Triboplasma – its generation and application for surface modification

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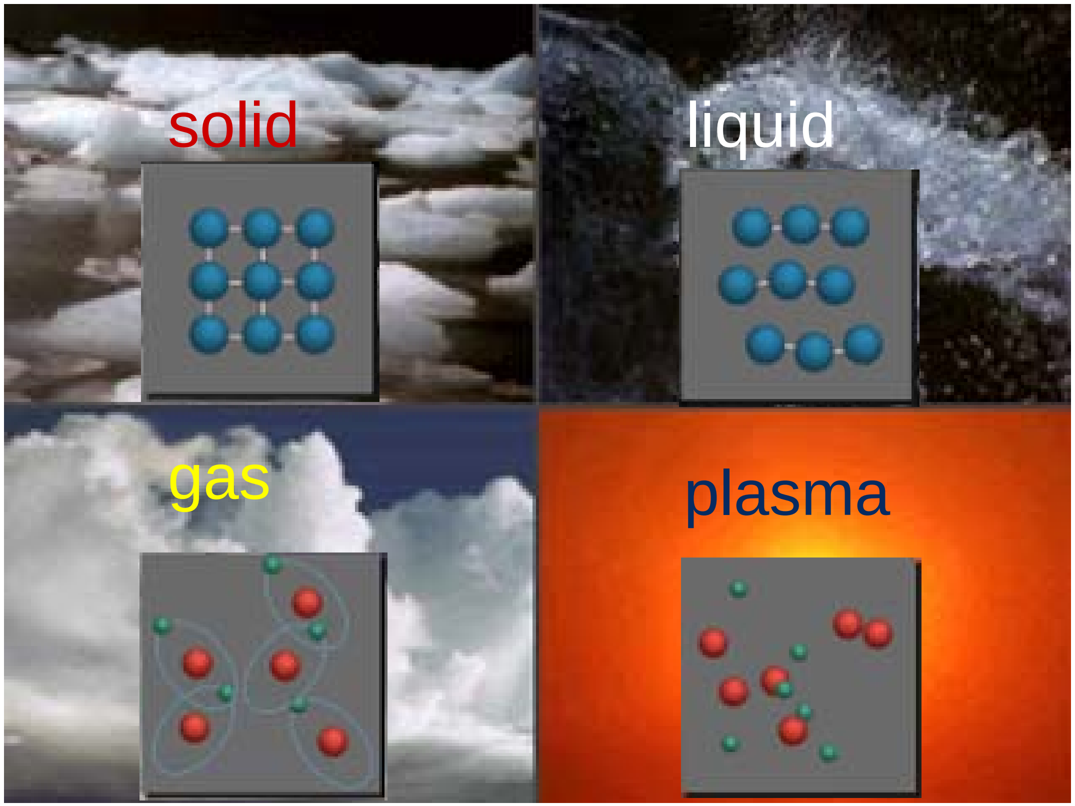
3 Summary

1 Process plasmas

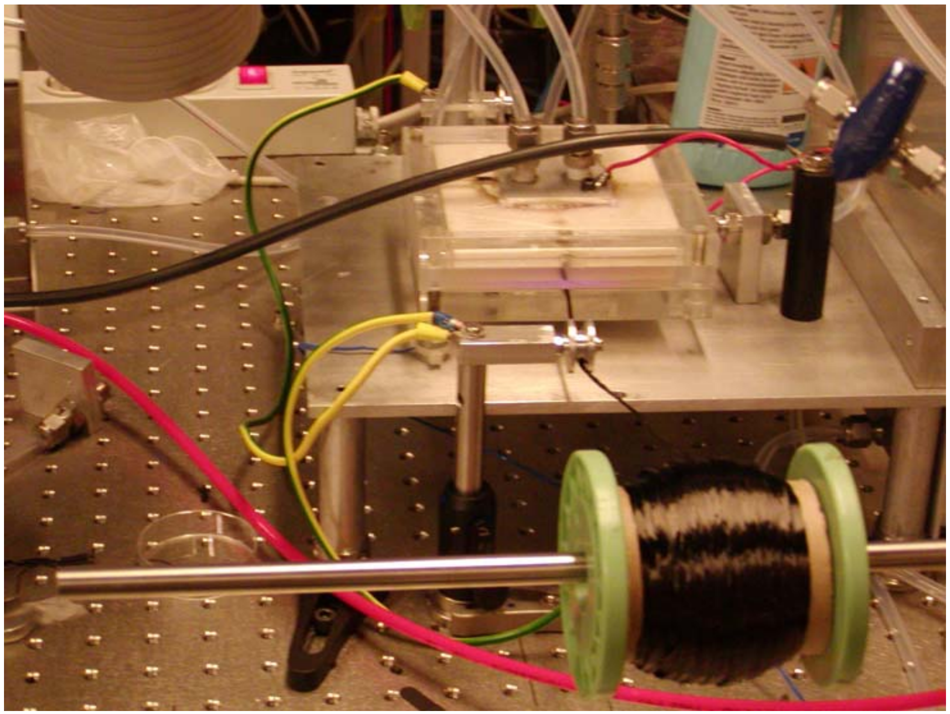
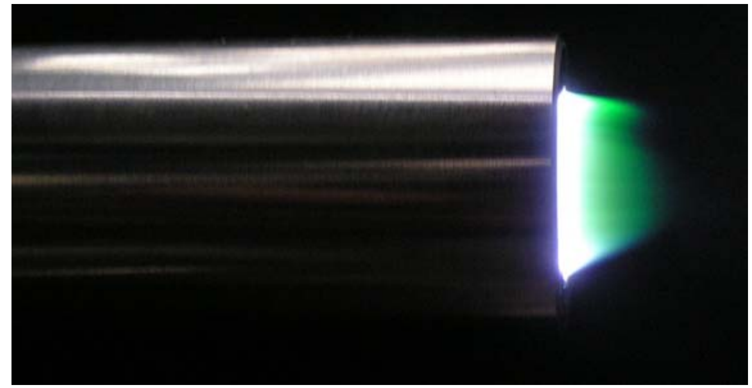
1.1 What is a plasma?

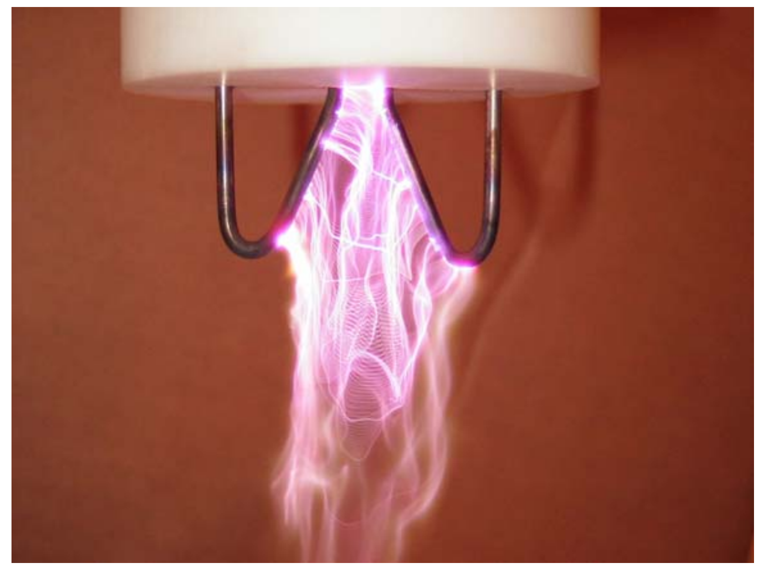


Characteristics of low temperature plasma

- Non-equilibrium ($T_{electron} >> T_{ion}$, $T_{molecule}$)
- Radicals, ions, electrons
- UV emission
- Surface modification, Polymerization, film synthesis
- Environmental compatibility
- High treatment effect
- High reproducibility
- Bulk property unchanged
- Easily generated at low pressures, but also possible at atmospheric pressure

1.2 Atmospheric pressure plasmas



need power supplies

2 Triboplasma

2.1 Processes with tribological activation

Triboemission

Emission of electrons, ions, radicals, photons, phonons etc. caused by tribological activation

Tribo-luminescence

Optical emission caused by the breaking of asymmetrical bonds in a material with tribological activation

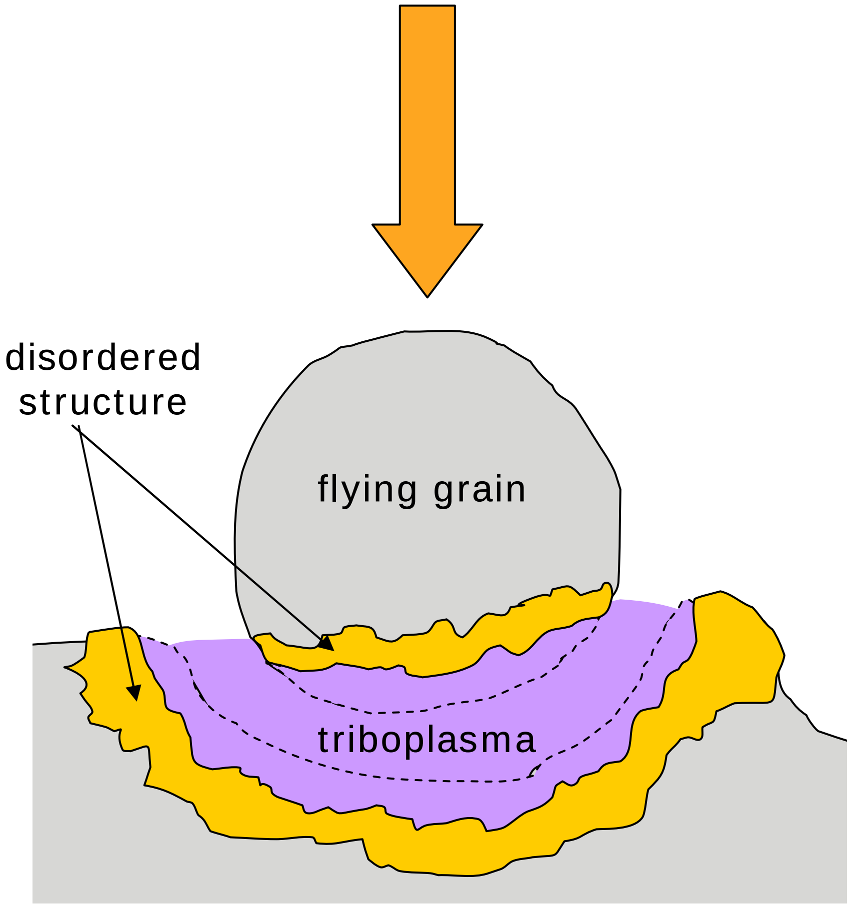
Triboplasma

Gas discharge with tribological activation

↓

Surface modification

2.2 Magna-plasma model



Impact stress of flying grain

quasi-adiabatic energy accumulation

formation of energy bubble
at the deformation zone

high excitation states
strong lattice loosenings
structural disruptions

detachment of lattice components,
photons, ions, electrons

Generation of triboplasma

Temperature by rubbing peaks between 600 - 1000 K in the course of period smaller than 10^{-4} s, leading the hot-spot theory.

based on Thiessen “Grundlagen der Tribochemie” 1967
& Heinricke “Tribochemistry” 1984

2.2 Magma-plasma model

Ceramization with Rocatec (3M) – dental application

SiO_2 coated alumina particles are blasted onto a surface

A triboplasma is generated at the contact.

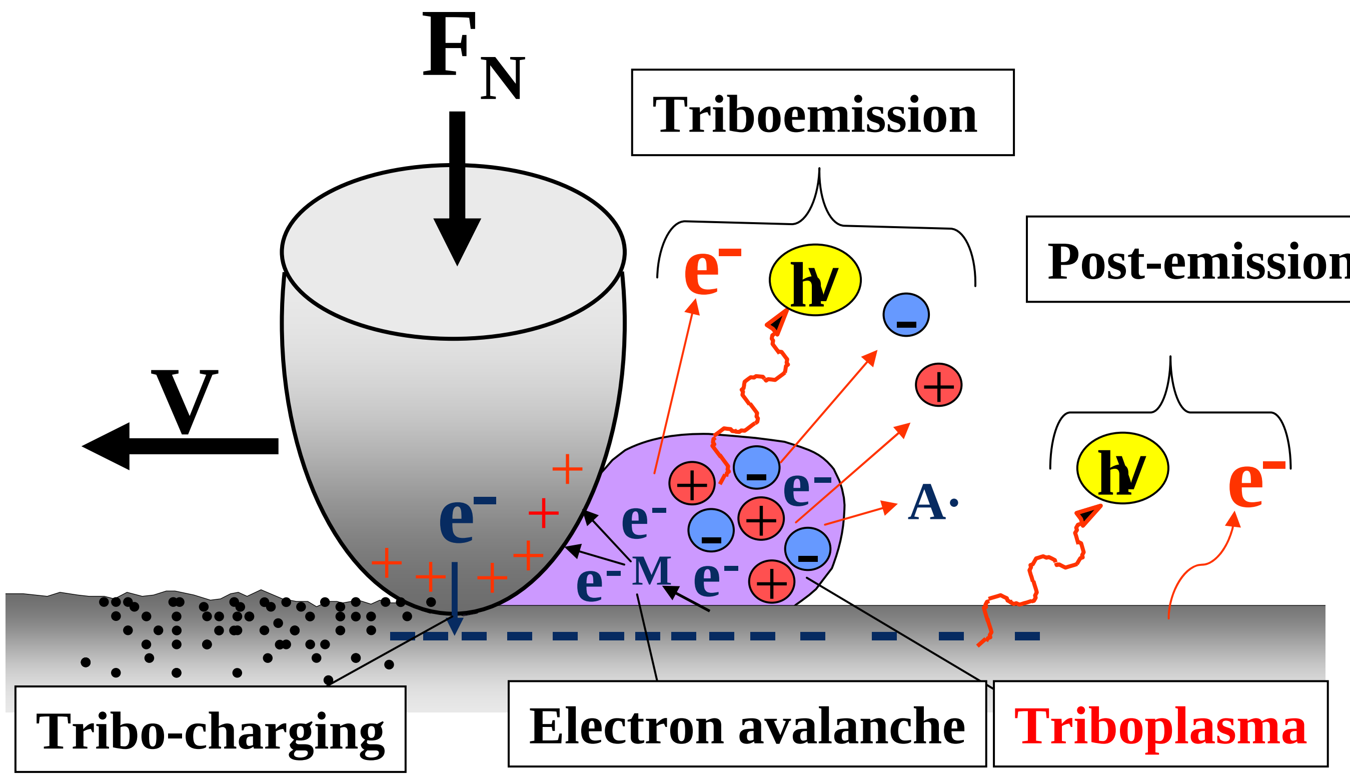
SiO_2 coatings are partially delaminated from the particles and attached onto the blasted surface.

The alumina particles are removed.

Detection of a triboplasma is not reported.

http://www.3m.com/intl/kr/medi/medi5/pdf/Rocatec.pdf

2.3 Tribo-electrification model



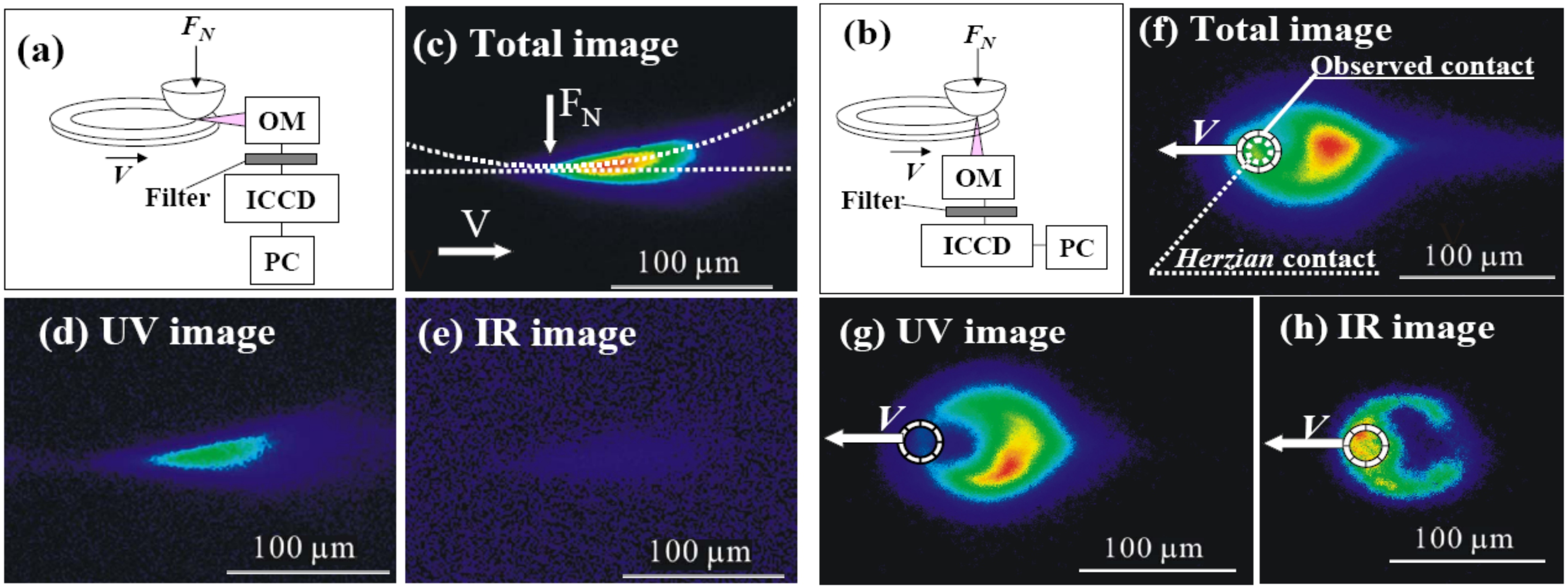
K. Nakayama, "Microplasma generated in a gap of sliding contact", J. Vac. Soc. Jpn. 49(10) (2006) 618-623

Sliding → Tribo-electrification → Electric field → Generation of triboplasma

strong impact unnecessary!

2.4 Generation of triboplasma

Observation of optical emission around the sliding contact



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Intense UV emssion NOT at the sliding contact

Materials with higher resistivity show higher charge-emission intensity
(Nakayama,_Tribology Lett. 6 (1999) 37-40)

Supporting tribo-electrification model

2.5 Tribo-electrification

The production of electro-static by rubbing together of dissimilar material surfaces.

The detailed physical mechanism in tribo-electrification is a long unsolved problem

Tribo-electric series

– a classification scheme for the ordering of the tendency for charge acquisition in rubbing

Surface morphology

2.5 Tribo-electrification

Tribo-electric series

positive

Air (*?)
Human hands
Asbestos
Rabbit fur
Silicone elastomer with silica filler
Borosilicate glass (fire polished)
Glass
Mica
Human hair
Nylon
Wool
Fur
Lead
Silk
Aluminium
Paper
Cotton
Steel, iron
Wood

zero

Borosilicate glass (ground surface)
Amber
Sealing wax
Natural rubber
Nickel, Copper
Brass, Silver
Gold, Platinum
Sulphur
Acetate, Rayon
Polyester
Polystyrene (Styrofoam)
Orlon
Saran
Polyurethane
Polyethylene (PE)
Polypropylene (PP)
polyvinylchloride (PVC)
Silicon
PTFE (Teflon)

negative

Adams "Nature´s electricity 1987, Freeman_ Mater.Sci.Technol._1999. Note that the order of the above list is different in different books

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2.5 Tribo-electrification

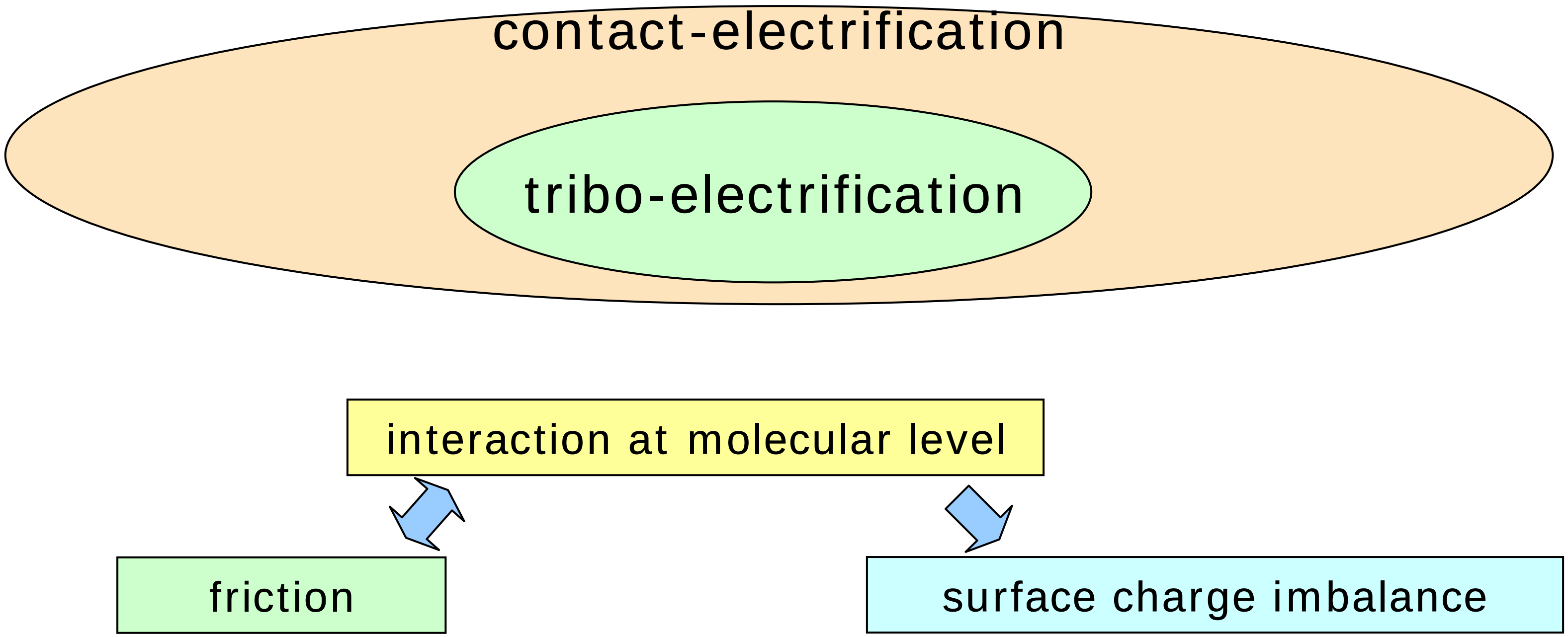
Tribo-electric series (polymers)

Coehn´s law: the order of materials corresponds with that of dielectric constants

	dielectric constant	
Nylon	4.0 – 4.5	positive
PMMA	3.0 – 3.5	↓
Polystyrene	2.4 – 2.65	↓
polyethylene (PE)	2.25 – 2.35	↓
PTFE (Teflon)	2.0	negative

Morris, Plastics Polym. (1970) 41-45

2.5 Tribo-electrification



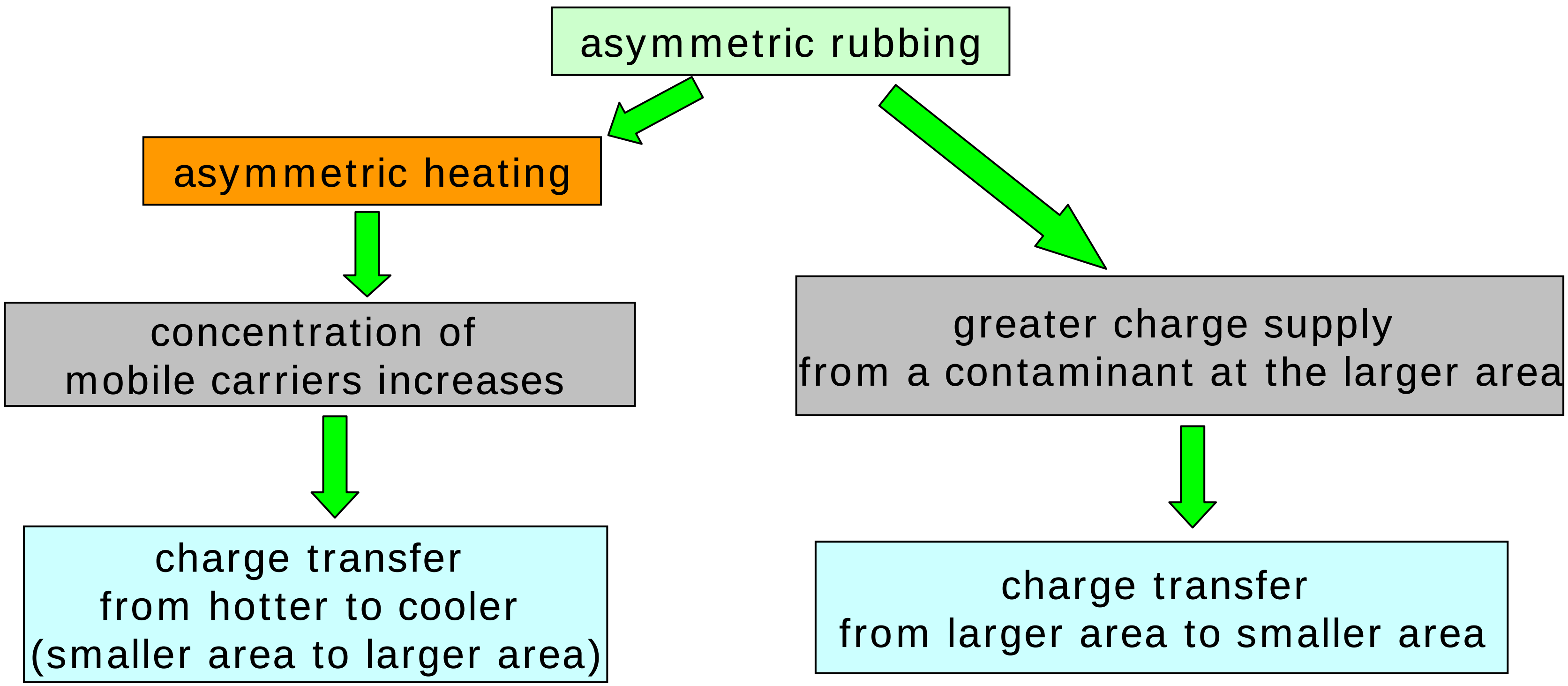
“contact and separation” is important for charging - Some surfaces, such as adhesive tape or plastic sheets, CAN attain intimate contact over a large area, and DO exhibit strong charging when they are simply touched to another surface and pulled away.

http://amasci.com/emotor/tribo.html

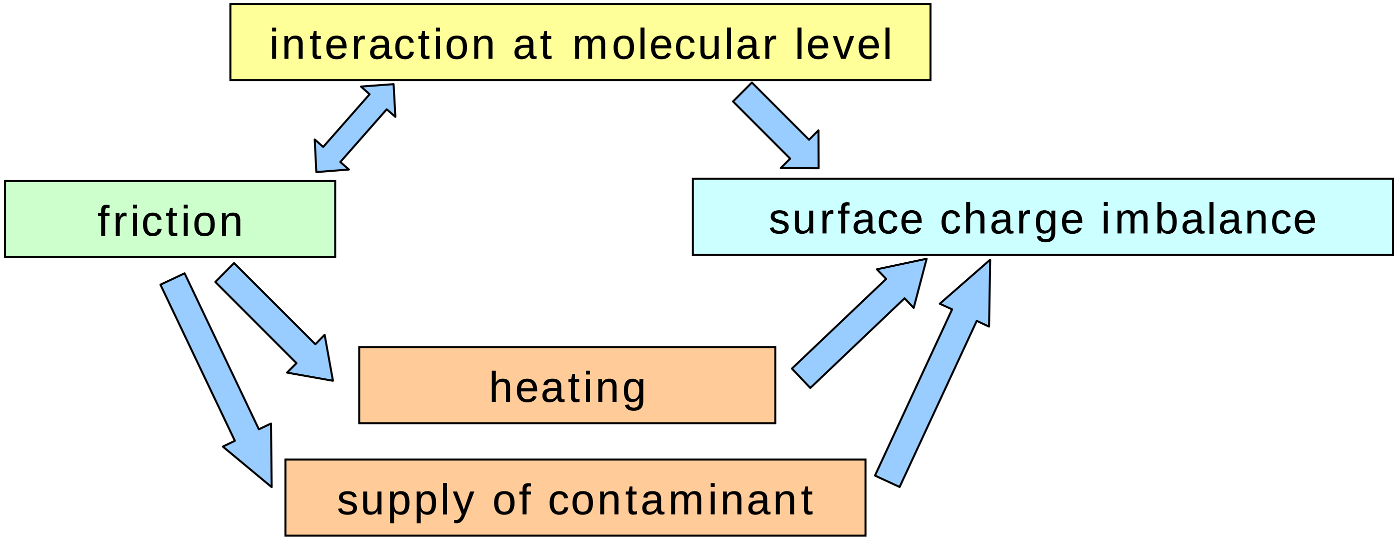
2.5 Tribo-electrification

The ordering of the tribo-electric series can be different when

surfaces are rubbed or simply touched, or
surfaces of differing roughness are rubbed together.



2.5 Tribo-electrification



Controllability of tribo-electrification

- physical and chemical nature of the contacting surfaces (bulk properties, surface morphology, surface layers of water, oxides, hydrocarbons, dusts etc.)
- pressure and duration of contact
- heating, transfer of bulk materials
- ambient medium

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2.6 Surface modification by triboplasma

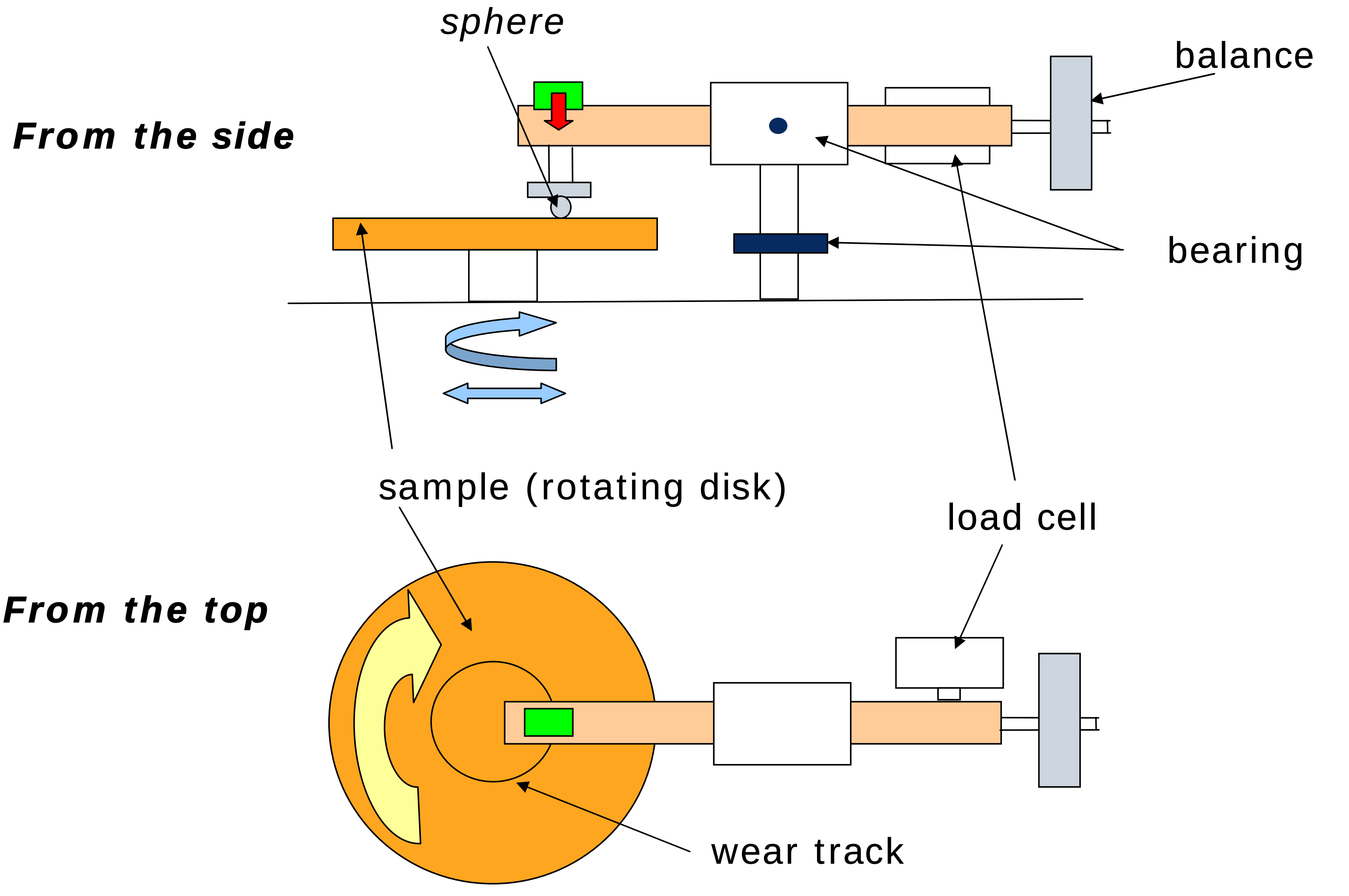
Good agreement of optical emission spectra between a triboplasma and other general discharge plasmas

A triboplasma can be useful for surface modification such as adhesion improvement of certain surfaces

Potential advantages
- simple system
- simultaneous mechanical rubbing to enhance the treatment effect.

Fluoropolymer lubricant is decomposed
(K. Nakayama, S.MD. Mirza, Tribology Trans., 49 (2006) 17-25)
Polymeric coatings can be synthesized by a triboplasma
(K. Nakayama, Tribology Int. 29(5) (1996) 385-393)

2.7 Experimental setup



3 Summary

- Processes with tribological activation
- triboplasma by tribo-electrification
- mechanisms of tribo-electrification
- surface modification effects
- experimental setup