• Thermophoresis

Small particles suspended in a gas having temperature gradient move from high temp. region to low temp. region.

- Example: dust free zone near heated object (ppt file)
  - Kerosine Lantern
  - Cigarette smoke
  - Fabrication of Optical fiber (ppt file)

Theory (Kn>>1 , free molecular regime)

rough analysis

$(\frac{1}{6} n_1 \bar{c}_1) \frac{\pi}{4} d^2 m \bar{c}_1$ momentum imparted to the right-hand side of the particle

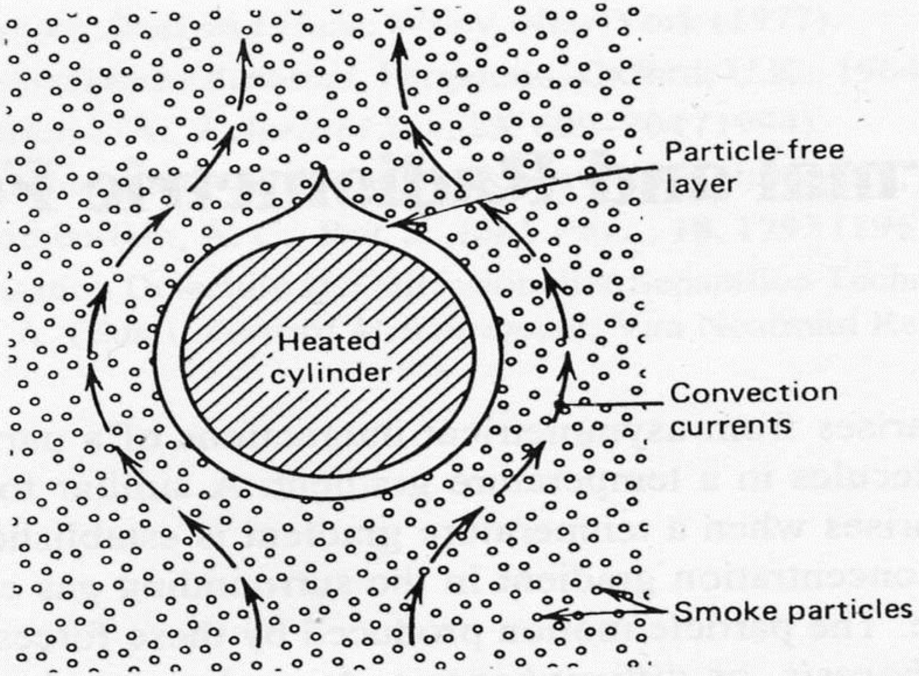


FIGURE 8.1 Dust-free space around a heated cylinder.

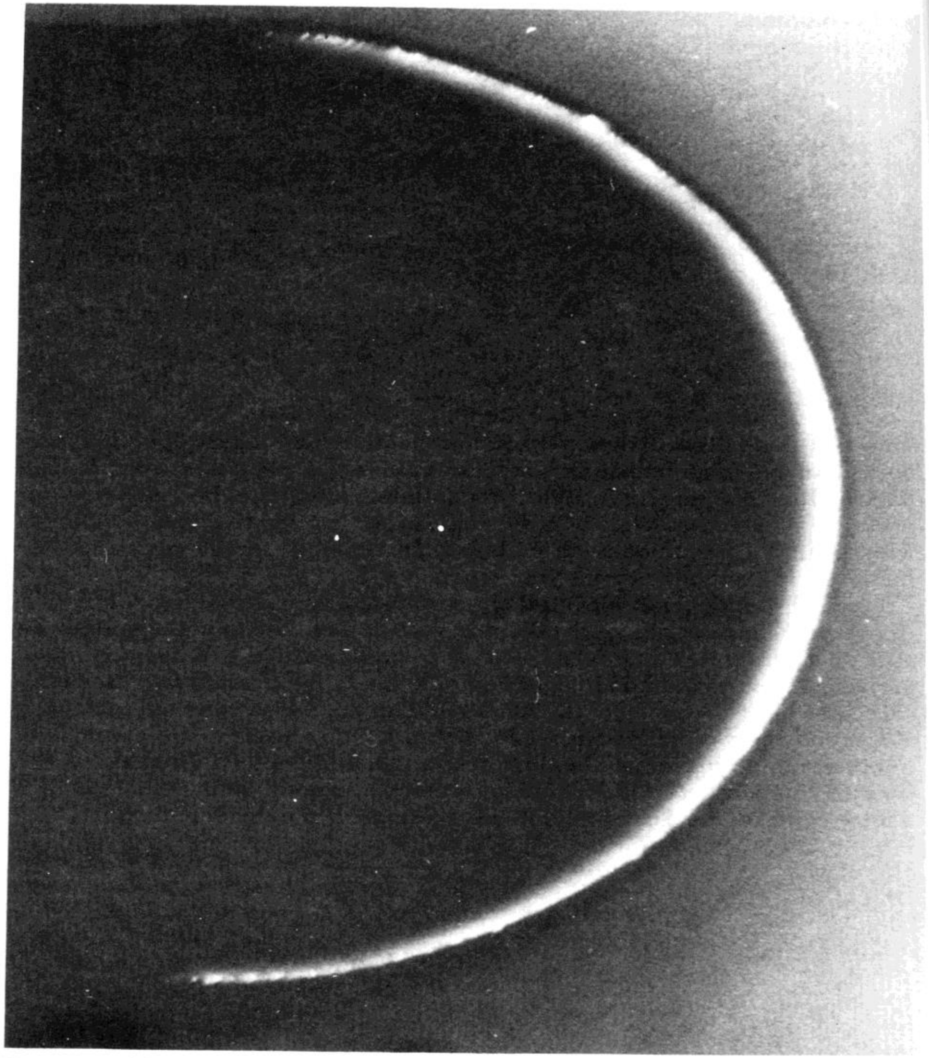


Figure 11.2 Photograph of the dark space surrounding a heated brass rod.

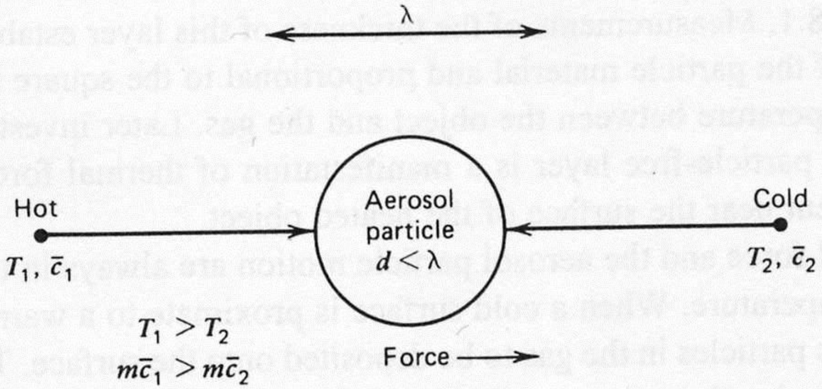


FIGURE 8.2 Molecular impacts on a particle ($d < \lambda$) in a temperature gradient.

$(\frac{1}{6}n_2\bar{c}_2)\frac{\pi}{4}d^2m\bar{c}_2$: to the left hand side

→ net change of momentum per unit time

$$=-\frac{1}{3}(\frac{\pi}{4}d^2)(\frac{n_1m\overline{c_1^2}}{2}-\frac{n_2m\overline{c_2^2}}{2})$$

$$n_1\sim n_2\sim n$$

$$F_T=-(\frac{n}{3})(\frac{\pi}{4}d^2)(\frac{1}{2}m\overline{c_1^2}-\frac{1}{2}m\overline{c_2^2})$$

$\frac{1}{2}m\overline{c^2}=\frac{3}{2}kT$ (Einstein)

$$F_T=-\frac{n\pi d^2}{4}k(\frac{T_1-T_2}{2\lambda})\lambda$$

$$\frac{T_1 - T_2}{2\lambda} = \nabla T \qquad nk = P/T$$

$$\therefore F_T = -\frac{\pi}{4} d^2 P\lambda \frac{\nabla T}{T} = fC_t = fV_{th}$$

C_t : Thermophoretic velocity

(i) K_n>>1 즉 d<λ

Kinetic theory

$$V_{th} = -\frac{3v\nabla T}{4(1+\frac{\pi\alpha}{8})T} = -0.55v\frac{\nabla T}{T} \quad \rightarrow \textbf{(8-2)}$$

(Waldmann & Schmitt (1966))
α : 0.9 : accommodation coefficient

* independent of particle size

(ii) d>λ : temperature gradient in the particle
→ affects gas field
(thermal conductivity of particle also influences thermophoresis)

$$F_{th} = \frac{-9\pi\mu\nu\frac{d_p}{2}\nabla T}{T_0}H$$

$$H \cong \left(\frac{1}{6+6\,{}^{\lambda}\!/_{d_p}}\right)\left(\frac{{}^{k_a}\!/_{k_p}+4.4\,{}^{\lambda}\!/_{d_p}}{1+2\,{}^{k_a}\!/_{k_p}+8.8\,{}^{\lambda}\!/_{d_p}}\right)$$

$$V_{th} = -\frac{3}{2}\nu C_c H\frac{\nabla T}{T}$$

for d>λ

→ **depends on particle size and thermal conductivity**

comparison between gravity settling and thermophoresis

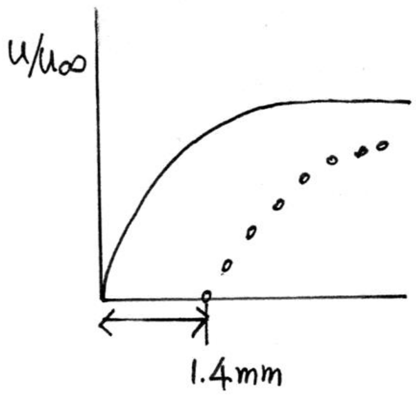
(100 K/m) at 293K

	$V_{terminal}$ (m/s)	V_{th} (m/s) → $k_p=10k_a$
0.01 μm	6.7×10^{-8}	2.8×10^{-6}
0.1	8.6×10^{-7}	2.0×10^{-6}
1.0	3.5×10^{-5}	1.3×10^{-6}
10.0	3.1×10^{-3}	7.8×10^{-7}

Talbot, Cheng, Schefer and Willis
J.F.M. vol. 101, pp. 737-758 (1980)

- LDV measurement of laminiar boundary layer flow over a heated flat plate

→ particle free zone



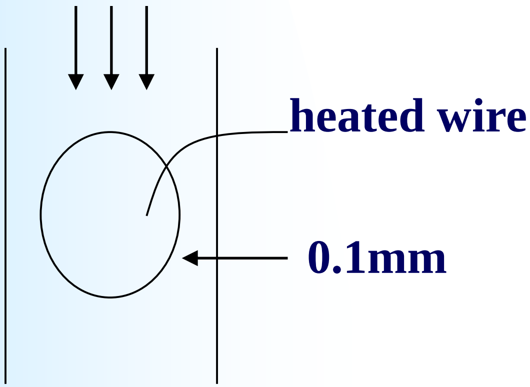
→ fitting formula covering entire image of Knudsen

$$V_{th} = -\frac{2\nu C_s\left(\frac{k_g}{k_p} + C_t\frac{\lambda}{R}\right)\left[1 + \frac{\lambda}{R}\left(A + Be^{-R/\lambda}\right)\right]\frac{\nabla T}{T}}{\left(1 + 3C_m\frac{\lambda}{R}\right)\left(1 + 2{k_g}/{k_p} + 2C_t\frac{\lambda}{R}\right)} \qquad \textbf{(2-56)}$$

$A=1.2$ $B= 0.41$

$C_t=2.18$ $C_s=1.17$ $C_m=1.14$

* Thermal precipitator



: collecting small quantity of particles for observation in optical & electron microscope

Optical fiber

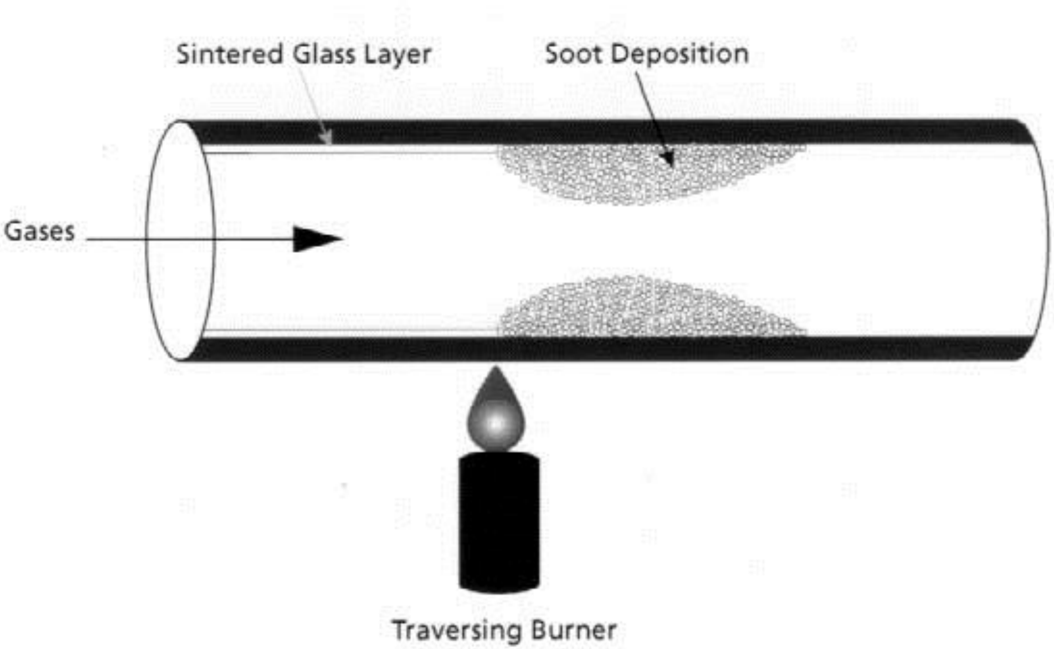
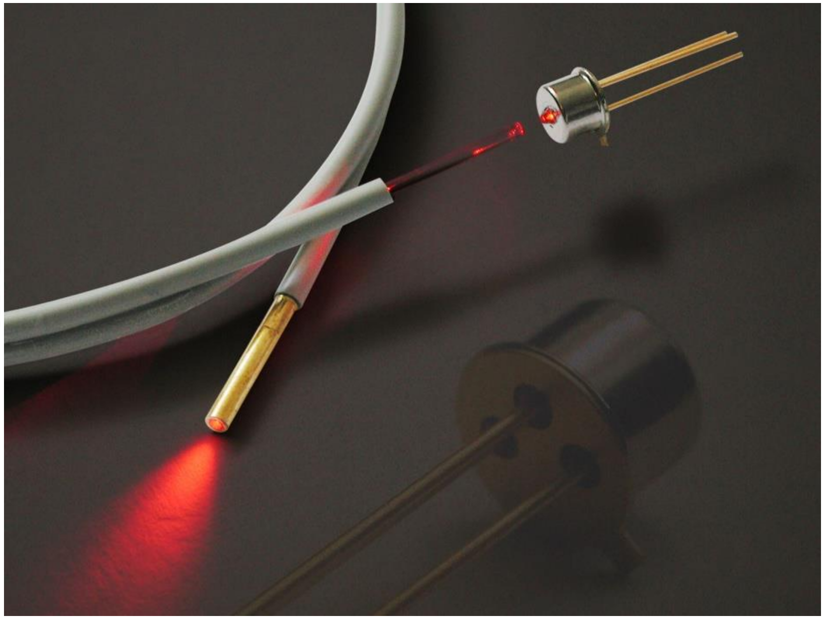
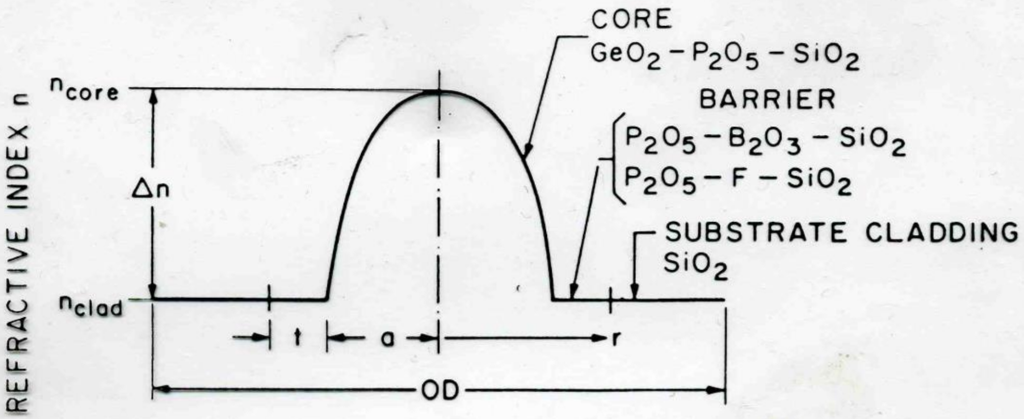


Figure 2 PREFORM FABRICATION

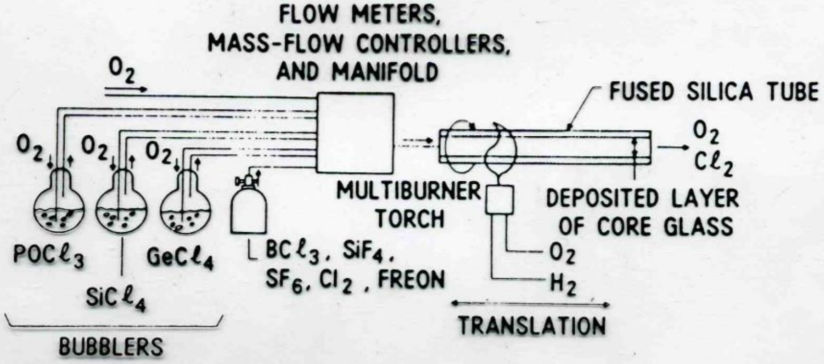


INTRODUCTION

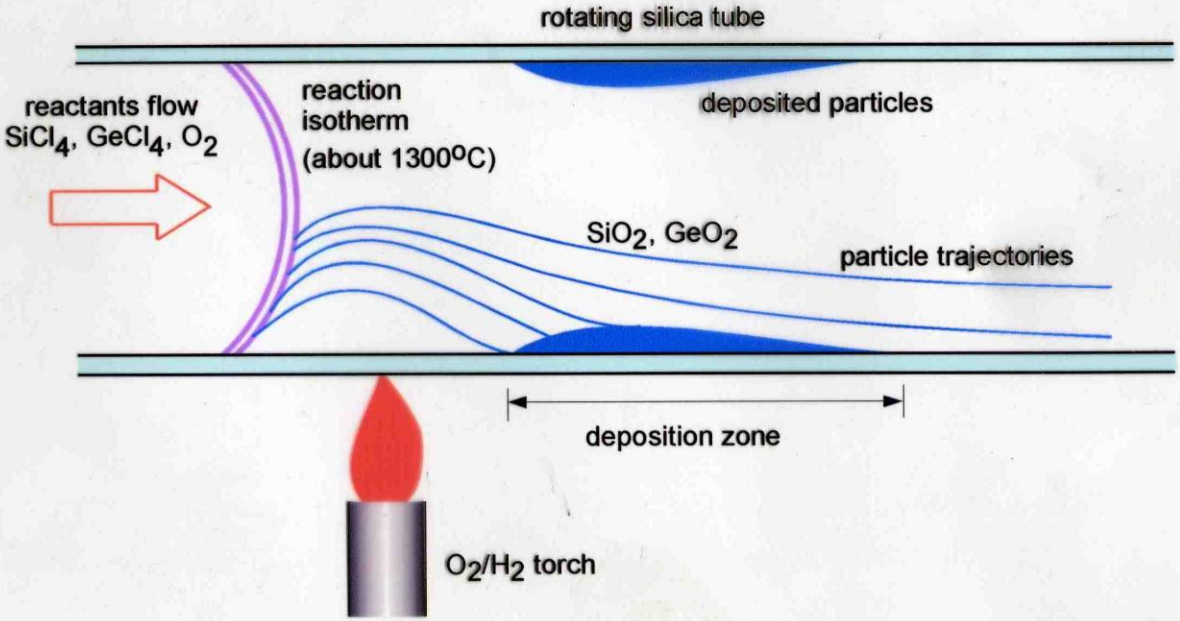
PROFILE OF REFRACTIVE INDEX



MODIFIED CHEMICAL VAPOR DEPOSITION PROCESS



MCVD deposition process



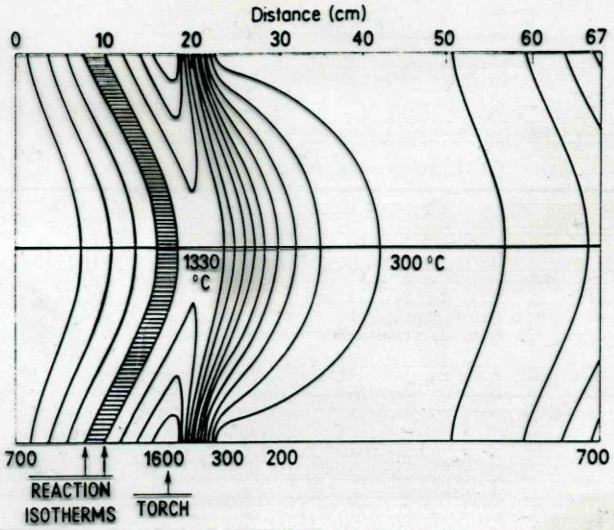


FIG. 5. Temperature field within an MCVD substrate tube relative to torch position.

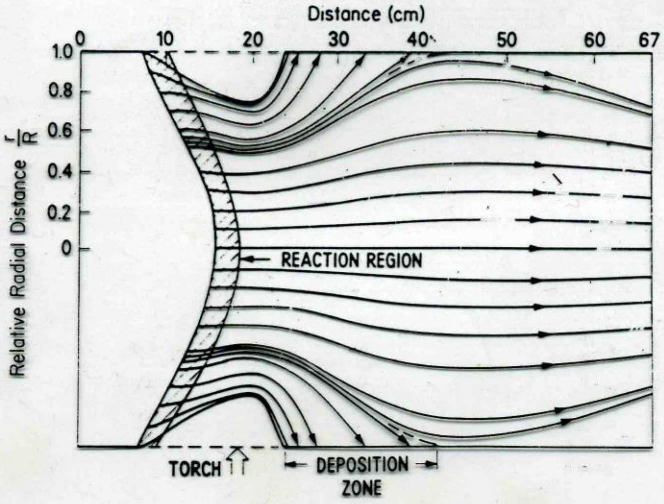
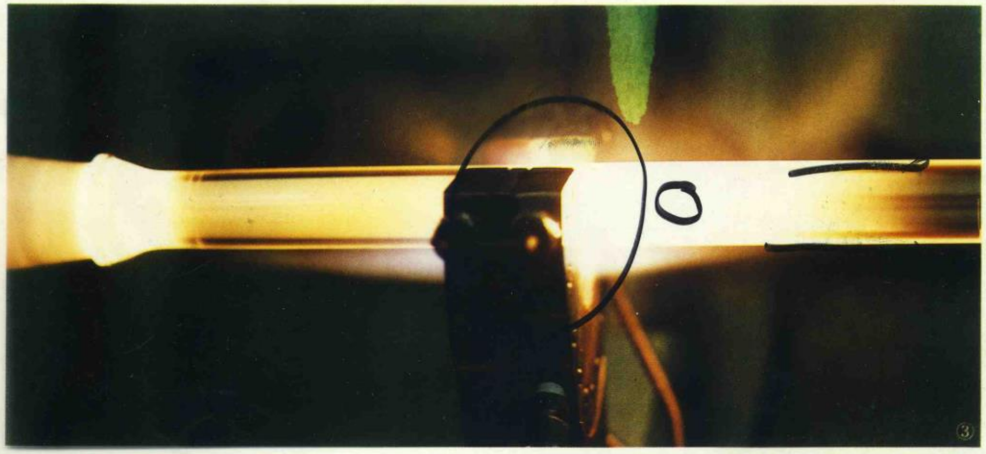


FIG. 6. Particle trajectories resulting from temperature field in Fig. 5.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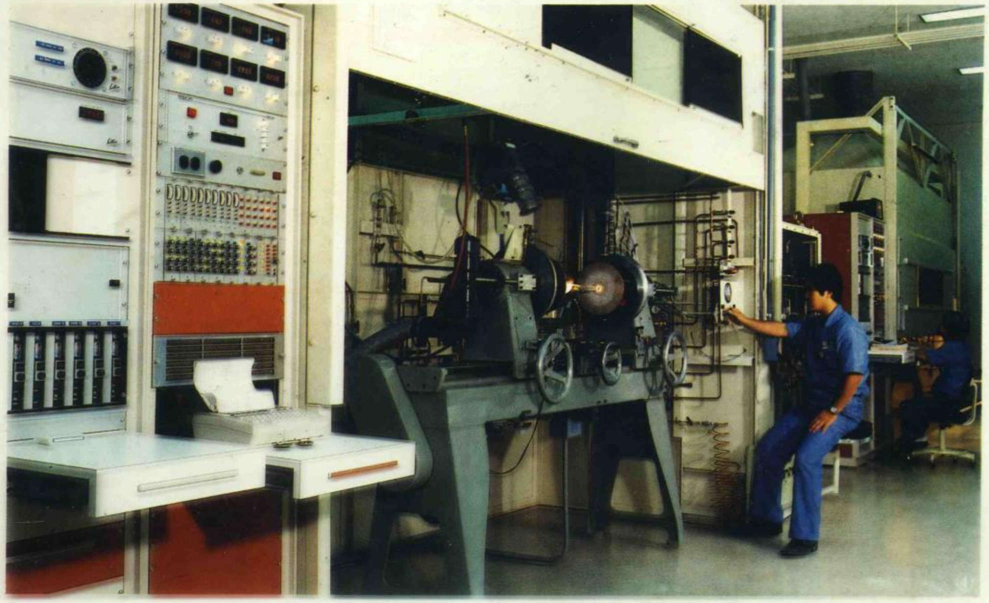
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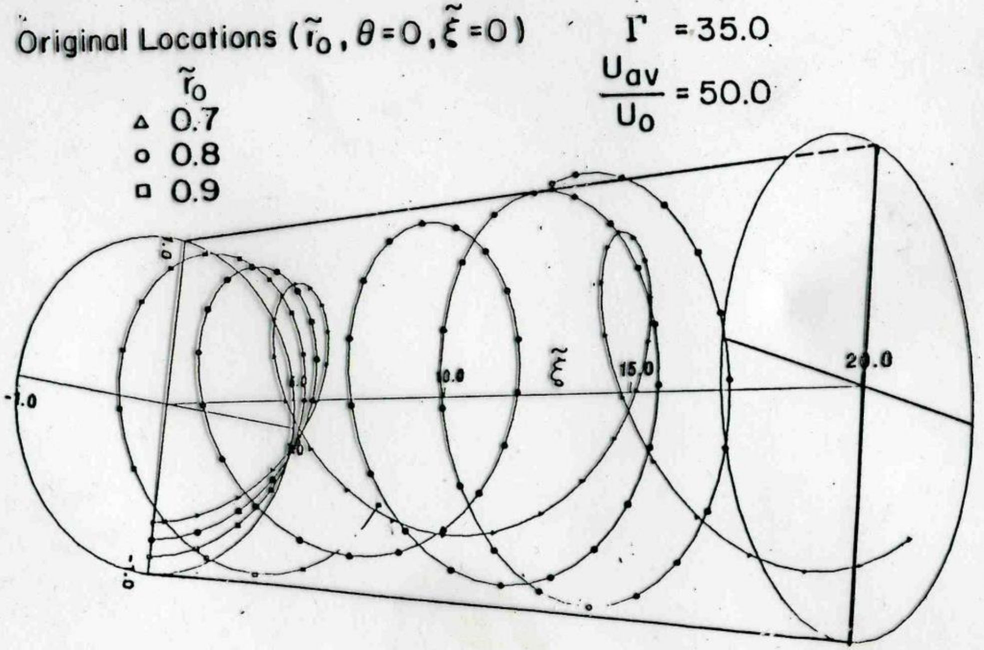
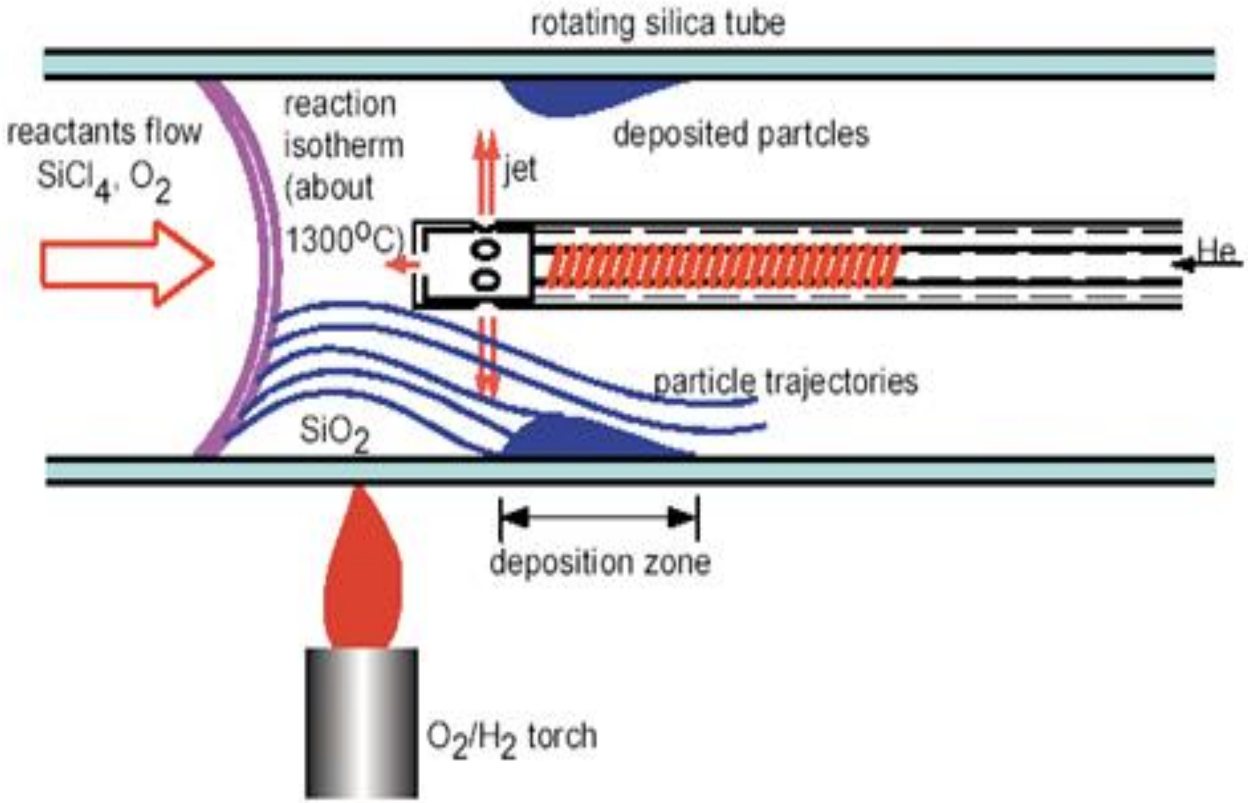


PARTICLE TRAJECTORIES; $\lambda = 0.5$, $Pe = 1.0$, $H_M = 3.0$

Jet assisted aerosol CVD method

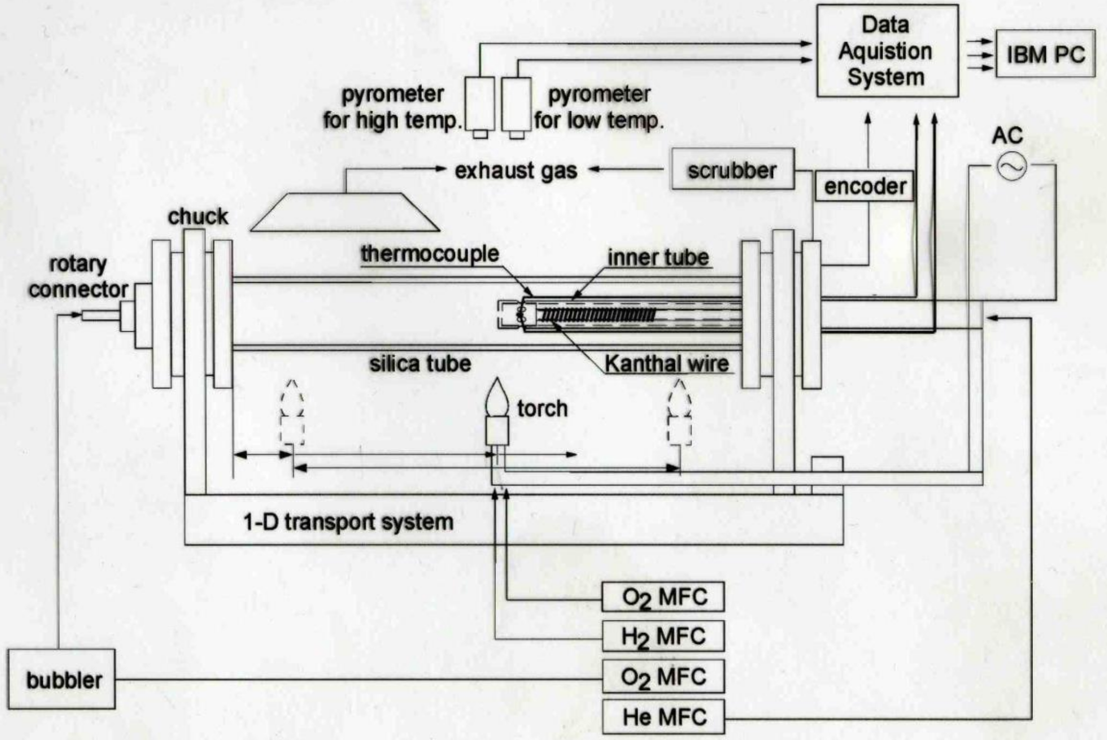
- Jet

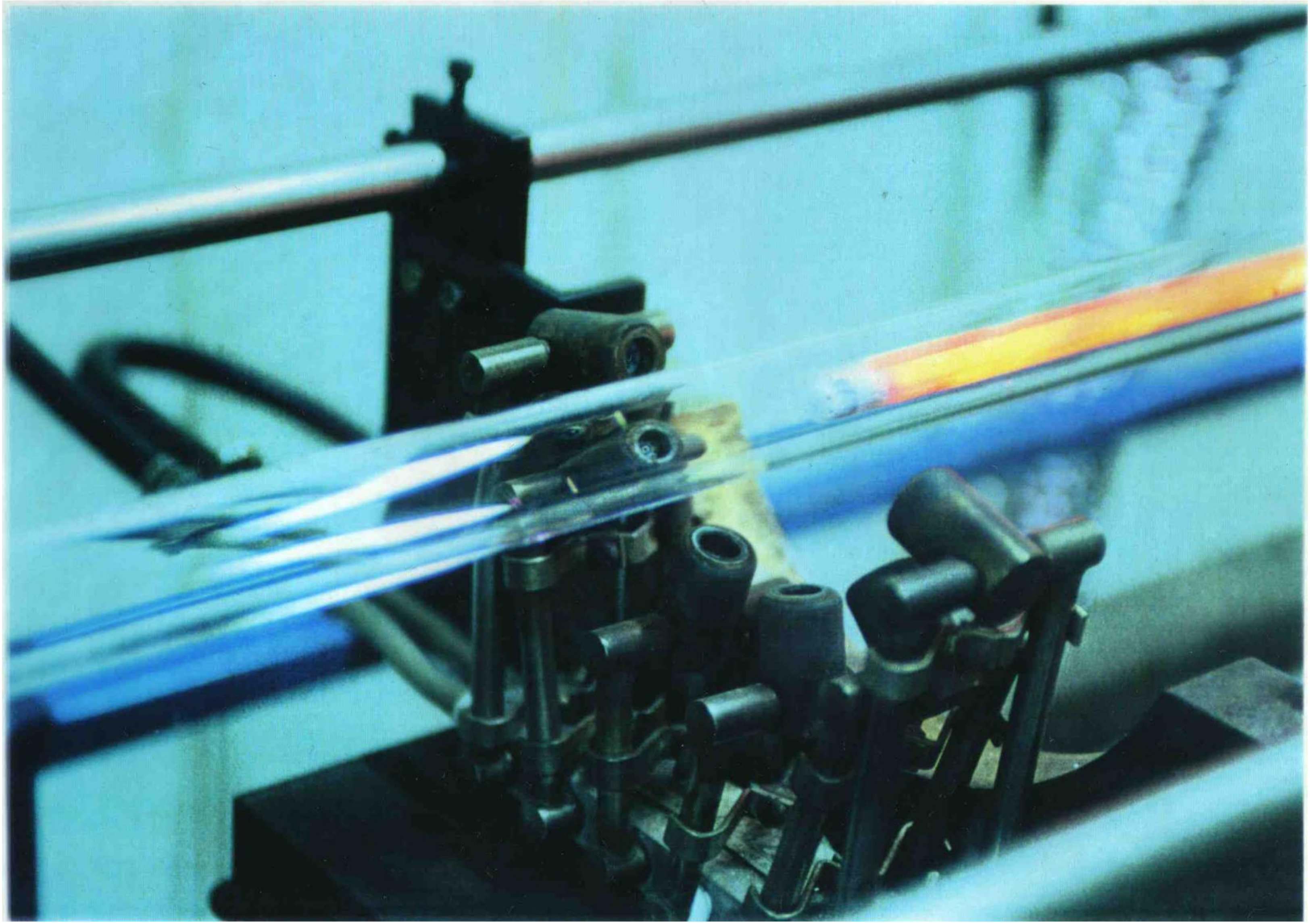


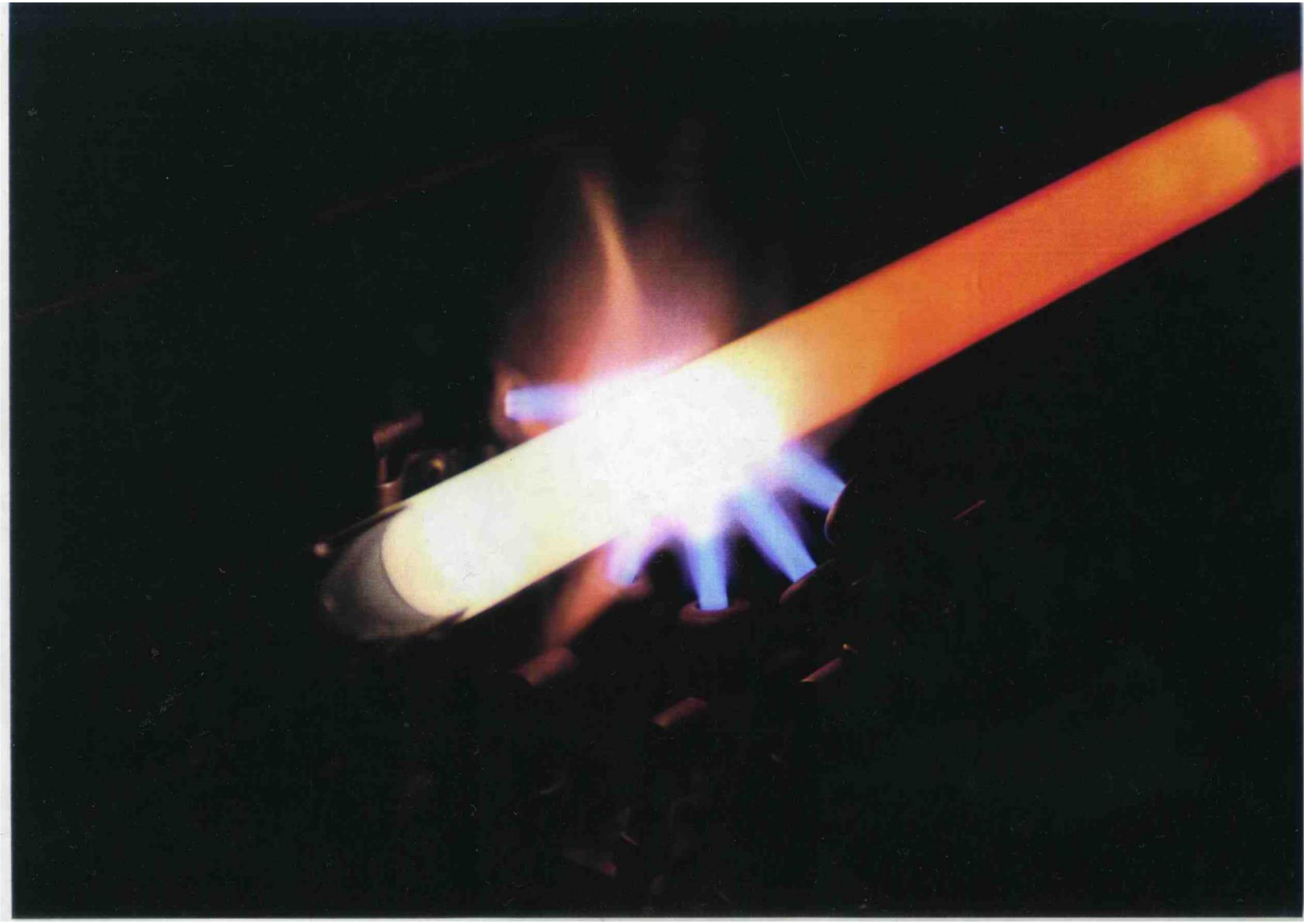
to simply insert the inner heated tube

← the propose of enhancing the efficiency, rate, and uniformity of particle deposition

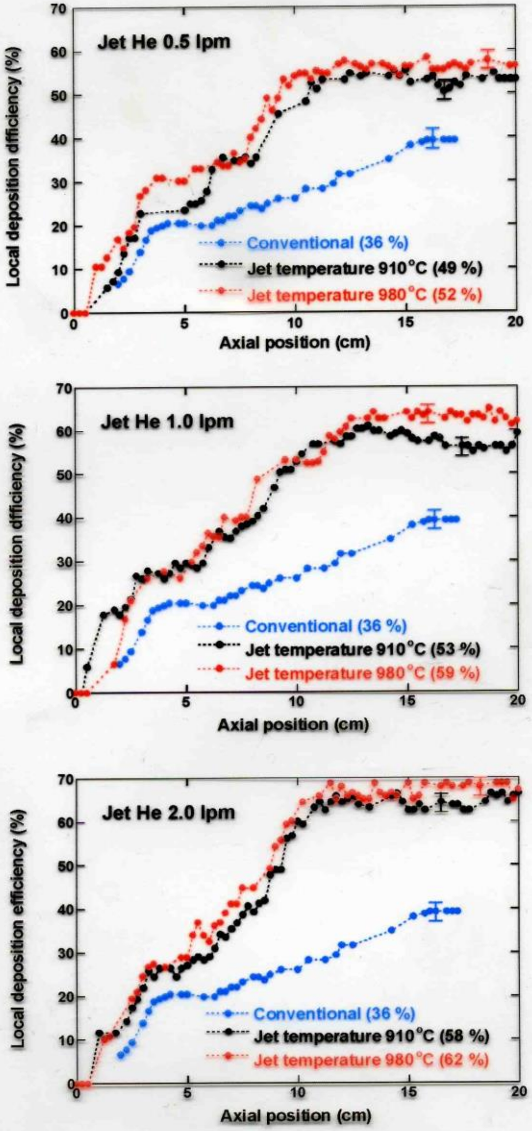
Experimental apparatus of Jet Assisted Aerosol CVD







Deposition Profile along the Axial Position



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