Magnetized Dusty Plasma Thoughts

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Outline

I. Plasma production
II. Particles
III. Diagnostics
IV. Physics experiments
V. Lab safety

I. Plasma production

- YES: RF discharge is great. Large negative axial plasma potential (≈100 V) confines dust.
- YES: "Anodic discharge", also large negative radial plasma potential, helps confine with horizontal B
- NO: hot filament discharge.
  Magnetic field prevents entry of electrons from filaments at the edge.
- NOVEL: Deuterium UV lamps photoionize NO gas. Commercial lamps may not work in B field.

IIa. Novel particles?

- Glass microballoons
  have 1-2 micron wall thickness, do <u>not</u> improve q/m ratio below about 5 microns
- Buckyballs, m = 720 amu
  Experiments done already in a Q machine
- Commerical nanoparticles
- In situ nanoparticles

IIb. Nanoparticles grown *in situ*

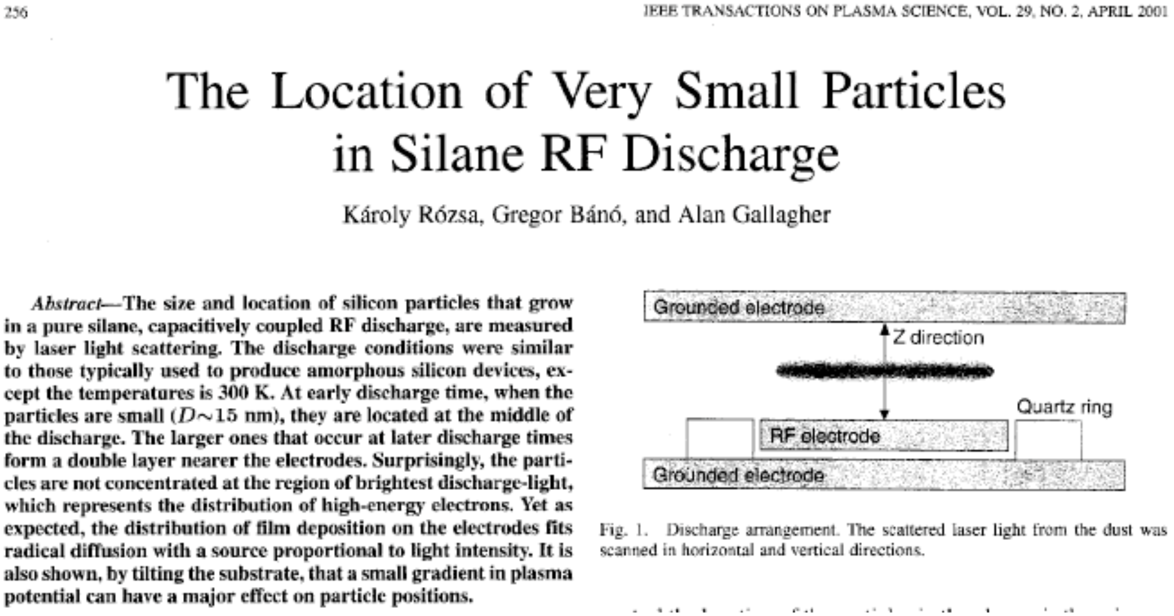
- Method 1: tungsten boat + 5 Torr gas pressure
- Method 2: rf discharge in SiH_4
- Photochemical haze or smog
- Problems

  Broad distribution in size

  So hard to see

III. Diagnostics

Laser scattering works to 10 nm dia.
with PMT detector and 1 W Ar laser



256 IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 29, NO. 2, APRIL 2001

The Location of Very Small Particles in Silane RF Discharge

Károly Rózsa, Gregor Bánó, and Alan Gallagher

Abstract—**The size and location of silicon particles that grow in a pure silane, capacitively coupled RF discharge, are measured by laser light scattering. The discharge conditions were similar to those typically used to produce amorphous silicon devices, except the temperatures is 300 K. At early discharge time, when the particles are small ($D\sim15$ nm), they are located at the middle of the discharge. The larger ones that occur at later discharge times form a double layer nearer the electrodes. Surprisingly, the particles are not concentrated at the region of brightest discharge-light, which represents the distribution of high-energy electrons. Yet as expected, the distribution of film deposition on the electrodes fits radical diffusion with a source proportional to light intensity. It is also shown, by tilting the substrate, that a small gradient in plasma potential can have a major effect on particle positions.**

Fig. 1. Discharge arrangement. The scattered laser light from the dust was scanned in horizontal and vertical directions.

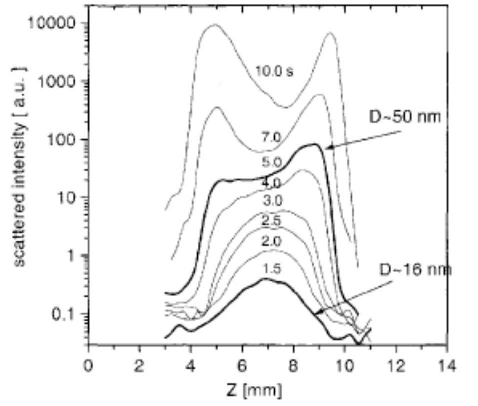
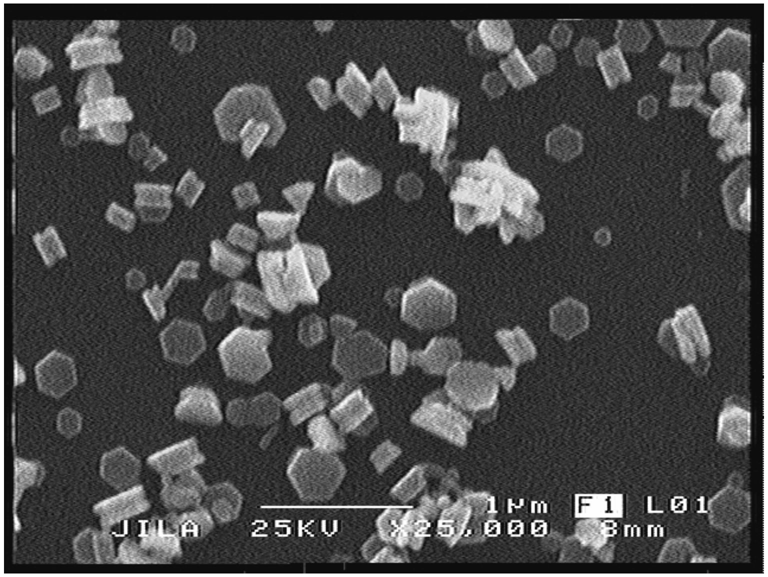


Fig. 2. Vertical distribution of the scattered light from the dust developed between 1.5- and 10.0-s discharge. The 1.5-s discharge represents ~16-nm diameter particles, and the particle size is growing near-linearity in time.

CCD detector has made $\leq$80 nm smoke visible

problem: Mie scattering scales as r^6

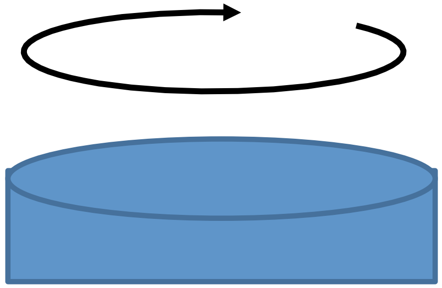


An argon ion laser (7-80 milliwatts at 488 nm) is used to illuminate the vacuum chamber directly above the oven. A CCD camera (Meade Deep Space Imager) is used to take long exposure photographs (typically 0.5 sec). The smoke is seen in forward scattered light at 10 degrees from the beam. A 488 nm filter is used in front of the camera to block the oven light, but is not necessary.

Reference:
Scott Robertson, Gregor Bano, Ward Handley, and Xu Wang, Poster at Dallas APS meeting, Nov. 2008.

IVa. Physics ideas – vertical B field

- <u>Confusing issue</u>
  Radial E makes azimuthal E x B ion drift,
  ions push dust particles around
  Perhaps no radial E
  with strong enough B,
  truly one dimensional.



IVb. Physics ideas – horizontal field

Macroscopic particles = bad idea, they fall.

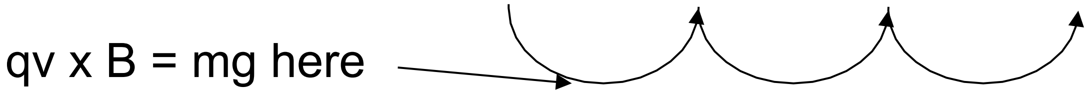
Case I – no strong radial E field

For 1 micron radius particles charged to 1 volt:

Q = 700e, Cyclotron period 10^5 s

Hop distance = $2\pi g/\Omega^2 = 10^{10}$ meters

Velocity at which $qv \times B = mg$ is $v = 2 \times 10^5$ m/s



What particle radius would be OK in gravity?

Solve for mass where hop distance d = 1 cm

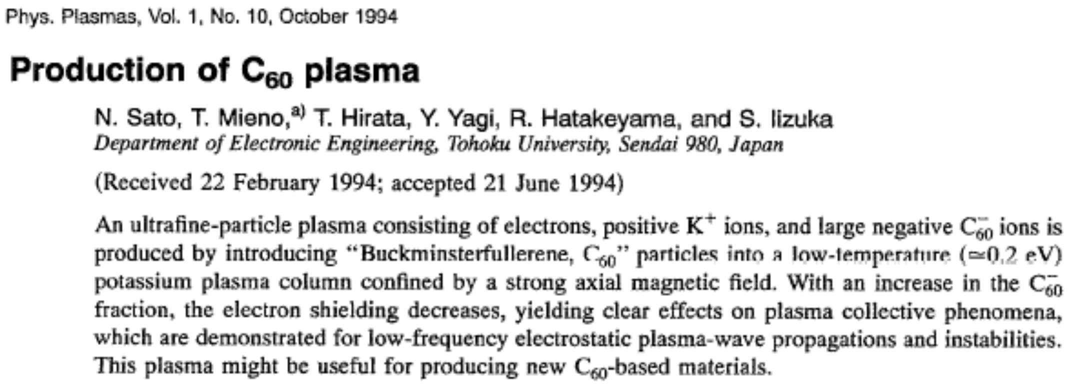
M_{ok} = 10^{-20} kg, $radius_{ok}$ = 10 nm

C_{60} has diameter 0.7 nm

Example of succesful magnetized dusty plasma

with B horizontal

$$M_{ok} := \sqrt{\frac{d \cdot q^{2} \cdot B^{2}}{2 \cdot \pi \cdot g}}$$



Phys. Plasmas, Vol. 1, No. 10, October 1994

Production of C_{60} plasma

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(Received 22 February 1994; accepted 21 June 1994)

An ultrafine-particle plasma consisting of electrons, positive K^+ ions, and large negative C_{60}^- ions is produced by introducing "Buckminsterfullerene, C_{60}" particles into a low-temperature (≃0.2 eV) potassium plasma column confined by a strong axial magnetic field. With an increase in the C_{60}^- fraction, the electron shielding decreases, yielding clear effects on plasma collective phenomena, which are demonstrated for low-frequency electrostatic plasma-wave propagations and instabilities. This plasma might be useful for producing new C_{60}-based materials.

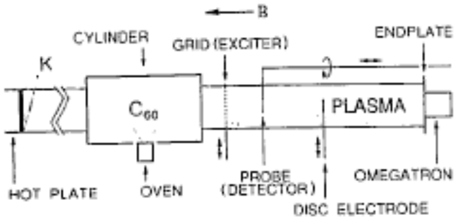

FIG. 1. Experimental apparatus.

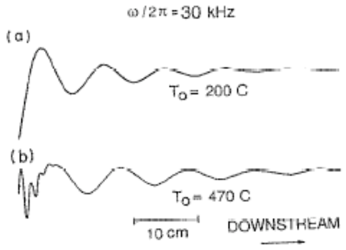

FIG. 7. Wave patterns of ion waves with frequency ω/2π=30 kHz at (a) T_0=200 °C and (b) T_0=470 °C.

IVc. Physics ideas – horizontal field anodic plasma & strong radial E

Numbers from Trottenberg et al., PoP 13, 042105, 2006.

Particle radius = 1 μm

$qE = 10^{-13}$ N

$Mg = 10^{-14}$ N

Assume $v = 10$ mm/s $= 0.01$ m/s

$Q = 3000\ e$

$Qv \times B = 2 \times 10^{-17}$ N

V. Lab Safety

- Safety rules same as for hospital NMR facilities
- Dangerous to have iron tools
- Dangerous to persons with metal pins in bones, army knife, keys, jewelry, etc.
- Metal detector for entry
- B may cause destruction of turbo pumps
- Alarm and personnel auto dialer for low helium

Questions?
Comments?