

粉体の帯電現象

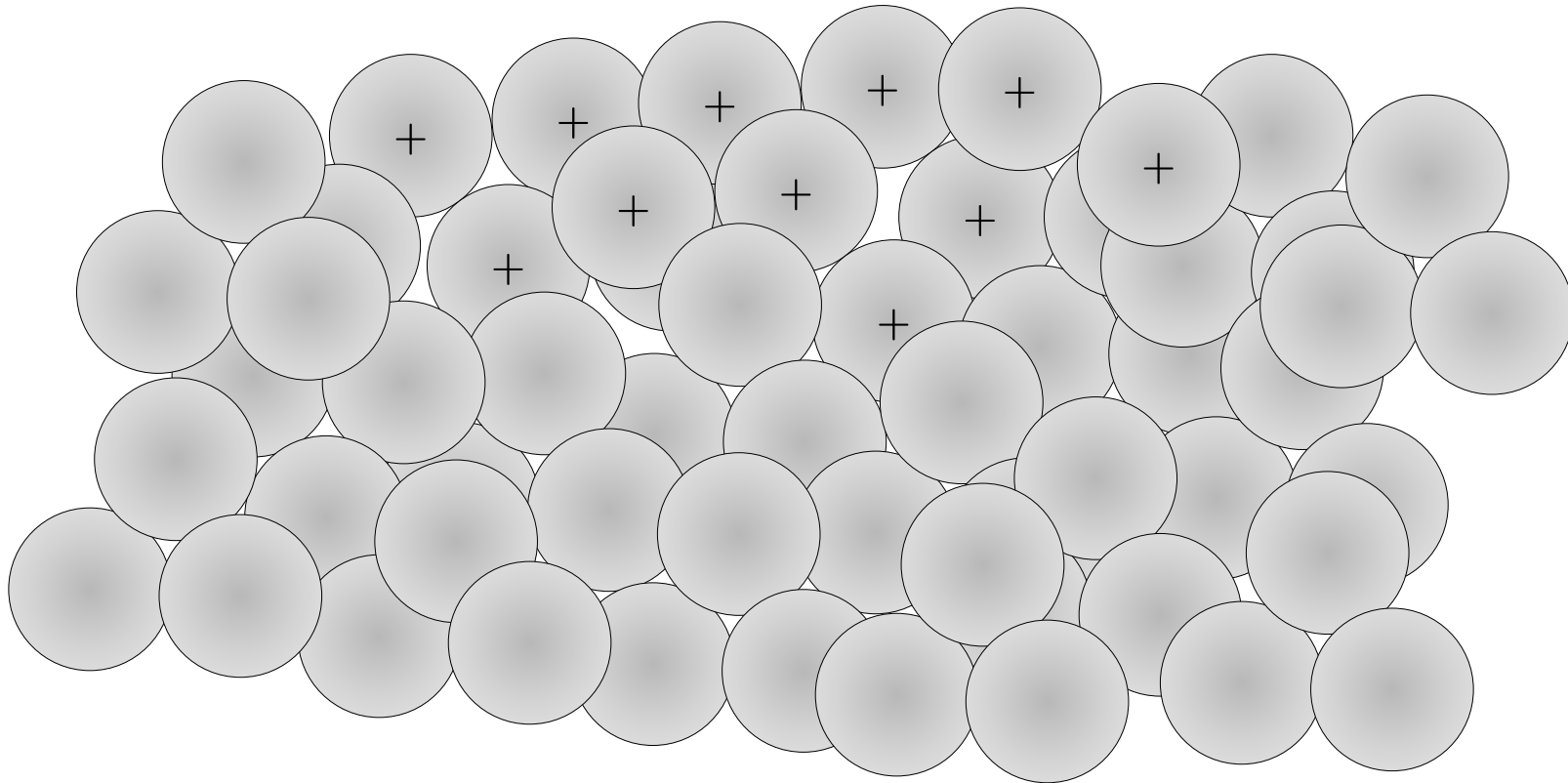
労働安全衛生総合研究所 庄山瑞季

1. 粉体の帯電とは？
2. 粉体帯電の利用と安全上の課題
3. 粉体帯電の種類

粉体の帯電とは？

局所的に帯電した粒子が存在または、電荷密度分布

電場によって電荷が移動→電場も変化



気相中における粉体帯電の利用と安全上の課題

静電気力を利用した粒子の運動および位置制御

- ✓ 電気集塵
- ✓ 静電粉体塗装
- ✓ 電子写真
- ✓ 静電分級、輸送など

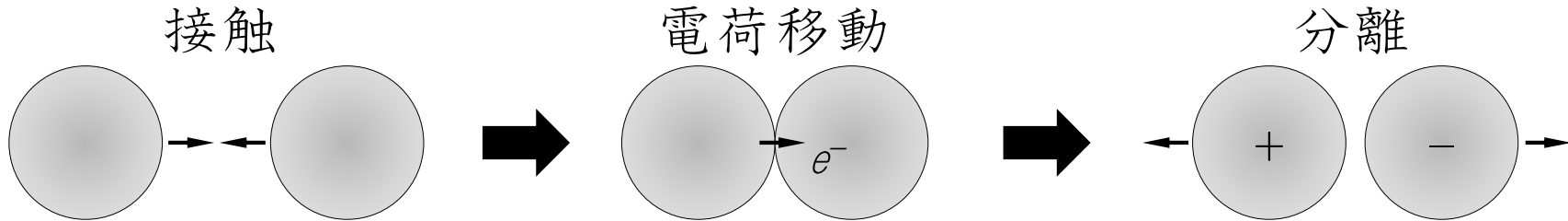
プロセス安全上の課題

- ✓ 粒子異常挙動（付着、凝集、浮遊）
- ✓ 電荷蓄積による放電

粉体帯電の種類

1. 接触・摩擦帯電
2. 電子・イオン付着による帯電
3. 電子・イオン放出による帯電
4. 誘導帯電

接触・摩擦帯電



帯電列

Henniker J. *Nature* 196
(1962) 474-474

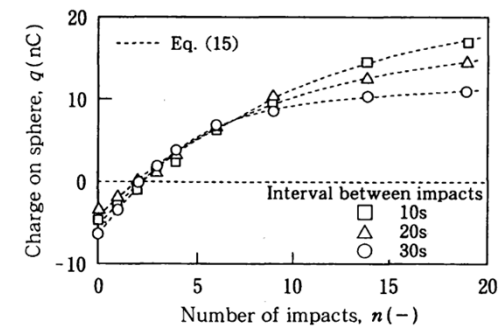
TRIBOELECTRIC SERIES

(positive end)

Silicone elastomer with silica filler
Borosilicate glass, fire-polished
Window glass
Aniline-formol resin (acid catalysed) —CH ₂ —Ph—NH—
Polyformaldehyde —CH ₂ —O—
Polymethylmethacrylate —CH ₂ —CMe(COOCH ₃)—
Ethylcellulose
Polyamide 11 —(CH ₂) ₁₀ CO—NH—
Polyamide 6-6 —(CH ₂) ₄ CO—NH(CH ₂) ₆ NH—CO—
Rock salt Na Cl
Melamine formol
Wool, knitted
Silica, fire-polished
Silk, woven
Poly-ethylene glycol succinate —(CH ₂) ₄ COO(CH ₂) ₂ OCO—
Cellulose acetate
Poly-ethylene glycol adipate —(CH ₂) ₄ COO(CH ₂) ₄ OCO—
Poly-diallyl phthalate —CH ₂ CH=OCOPhCOOCH=CH ₂
Cellulose (regenerated) sponge
Cotton, woven
Polyurethane elastomer —NIPhNHCOOROCO—
Styrene acrylonitrile copolymer
Styrene butadiene copolymer
Polystyrene —CH ₂ —CHPh—
Polyisobutylene —CH ₂ —CMe ₂ —
Polyurethane flexible sponge
Borosilicate glass, ground surface
Polyethylene glycol terephthalate —COPhCOO(CH ₂) ₂ O—
Polyvinyl butyral
Formo-phenolic, hardened —CH ₂ —PhOH—CH ₂ —
Epoxide resin —OPhCMe ₂ PhOCH ₂ CHOHCH ₂ —
Polychlorobutadiene —CH ₂ CCl—CHCH ₂ —
Butadiene acrylonitrile copolymer
Natural rubber —CH ₂ CMe=CHCH ₂ —
Polyacrylonitrile —CH ₂ —CH(CN)—
Sulphur
Polyethylene —CH ₂ —
Polydiphenylol propane carbonate —OPhCMe ₂ PhOCO—
Chlorinated polyether —CH ₂ —C(CH ₂ Cl) ₂ CH ₂ O—
Polyvinylchloride with 25 per cent D.O.P.
Polyvinylchloride without plasticizer —CH ₂ —CHCl—
Polytrifluorochloroethylene —CF ₂ CFCl—
Polytetrafluoroethylene —CF ₂ —

繰り返し接触による帯電量

$$q = q_0 \exp\left(-\frac{n}{n_0}\right) + q_{\infty} \left\{1 - \exp\left(-\frac{n}{n_0}\right)\right\}$$



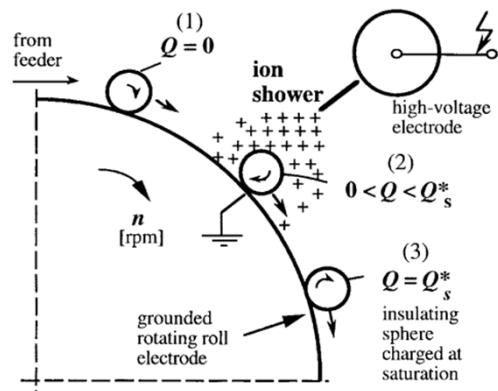
Matsusaka S. and Masuda H. J. Soc. Powder Technol. Japan 43 (2006) 104-114

詳細なメカニズムは不明

摩擦なしでも生じるのか、電荷キャリアは電子／イオンどちらなのか等

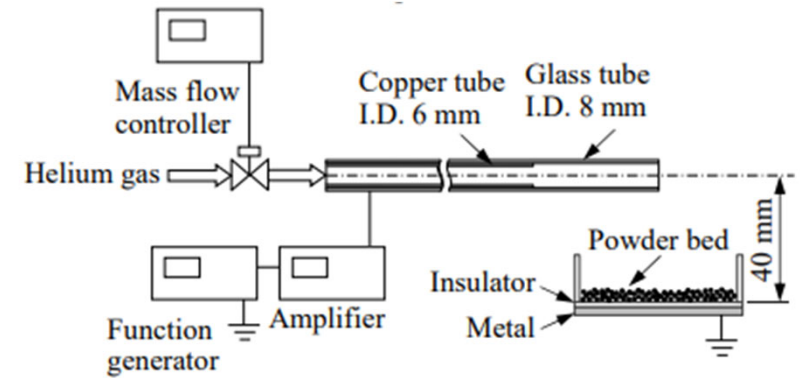
電子・イオン付着による帯電

針電極



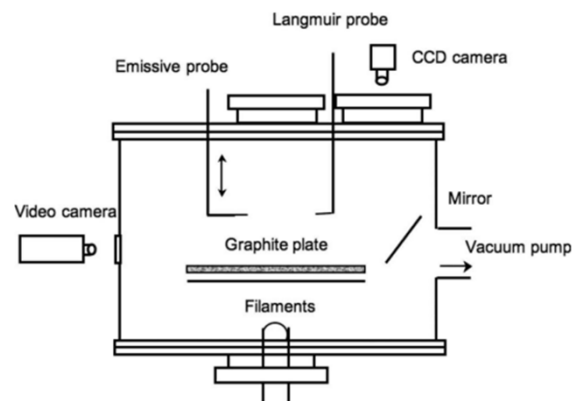
Dascalescu L. et al. IEEE T. Ind. Appl. 34 (1998) 35-42

プラズマジェット



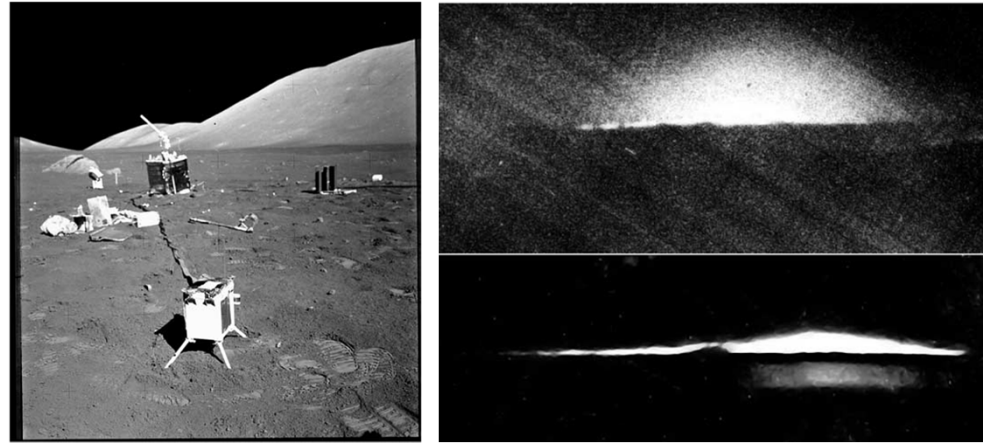
Matsusaka S. et al. Kagaku Kogaku Ronbun. 42 (2016) 137-141

熱電子放出

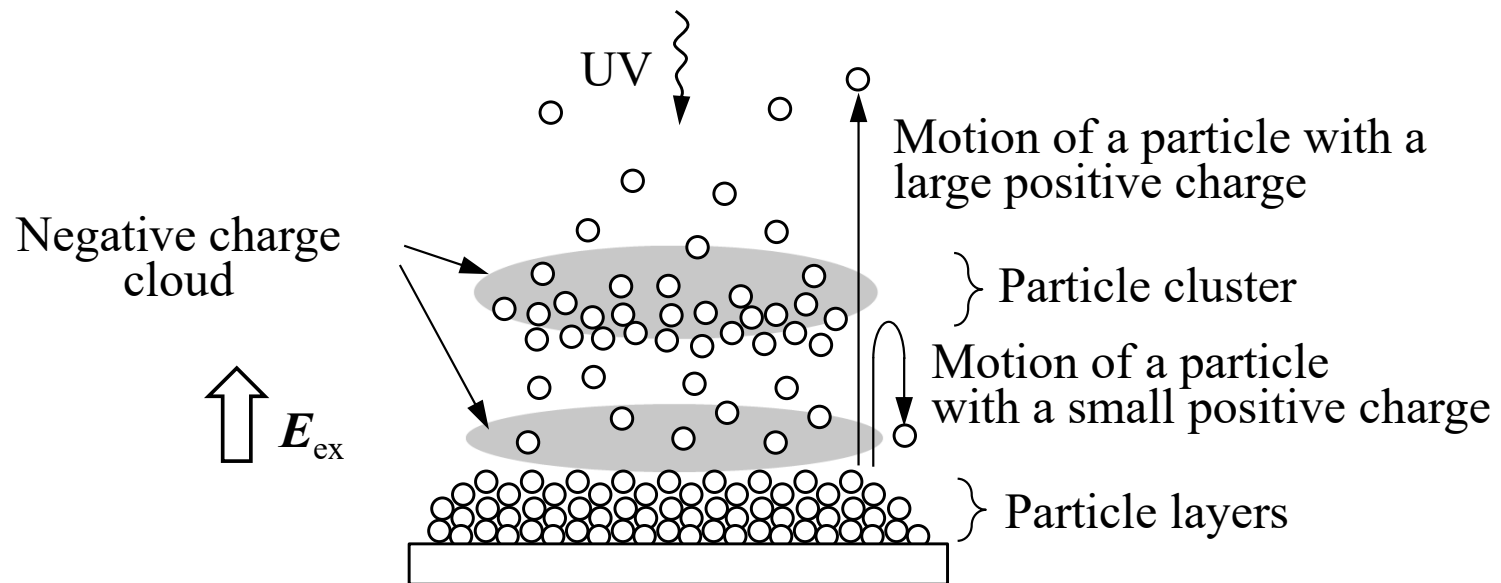


Colwell J. E. et al., J. Aerosp. Eng. 22 (2009) 2-9

電子・イオン放出による帯電

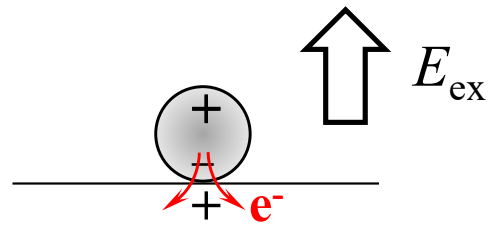


Colwell J. E. et al., J. Aerosp. Eng. 22 (2009) 2-9

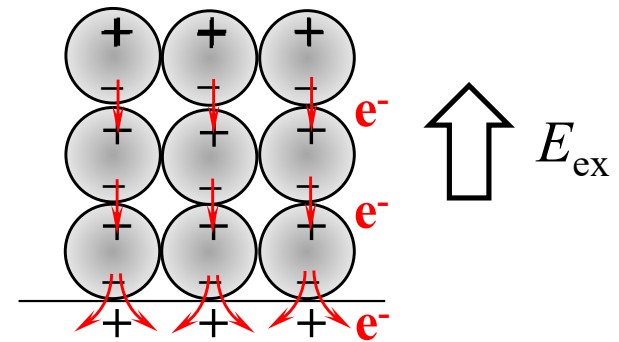


誘導帯電

単一粒子

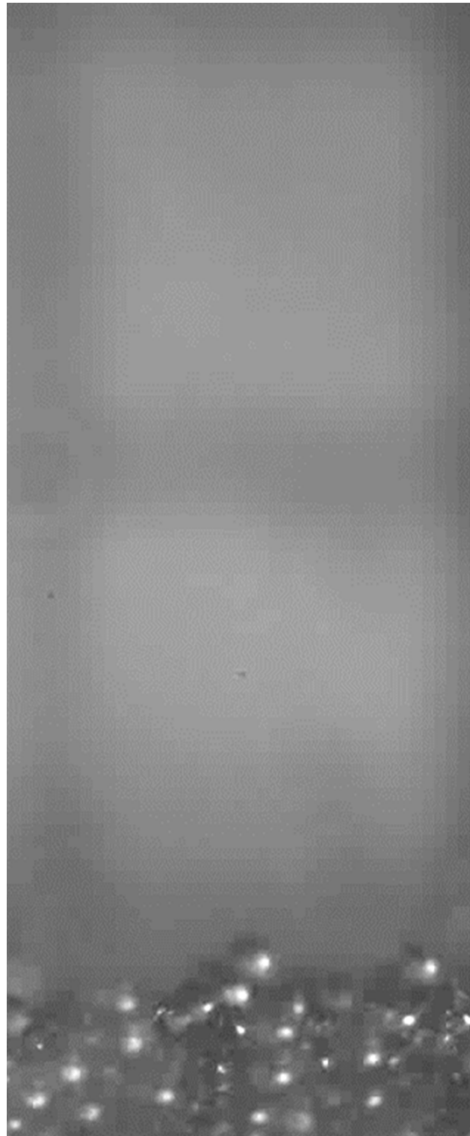


粒子層

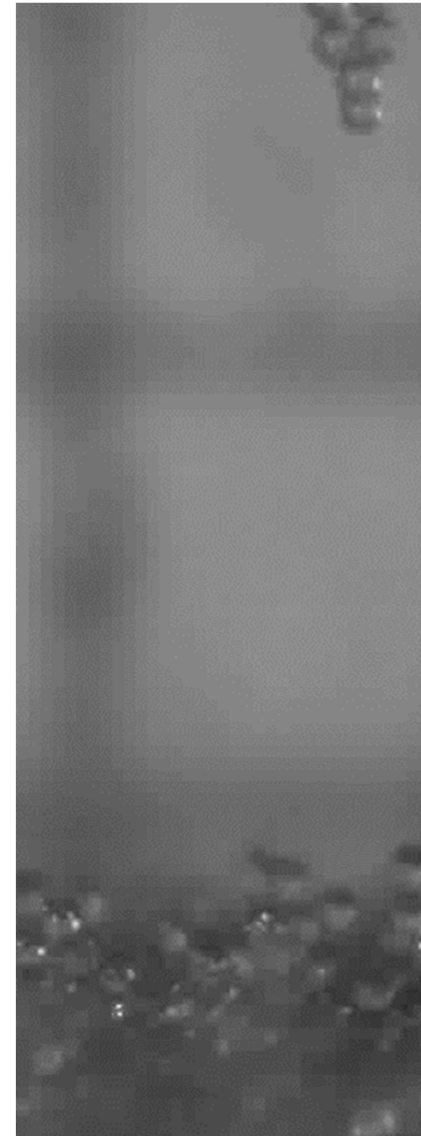


粒子は電極と同極性に帯電

誘導帯電（一様電場中）



一次粒子



凝集粒子