLC/SUS	Dry:0.176
	Wet:0.117

Dry：Under the dry condition

Wet：Under physiological saline (Temp：25℃, RH：15%, Saline：250μL)

The friction coefficient of DLC/SUS is lower than that of SUS.



Schematic diagram of measurement of friction coefficient

Friction coefficient of each samples

Weight [g]	Urethane rubber	SUS	DLC/SUS	O-DLC/SUS
			（n=5）	
0	2.79	1.14	2.29	1.01
100	1.54	0.73	1.33	0.67
200	1.24	0.87	1.14	0.59
300	1.27	0.87	0.97	0.60

The friction coefficient of O-DLC/SUS is lower than that of each samples.

Conclusions

By DLC coating
① Acid tolerance and sterilization test
② Reduction of friction to living body

- **Evaluation of durability against sterilization and acidic solution**
  ⇒DLC has durability against sterilization and acidic solution.
- **Wear property of DLC coating**
  ⇒DLC has high wear property against mechanical and under simulated living environment.

This work was supported by JKA and its promotion funds from KEIRIN RACE. 2018M-113