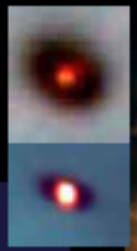
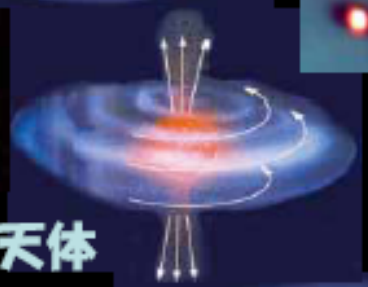
実験惑星学1：実験室で星間ダストを作る

- 原始太陽系形成過程のシミュレーション実験
- 凝縮（Condensation)と蒸発（Evaporation）
- 多成分系
- 非平衡コンドライトとの比較
- プラズマ、レーザーによる蒸発

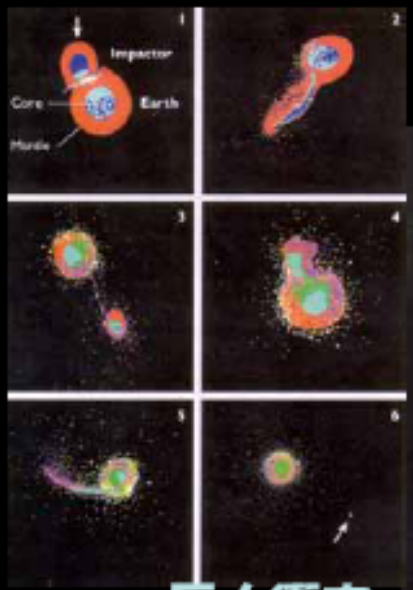
2012.9. 13

太陽系の起源と進化



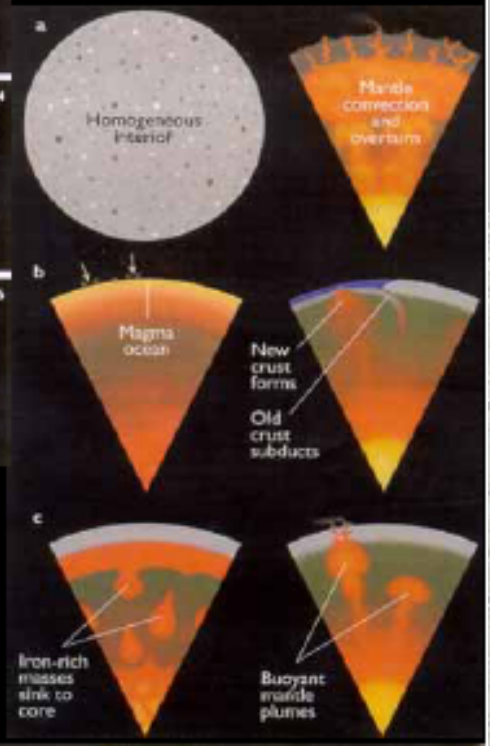


始原天体

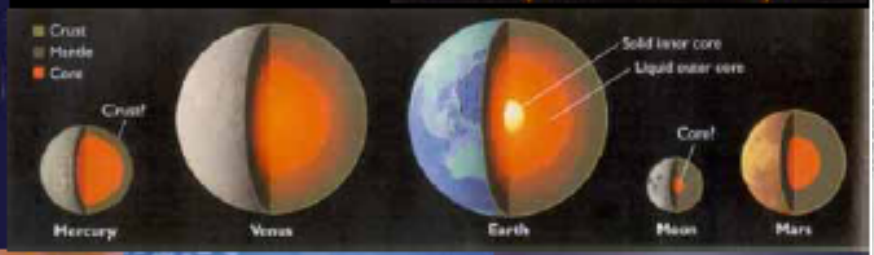


巨大衝突

内部構造進化



惑星大気

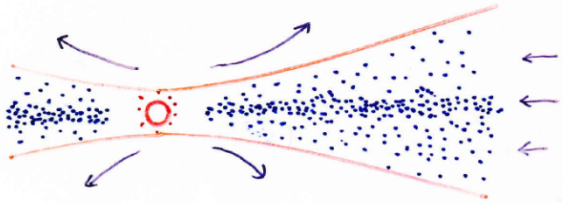


Solar System Evolution

(1) Protostar Formation

GMC T-Tauri

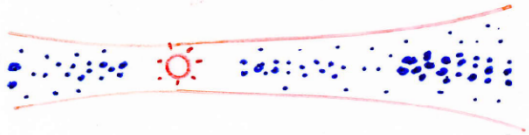
(2) Condensation & Sedimentation



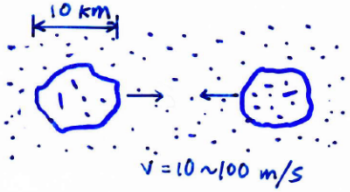
Condensation

Vaporization

(3) Gravitational Fragmentation

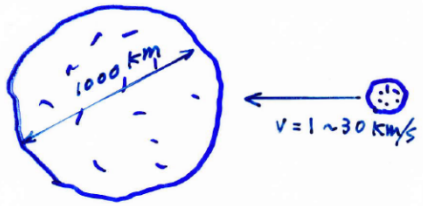


(4) Planetesimal Collision



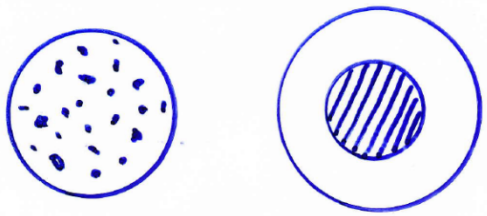
Accretion & Fragmentation

(5) Protoplanet - Planetesimal Collision



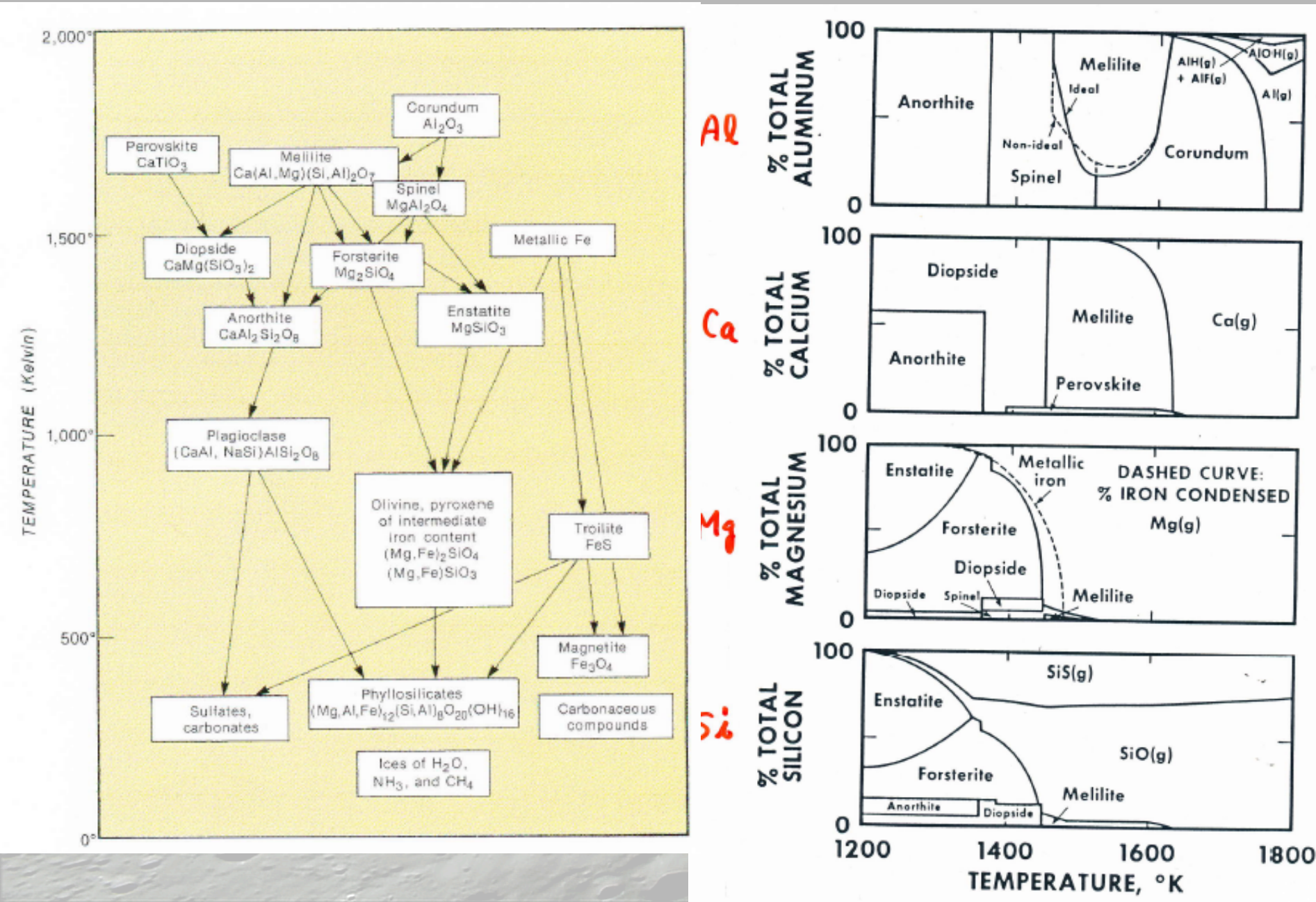
Accretion & Cratering

(6) Internal Evolution of Protoplanet



High P & T Phase Relation

Condensation Sequence from 10^{-3}atm Solar Abundance



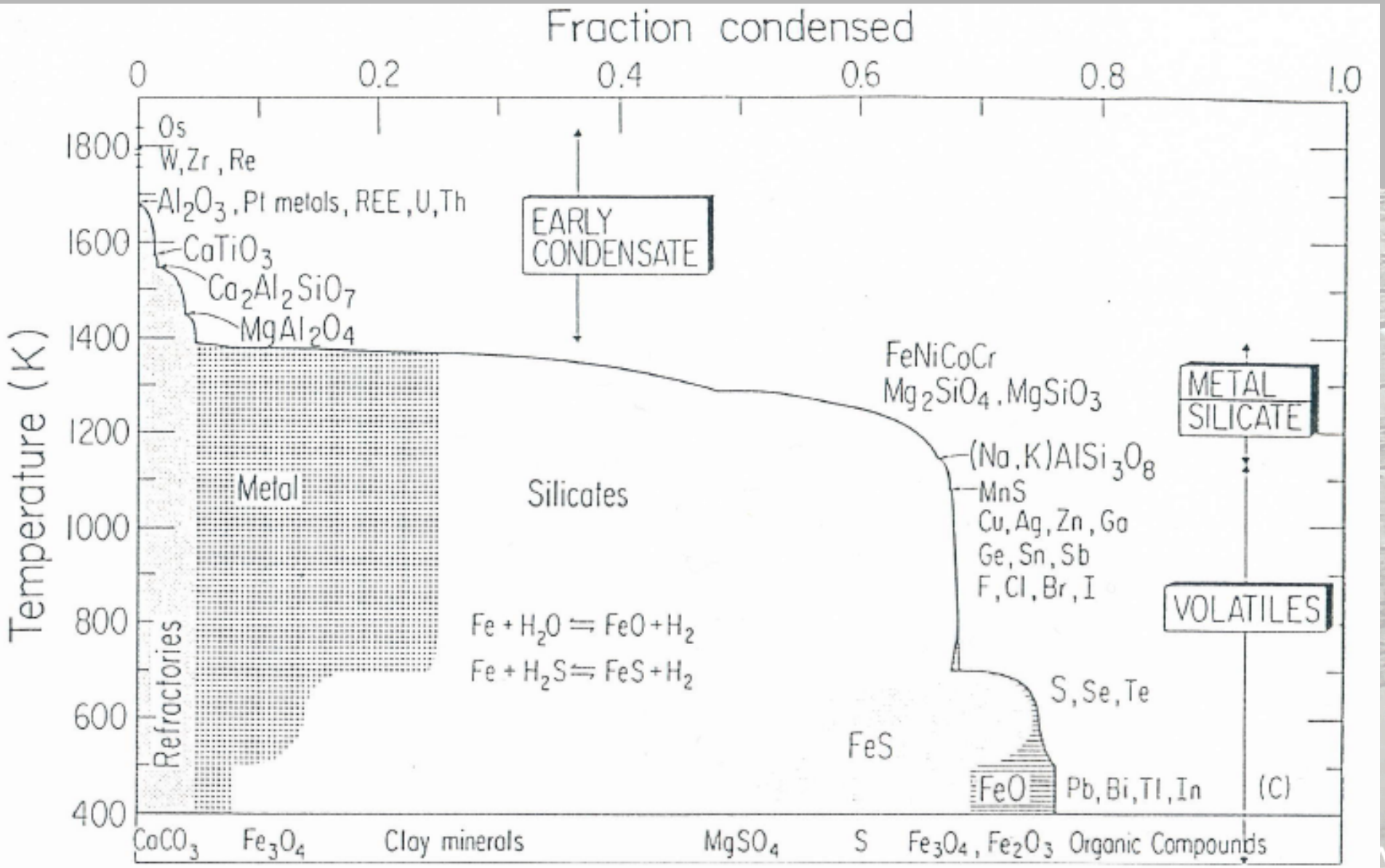
Al

Ca

Mg

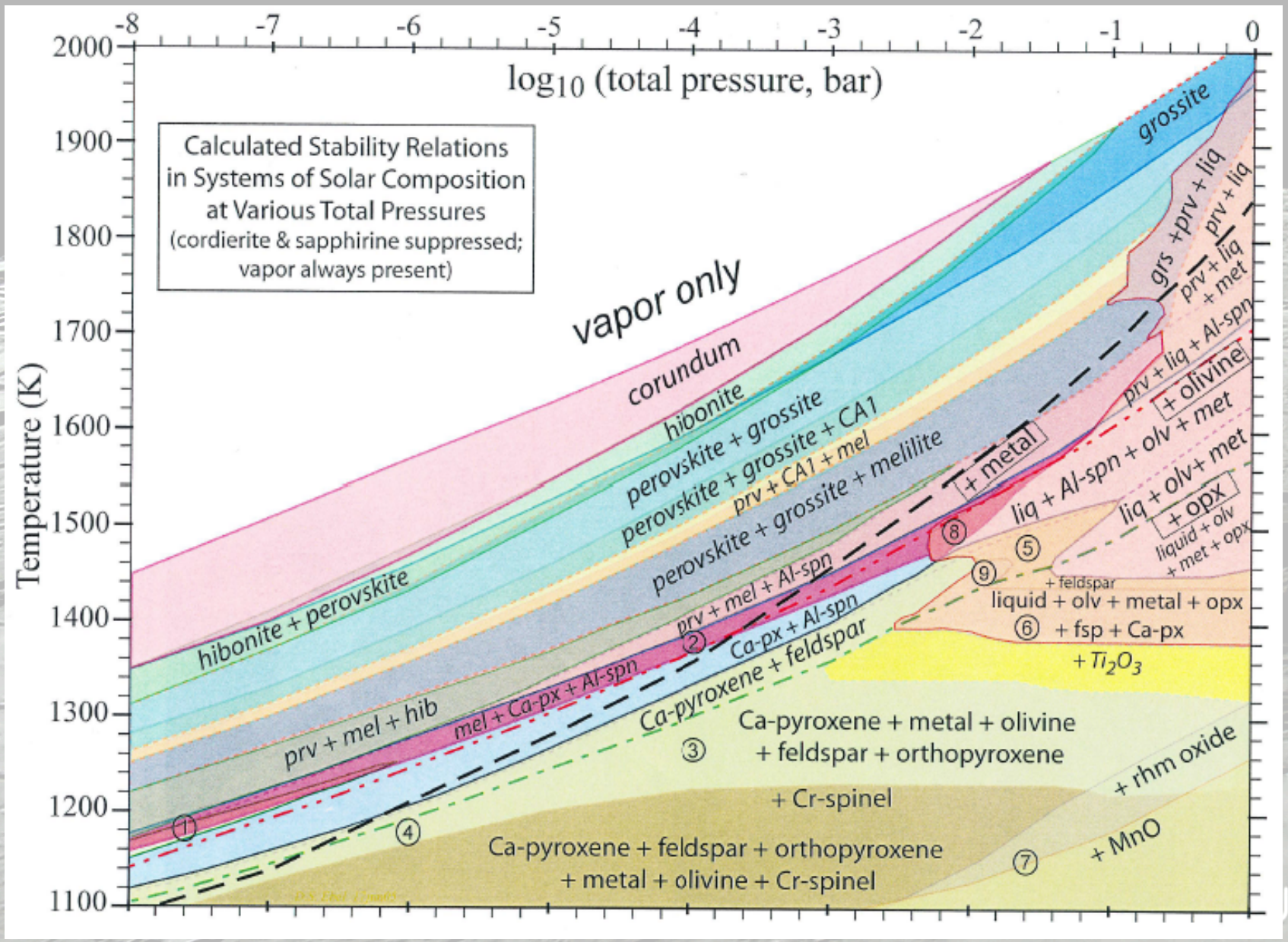
Si

Mineral Fractionation



P^{total}: 10^{-4}atm, Morgan & Anders (1980)

Stability of Condensed Phase in Solar Composition



Ebel, 2006

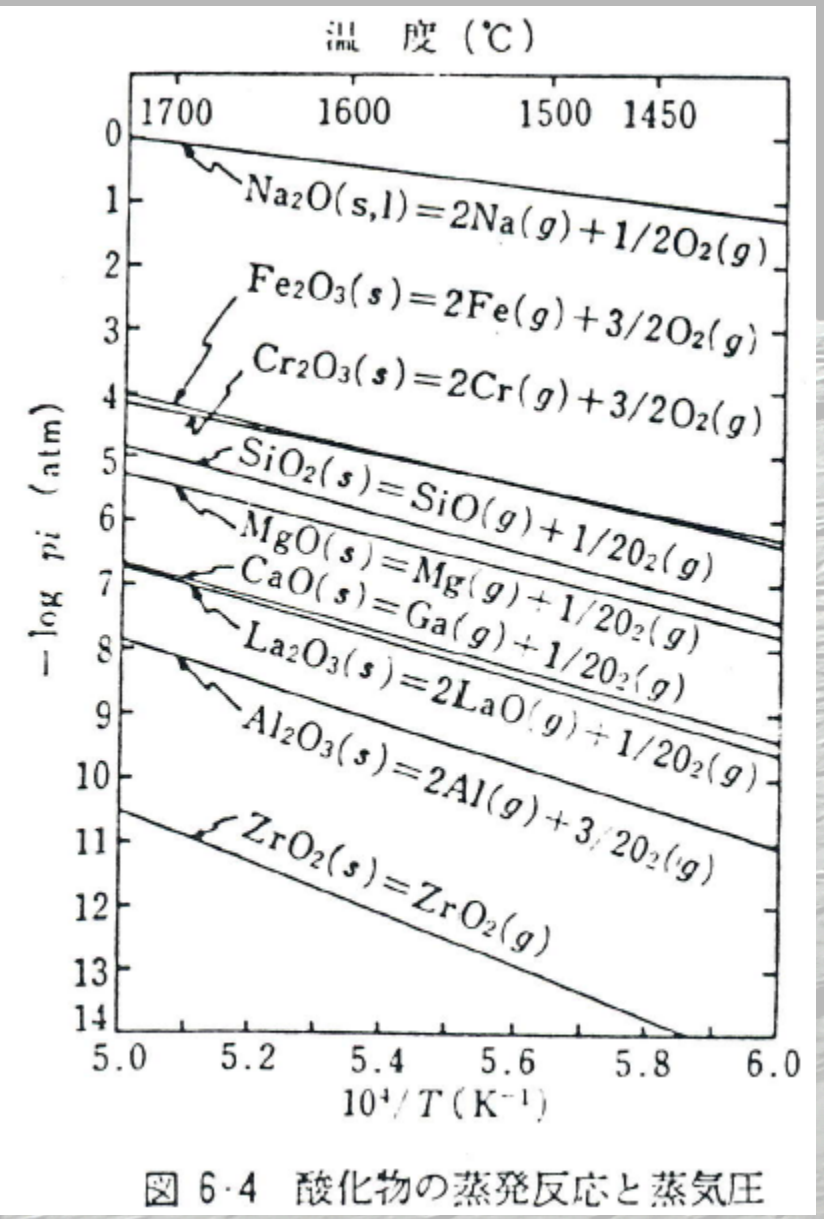
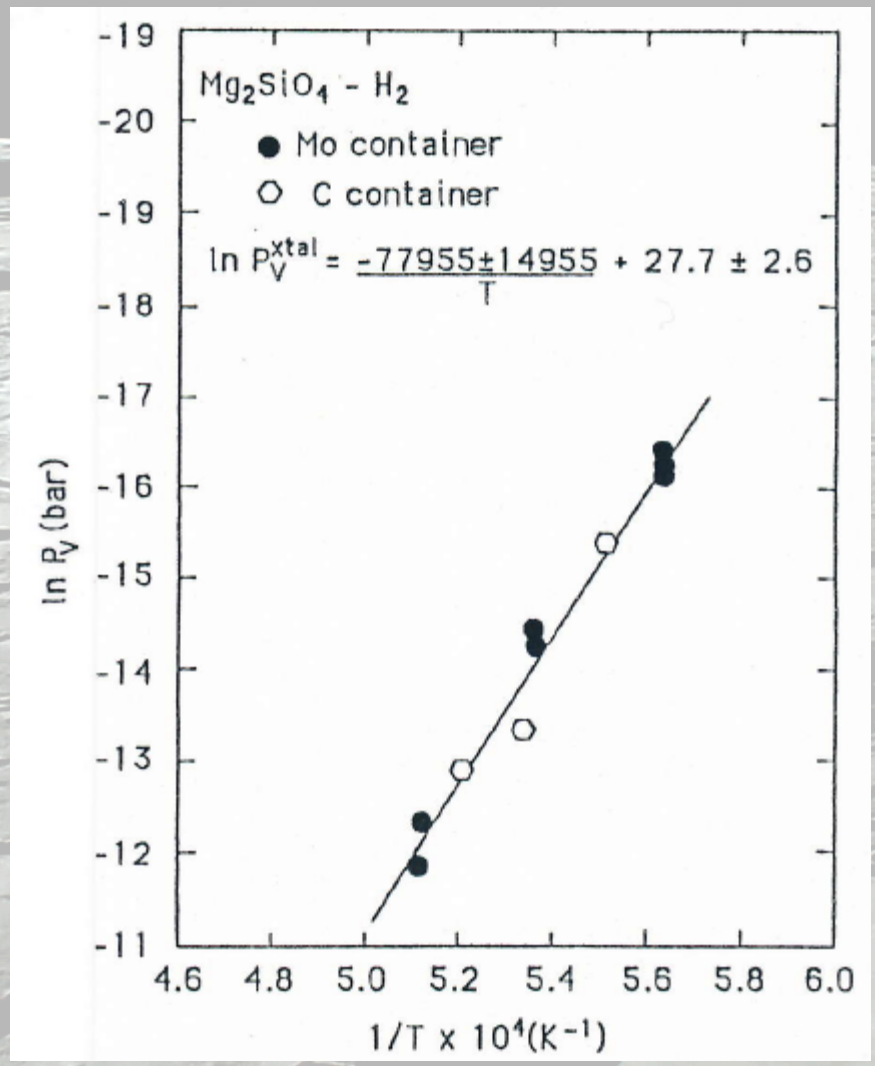
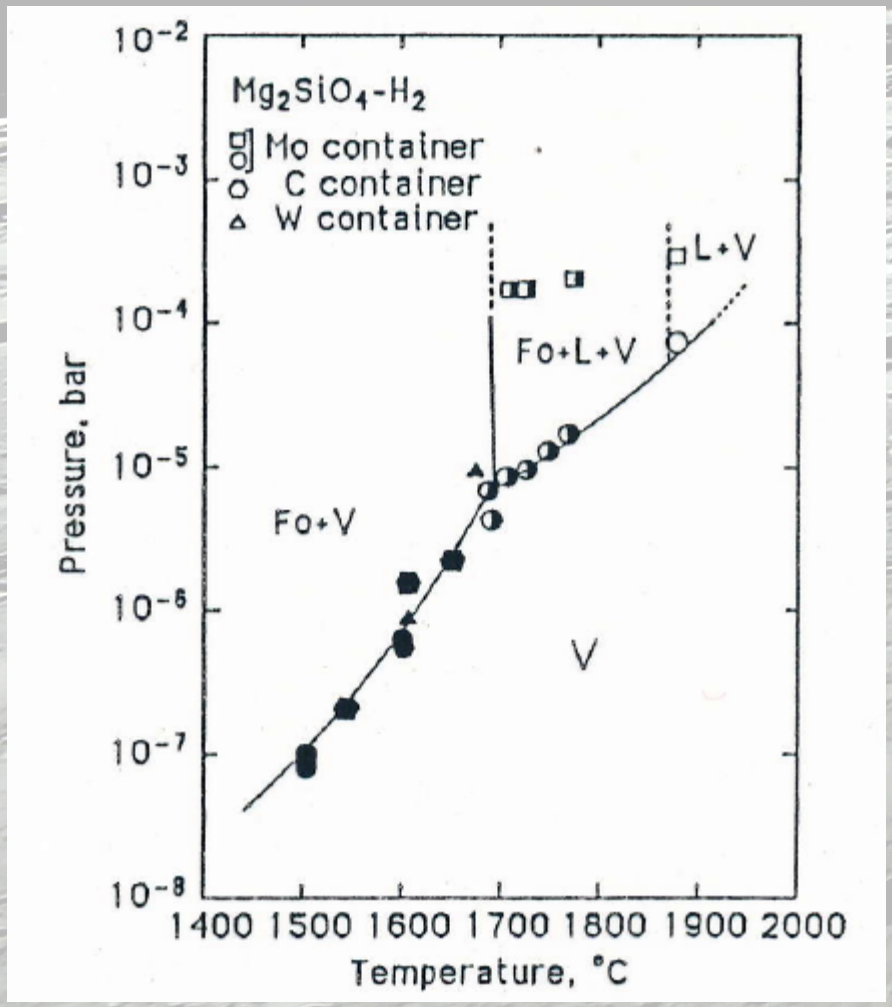
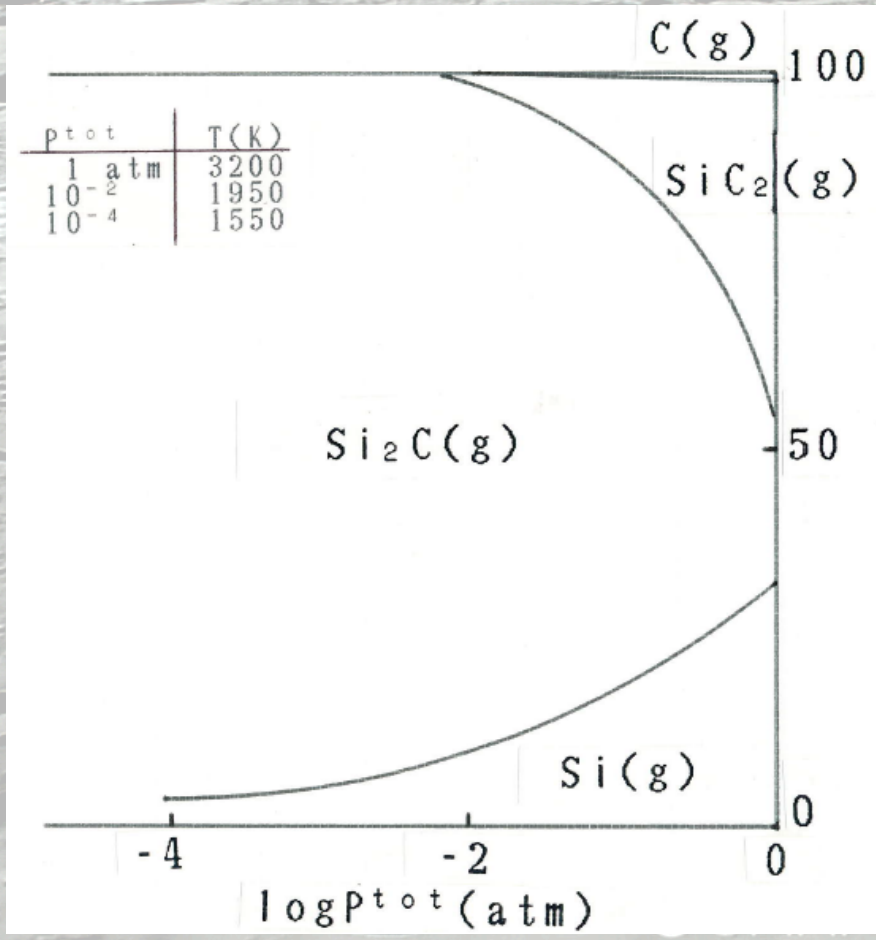


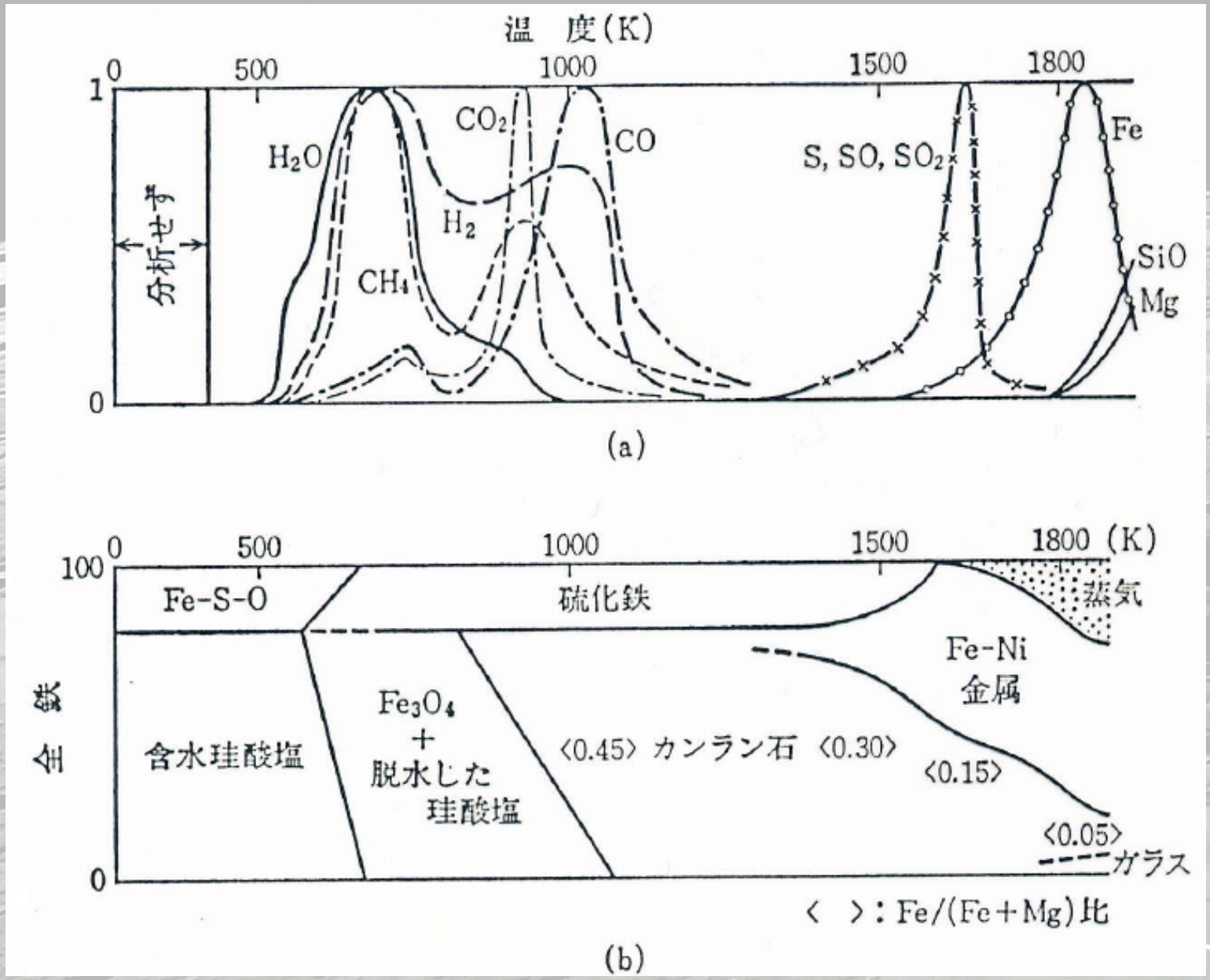
図 6·4 酸化物の蒸発反応と蒸気圧




Mg_2SiO_4-H_2
Mo container
C container
W container
L+V
Fo+L+V
Fo+V
V
Pressure, bar
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1400 1500 1600 1700 1800 1900 2000
Temperature, °C

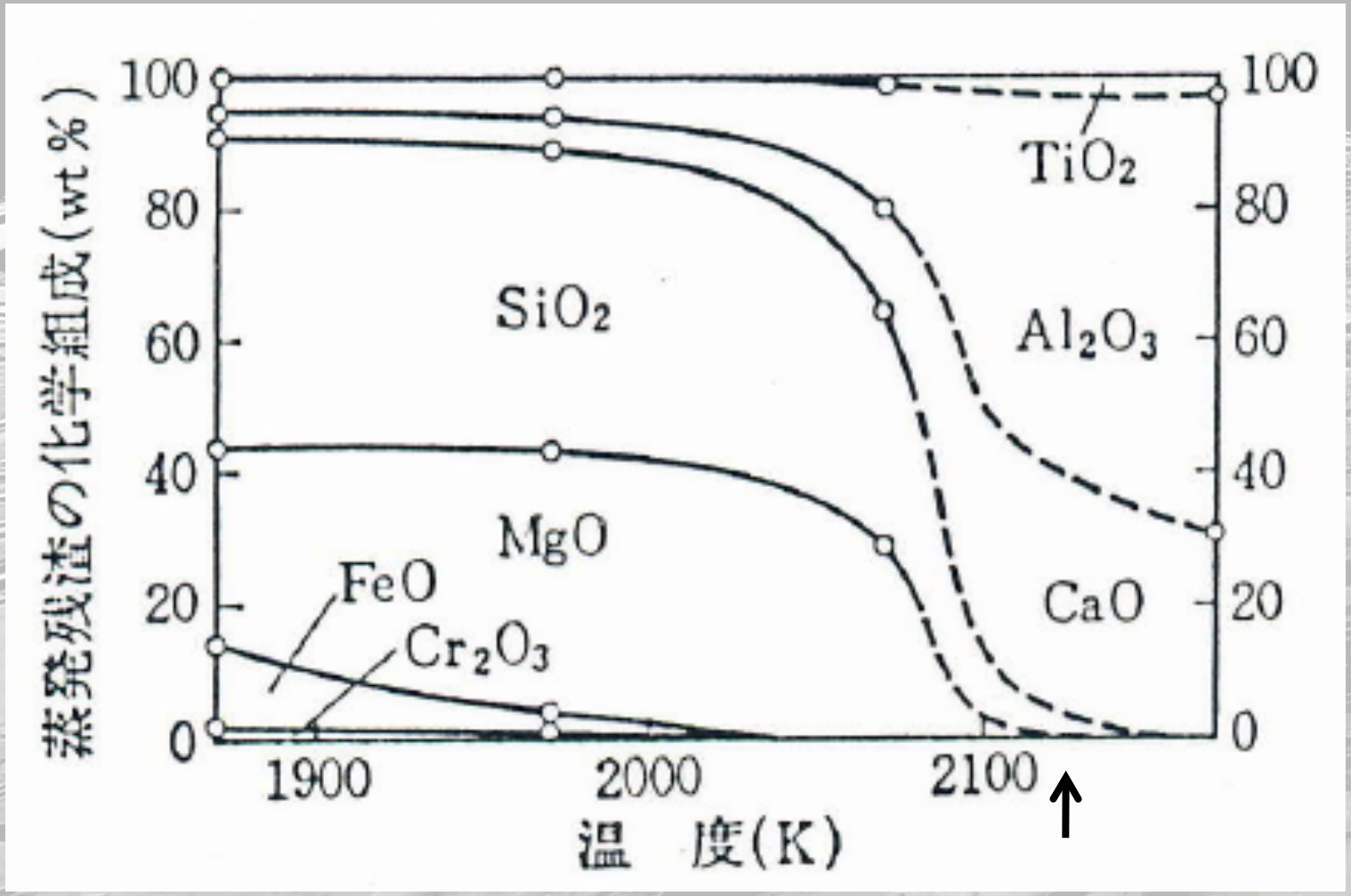

C(g)
100
SiC_2(g)
Si_2C(g)
50
Si(g)
0
-4
-2
0
$\log P_{tot}$ (atm)
Ptot | T(K)
1 atm | 3200
10^{-2} | 1950
10^{-4} | 1550

Evaporation Experiment of Murchison Matrix



Hashimoto et al.,

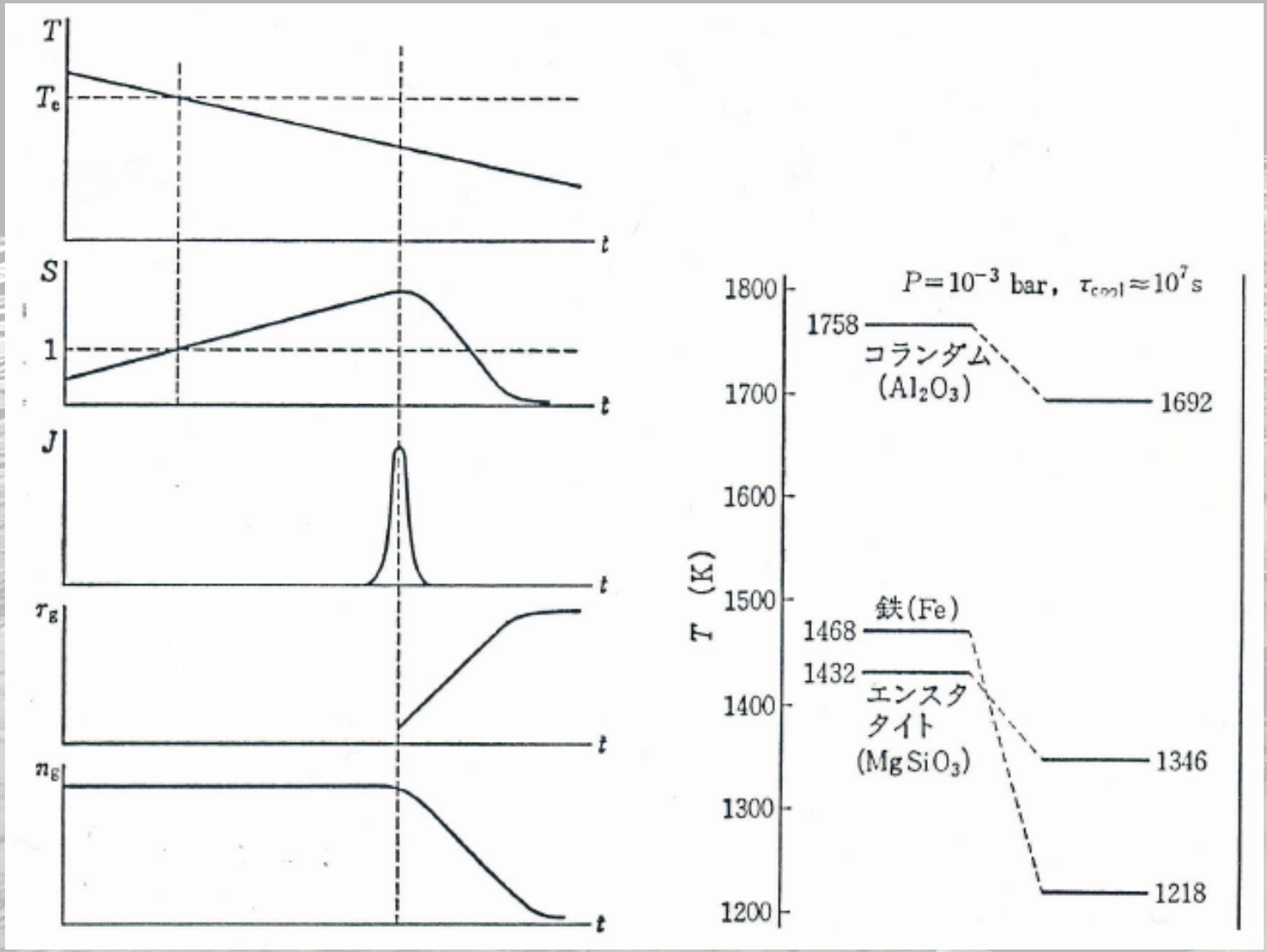
Evaporation Experiment of Murchison Matrix



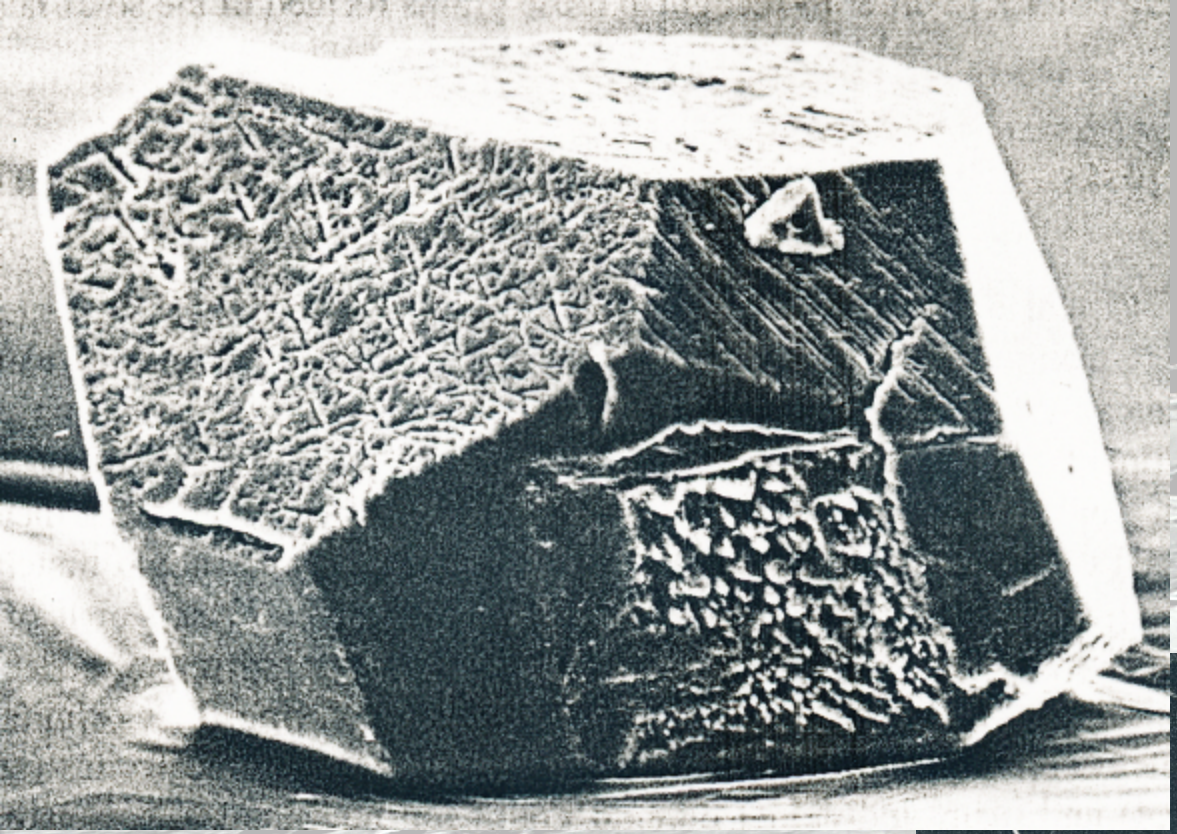
CAI

1800 K以上の詳細

非平衡凝縮モデル

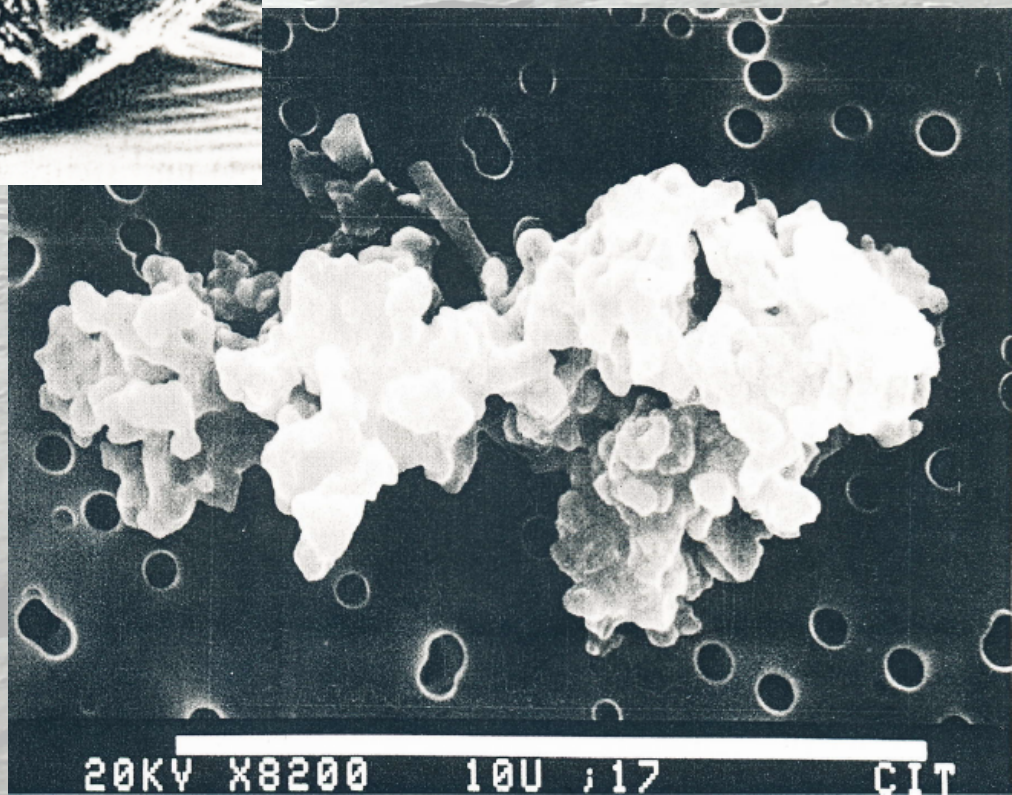


Yamamoto & Hasegawa, 1977

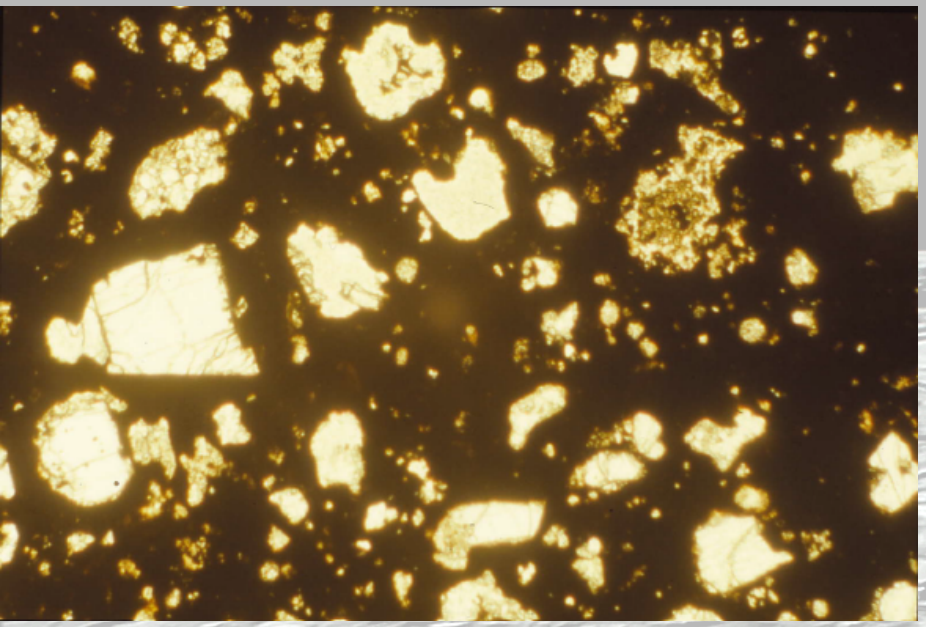


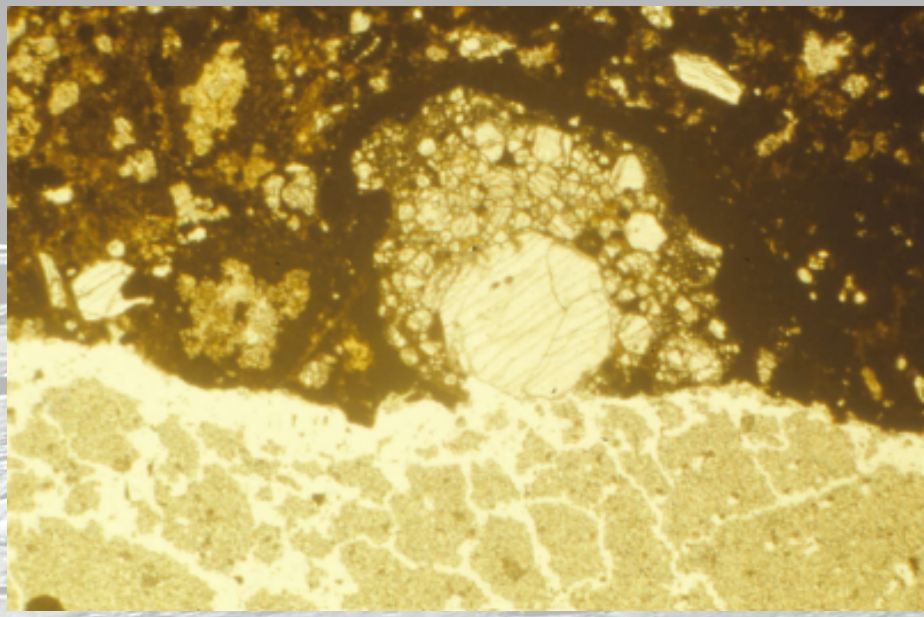
Murchison (CM2)
Olivine, 200 micron

IDP, 10 micron

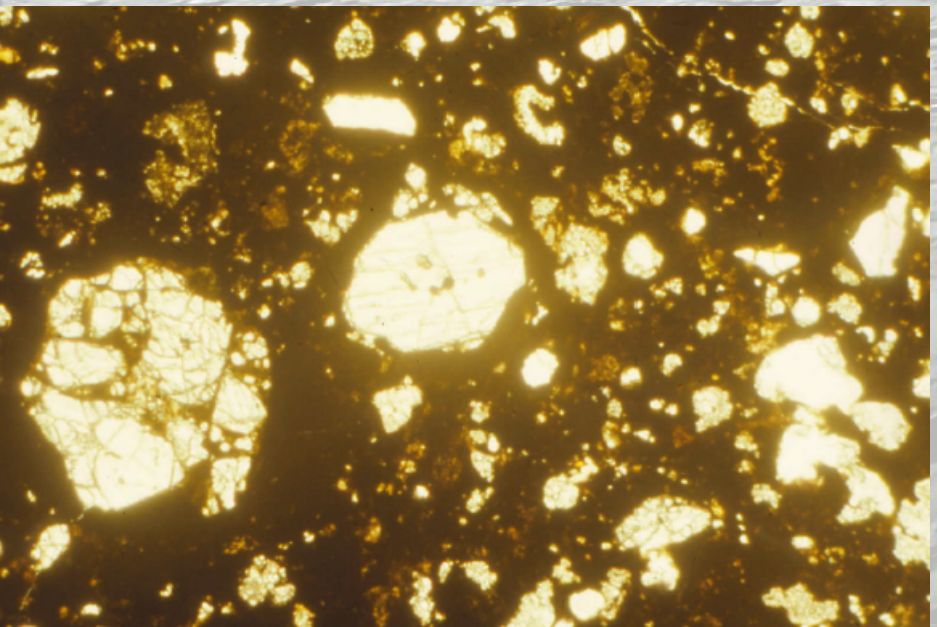


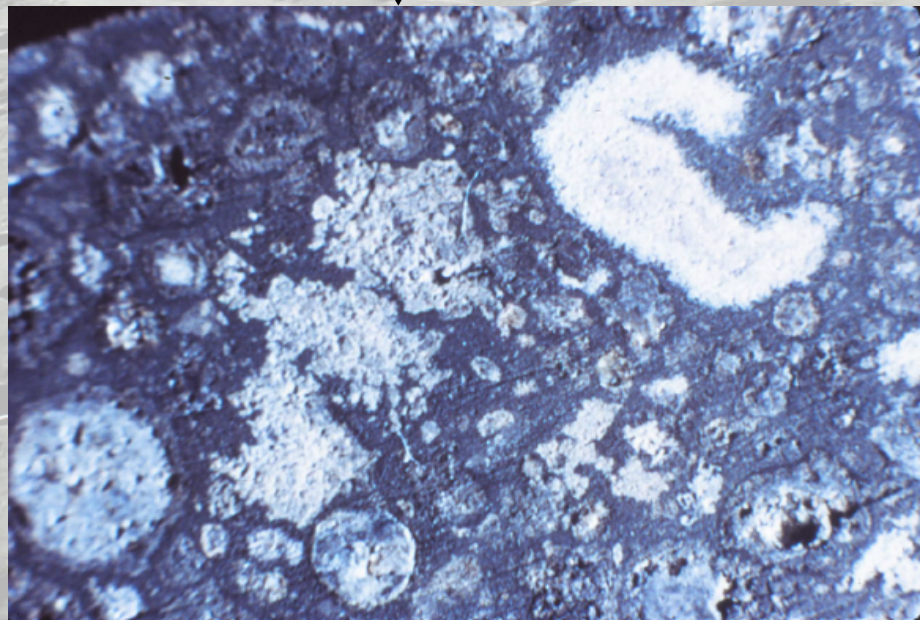
Murchison (CM2) Euhedral Olivine



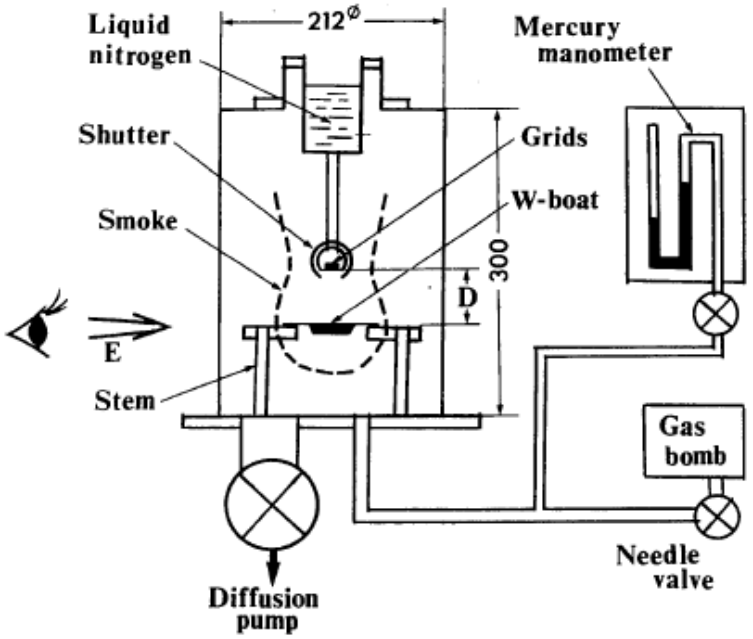


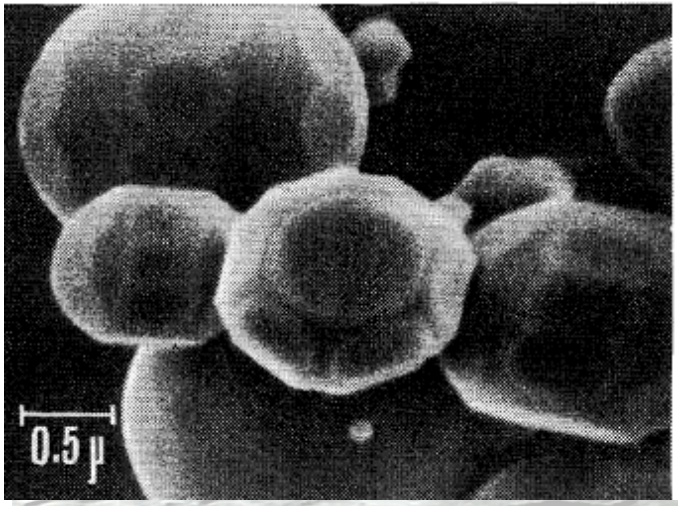
Allende (CV3)

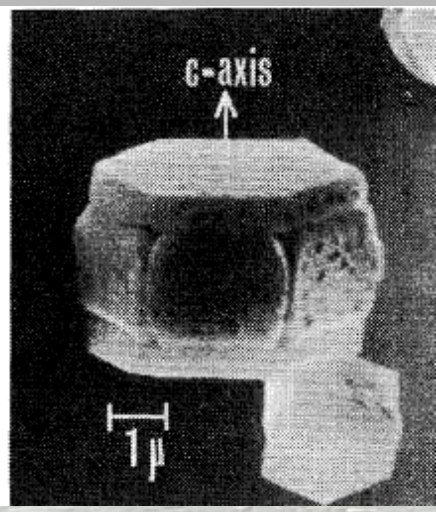




Ultrafine metal Particle by Gas Evaporation Method

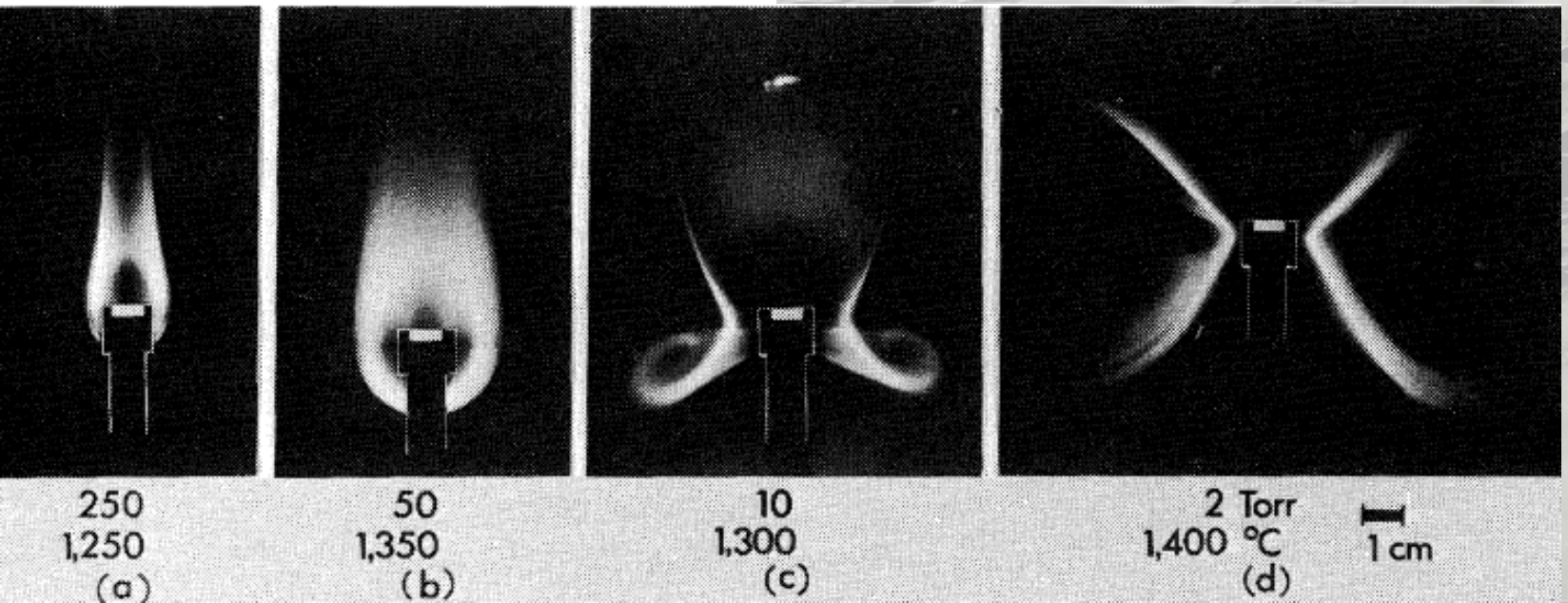




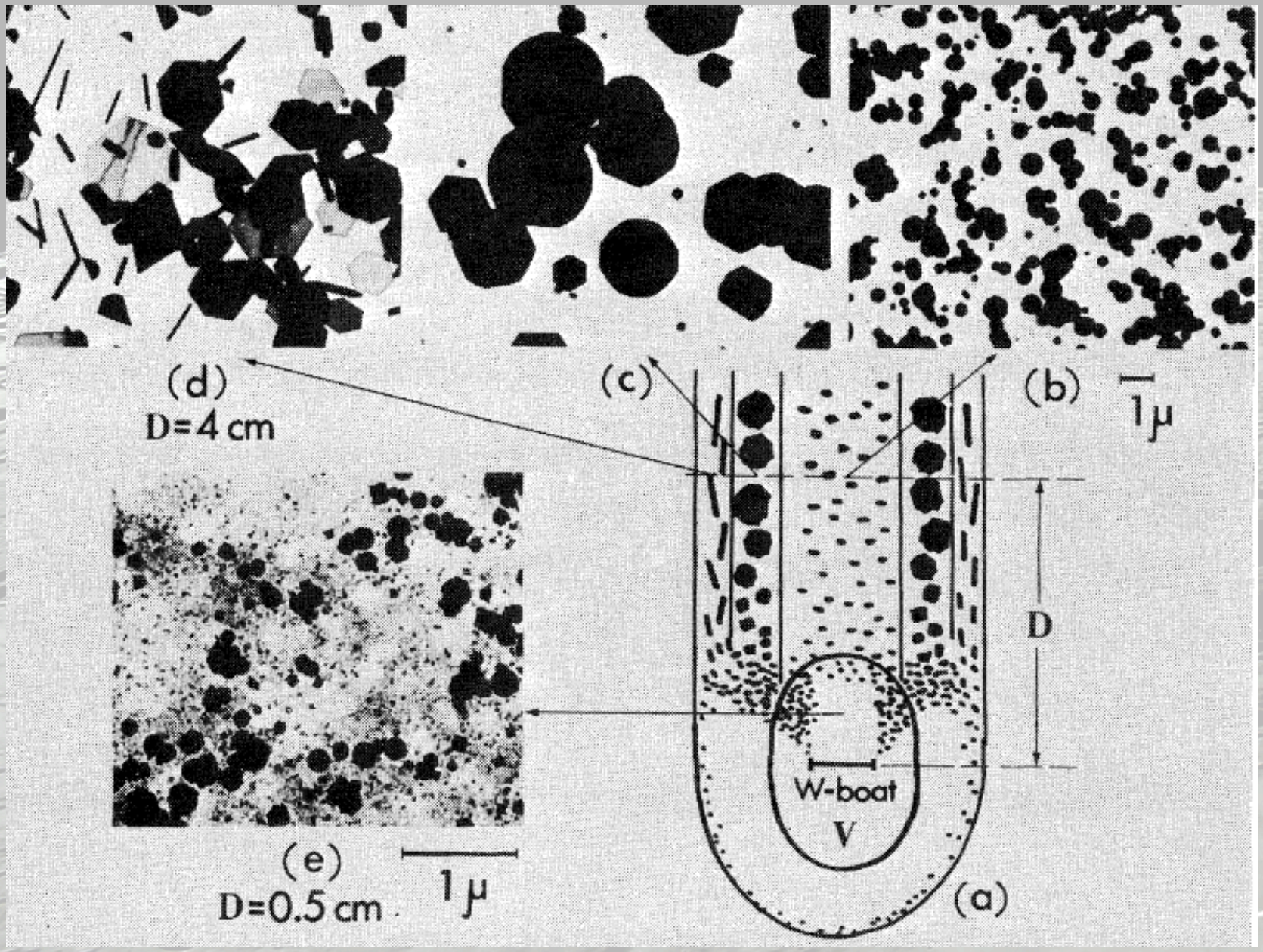


Ag Particles

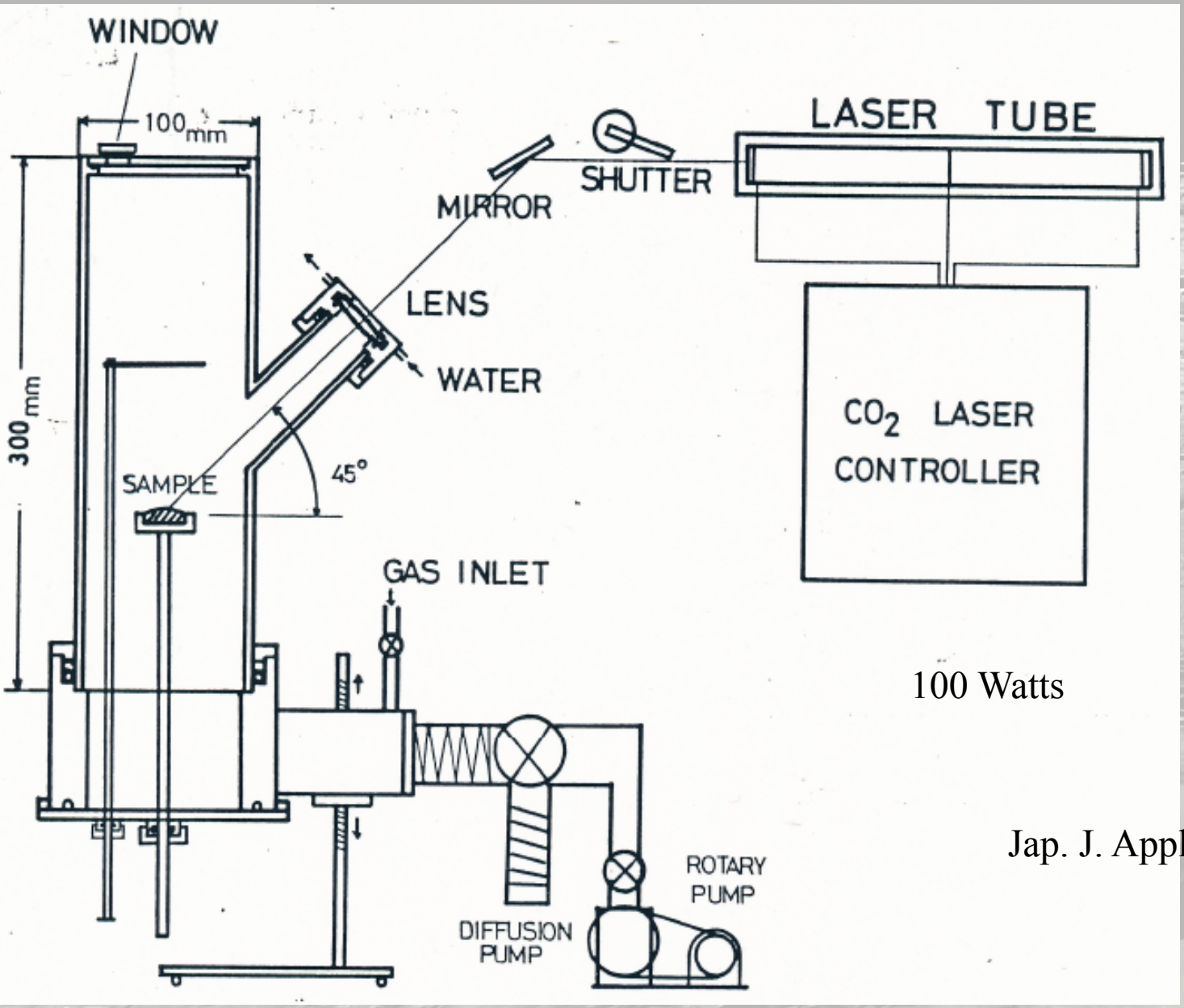
Kasukabe et al., 1974



Formation of Magnesium Ultrafine Particles



Oxide Particles Condensation by Laser Evaporation in Inert Gas



100 Watts

Jap. J. Appl. Phys., 1976

By Plasma Jet Flame

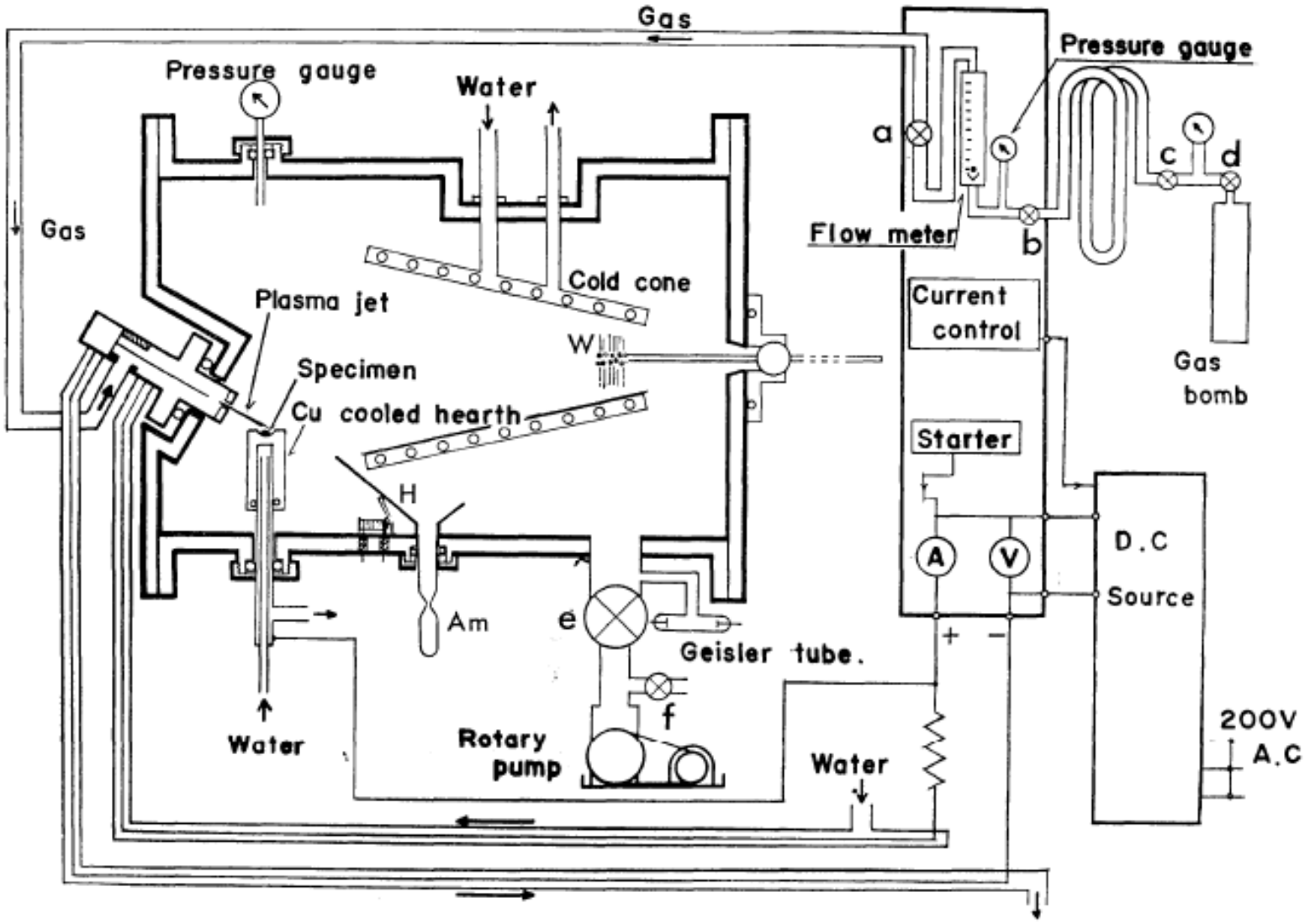
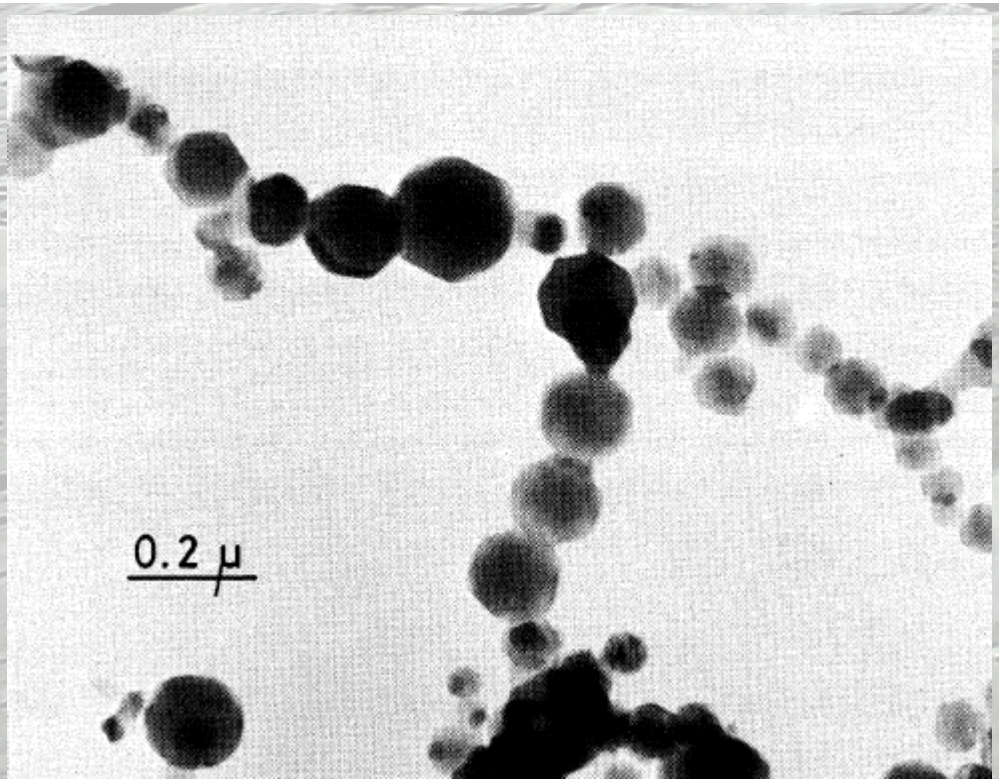


Fig. 2. Schematic arrangement of the evaporation unit with a plasma jet gun.

Wada, Jap.J.Appl.Phys.,1969

Table I. Summary of experimental results.

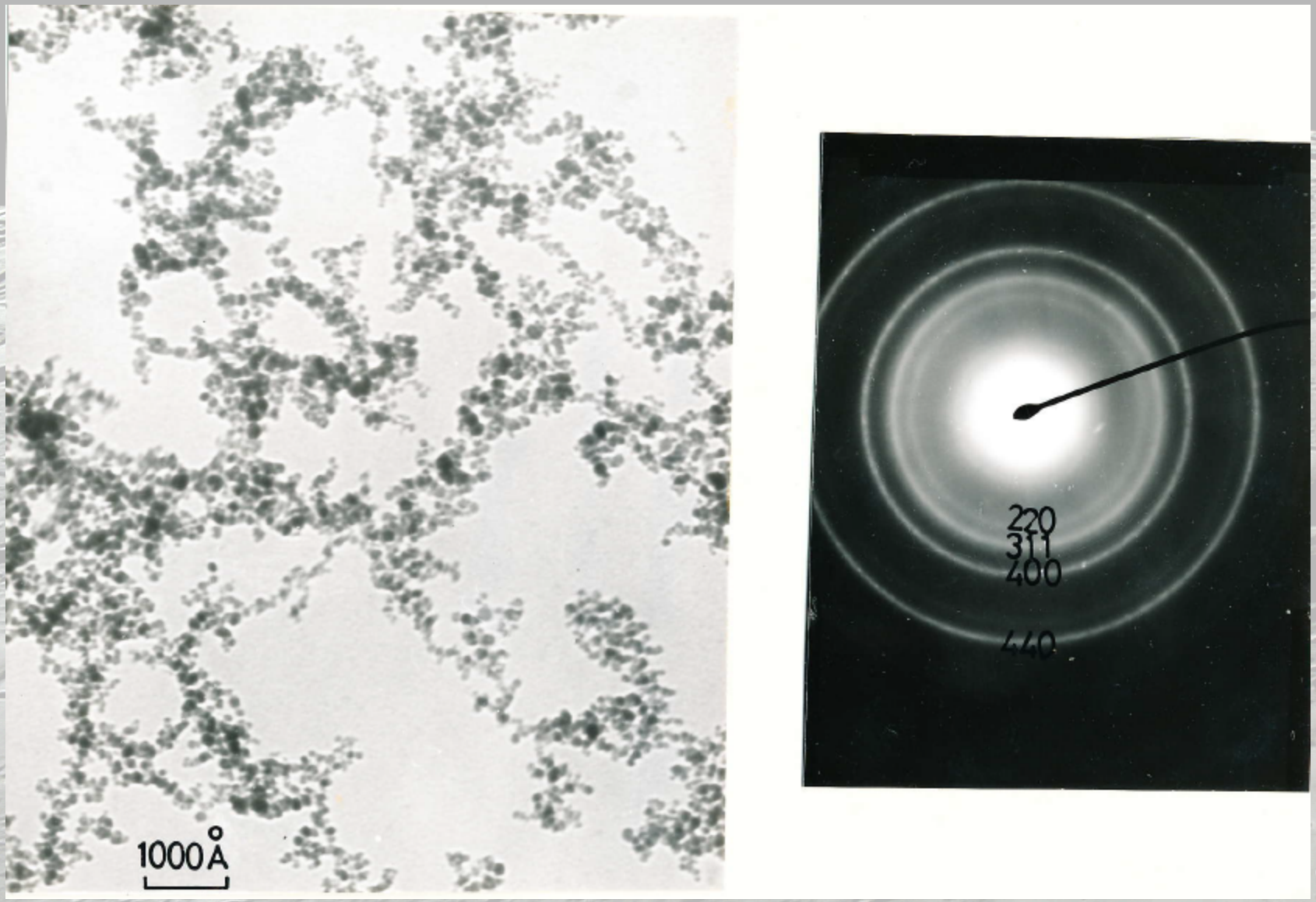
Starting materials		Environmental gas		Ultrafine particles		
Compound	Form	Element	Pressure	Mean grain size	Composition	Structure
SiO_2	Fused quartz	He	3.5～450 Torr	～60 A	SiO_2	Amorphous
MgO	Single crystal	He	3.5～450	60～150	MgO	Rock salt
Al_2O_3	Sintered block	He	3.5	?	?	Amorphous
		He	40～450	60～80	Al_2O_3	Spinel
		Ar	40～670	90～150	Al_2O_3	Spinel
		Xe	50, 100	100	Al_2O_3	Spinel
Fe_3O_4	Reagent powder	Ar	40, 250	80, 100	Fe_3O_4	Spinel
Mg_2SiO_4	Sintered block	Ar	40～250	100	Mg_2SiO_4	Amorphous＋Olivine
$CaTiO_3$	Sintered block	Ar	40～450	500～1000	$CaTiO_3$	Perovskite
$MgAl_2O_4$	Sintered block	Ar	40～450	500	MgO＋ $MgAl_2O_4$	Rocksalt＋ Spinel



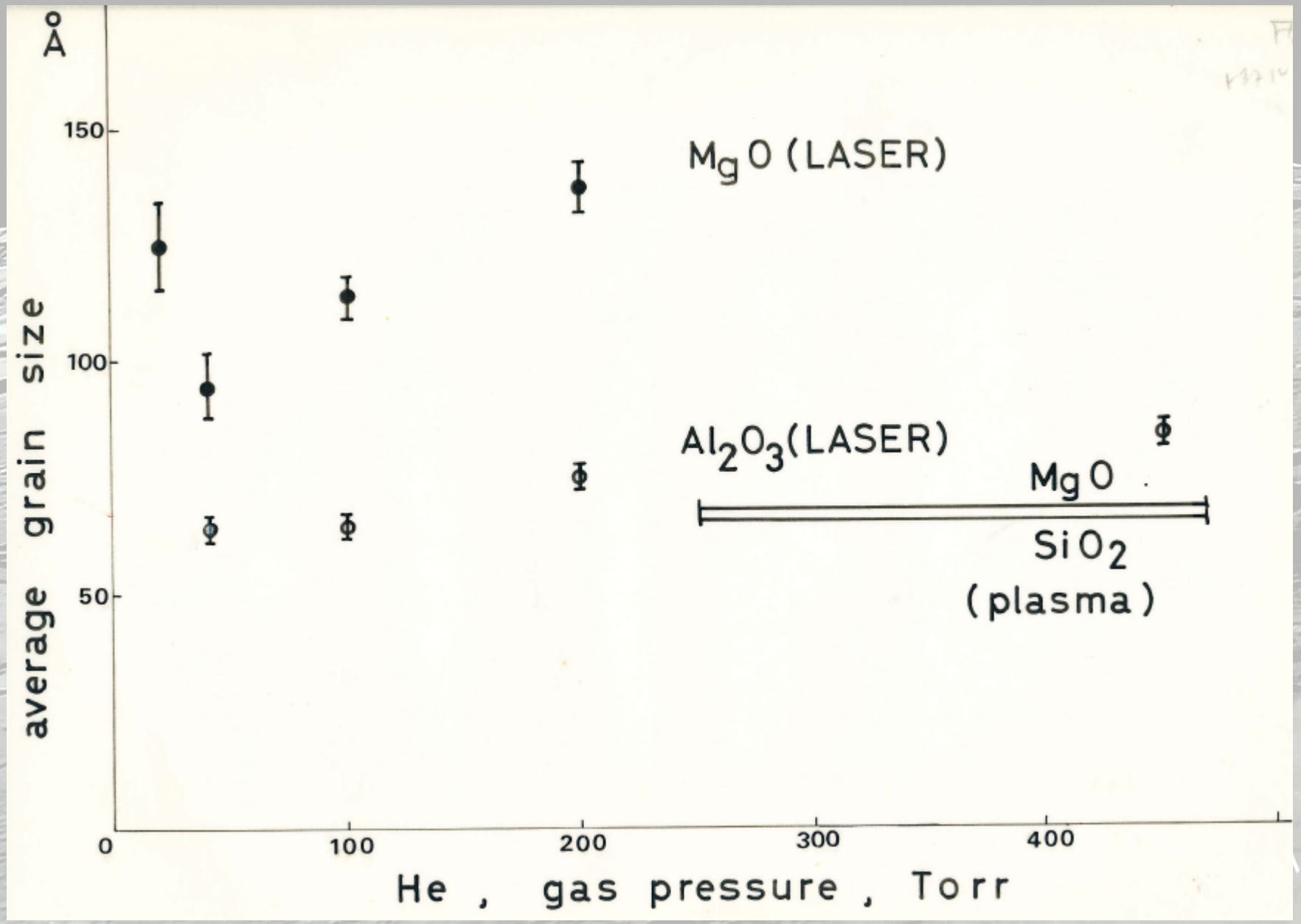
$CaTiO_3$

250 Torr Ar

MgO Ultrafine Particles by Plasma Jet Heating

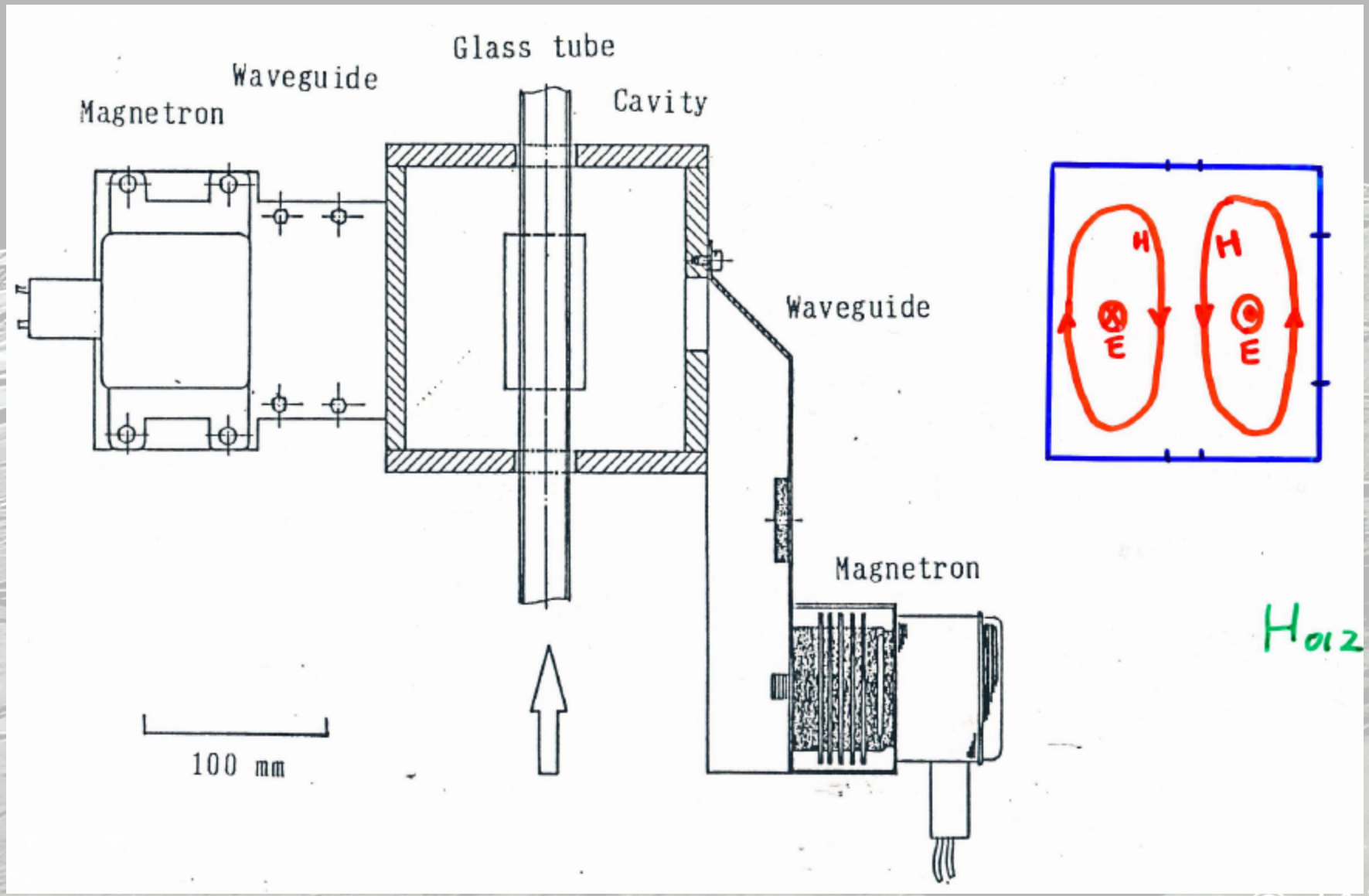


He gas pressure – grain size

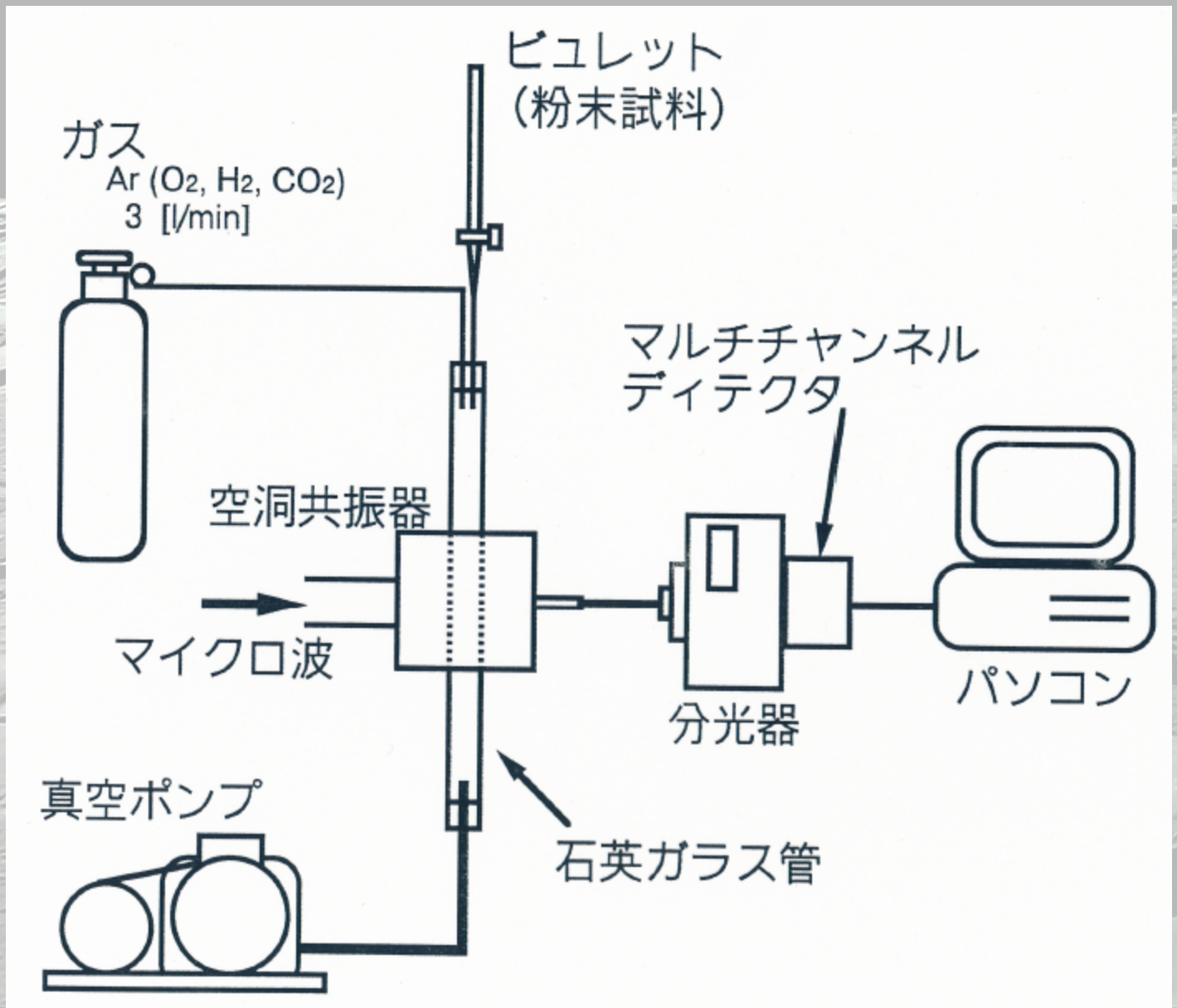


Starting materials		Environmental gas		Ultrafine particles		
Compound	Form	Element	Pressure	Mean grainsize	Composition	Structure
SiO_2	Fused quartz	He	3.5∿450 Torr	∿ 60 A	SiO_2	Amorphous
MgO	Single crystal	He	3.5∿450	60∿150	MgO	Rock salt
Al_2O_3	Sintered block	He	3.5	?	?	
		He	40∿450	60∿80	Al_2O_3	Spinel (distorted)
		Ar	40∿670	90∿150	Al_2O_3	Spinel (distorted)
		Xe	50,100	100	Al_2O_3	Spinel (distorted)
Fe_3O_4	Reagent powder	Ar	40,250	80,100	Fe_3O_4	Spinel
Mg_2SiO_4	Sintered block	Ar	40∿250	100	Mg_2SiO_4	Amorphous + Olivine
$CaTiO_3$	Sintered block	Ar	40∿450	500∿1000	$CaTiO_3$	Perovskite
$MgAl_2O_4$	Sintered block	Ar	40∿450	500	MgO + $MgAl_2O_4$	Rock salt + Spinel
$MgSiO_3$	Sintered block	Ar	250	100	SiO_2 (Fractional vaporization)	Amorphous
$CaMgSi_2O_6$	Sintered block	Ar	250	200	$CaMgSi_2O_6$ + glass	Pyroxene + Amorphous
CaO 25mol% MgO 25 Al_2O_3 37 SiO_2 13	Powder	Ar	250	200	$CaSiO_3$ (Fractional vaporization)	Amorphous
$Ca_2Al_2SiO_7$	Powder	Ar	250	300	$Ca_2Al_2SiO_7$	Amorphous
$BaTiO_3$	Reagent powder	Ar	250	400	Ba_2TiO_4	Olivine
$NaAlSi_3O_8$	Powder	Ar	250	200	$NaAlSiO_4$	
Fe	Sintered block	He	50∿250	300	α Fe	bcc
C	Sintered block	Ar	200	100	C	Amorphous
SiC	Powder	Ar	100	350	βSiC + Si	Zinc blende
NbC	Powder	Ar	100	150	NbC	Rock salt
HfC	Powder	Ar	100	100	HfC	Rock salt
TiC	Powder	Ar	100	60	TiC	Rock salt
ZrC	Powder	Ar	100	50	ZrC	Rocksalt
B_4C	Powder	Ar	100	50	B_4C ?	Amorphous
TaC	Powder	Ar	100	30	TaC ?	Amorphous
LaB_6	Powder	Ar	100	30	LaB_6 ?	Amorphous

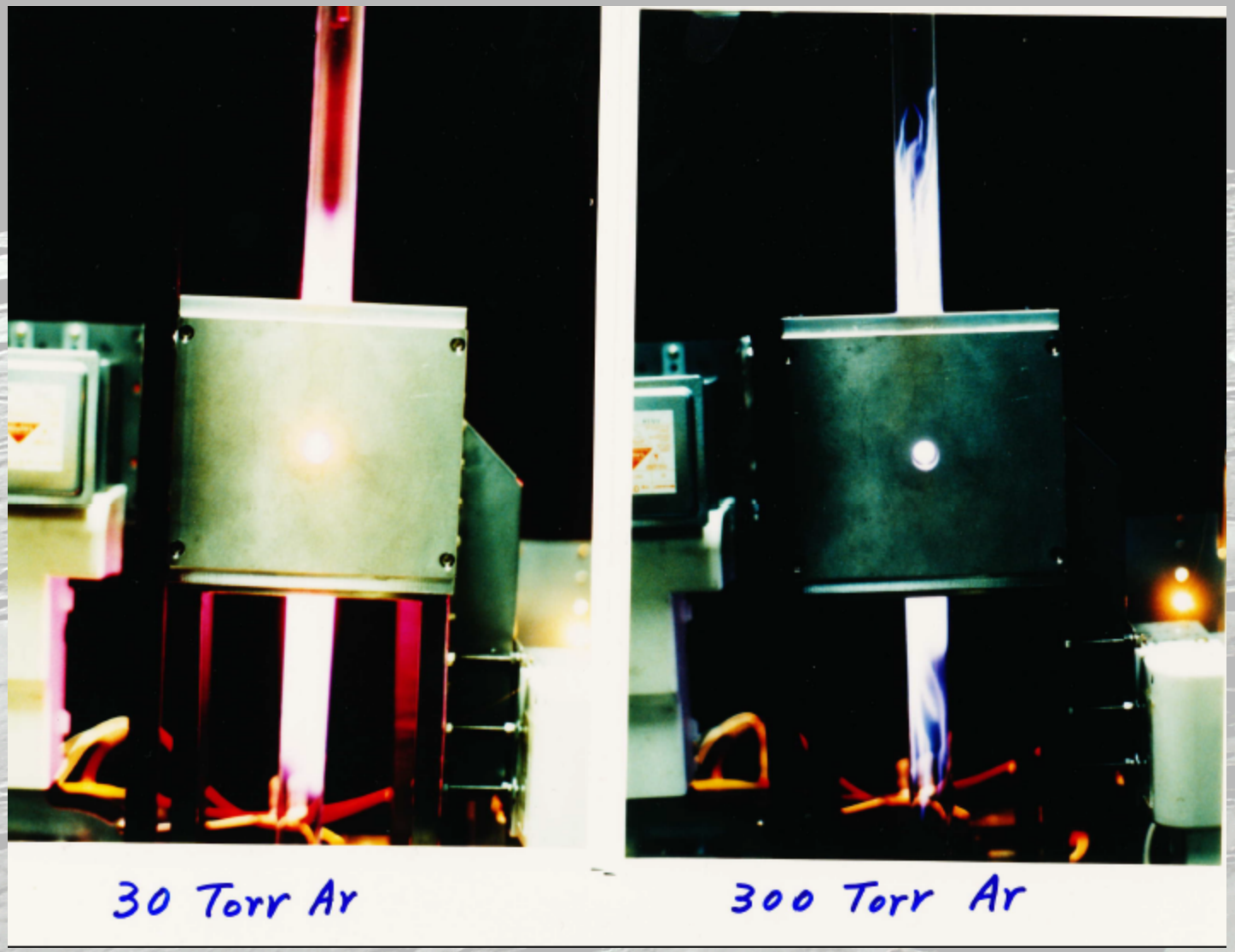
Microwave Heating

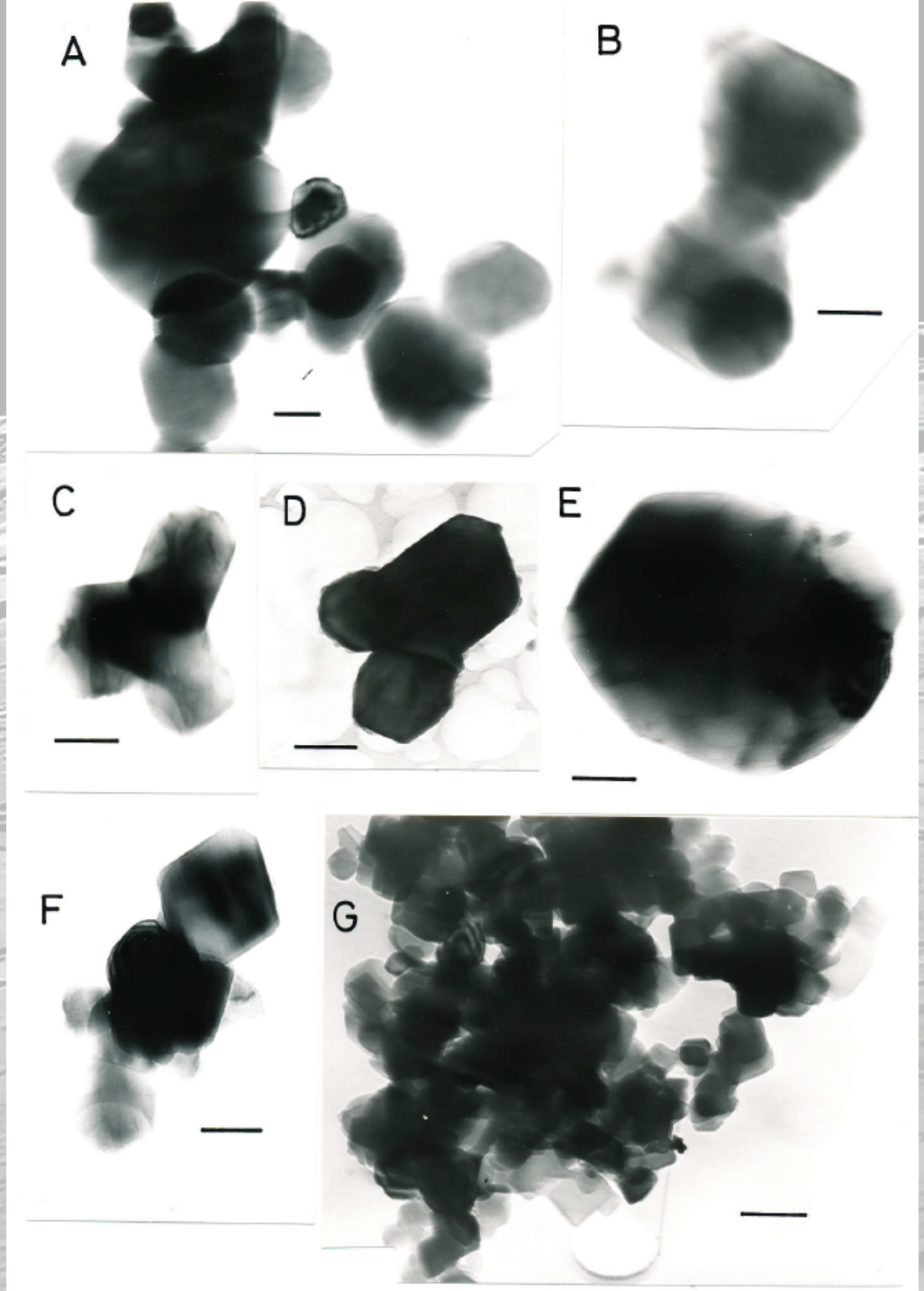


Temperature Measurements of Plasma



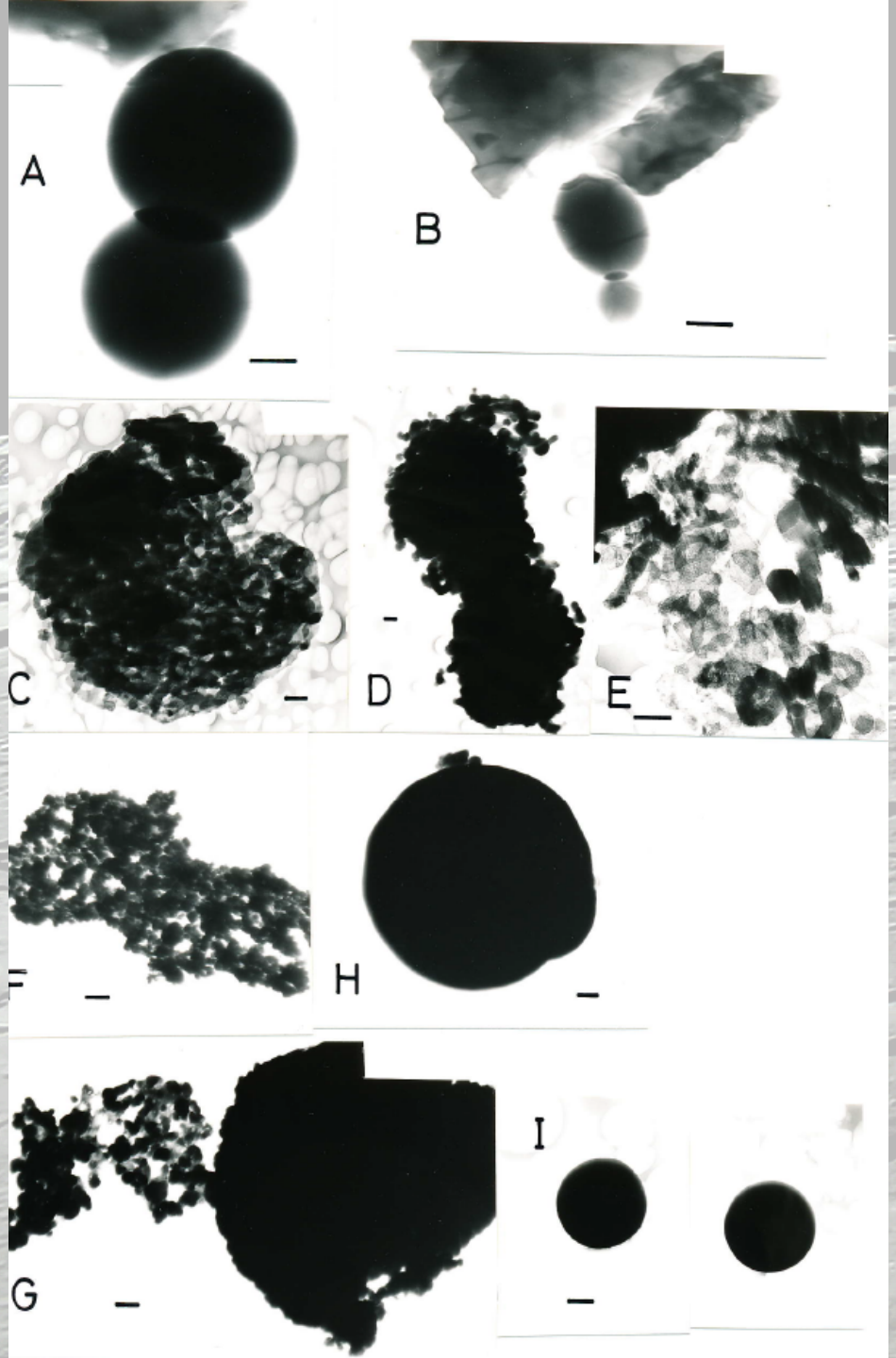
10 litre / min.





A-E: Forsterite
F: Fayalite
G: Periclase
condensed in Ar 20 kPa

Scale Bars: 100 nm

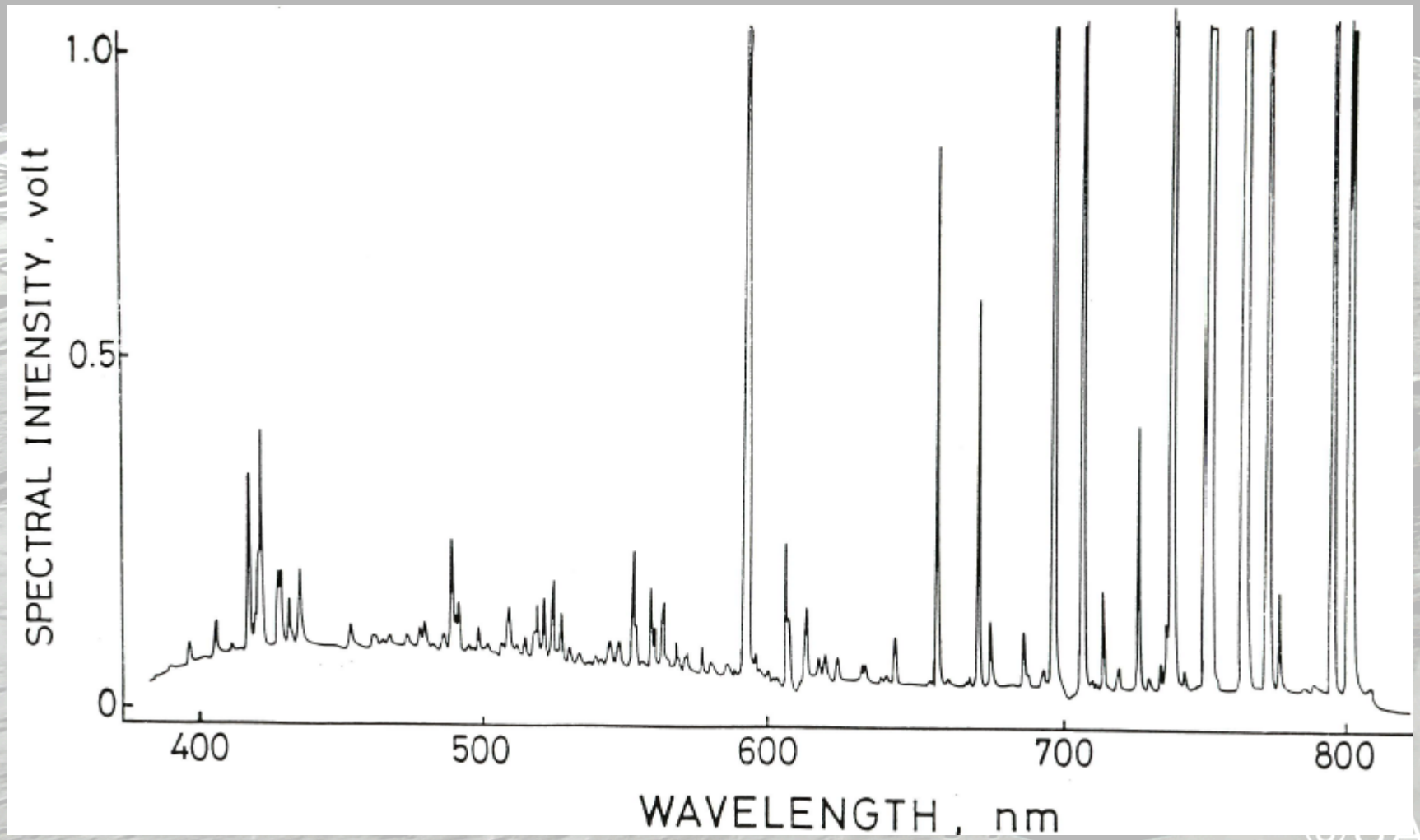


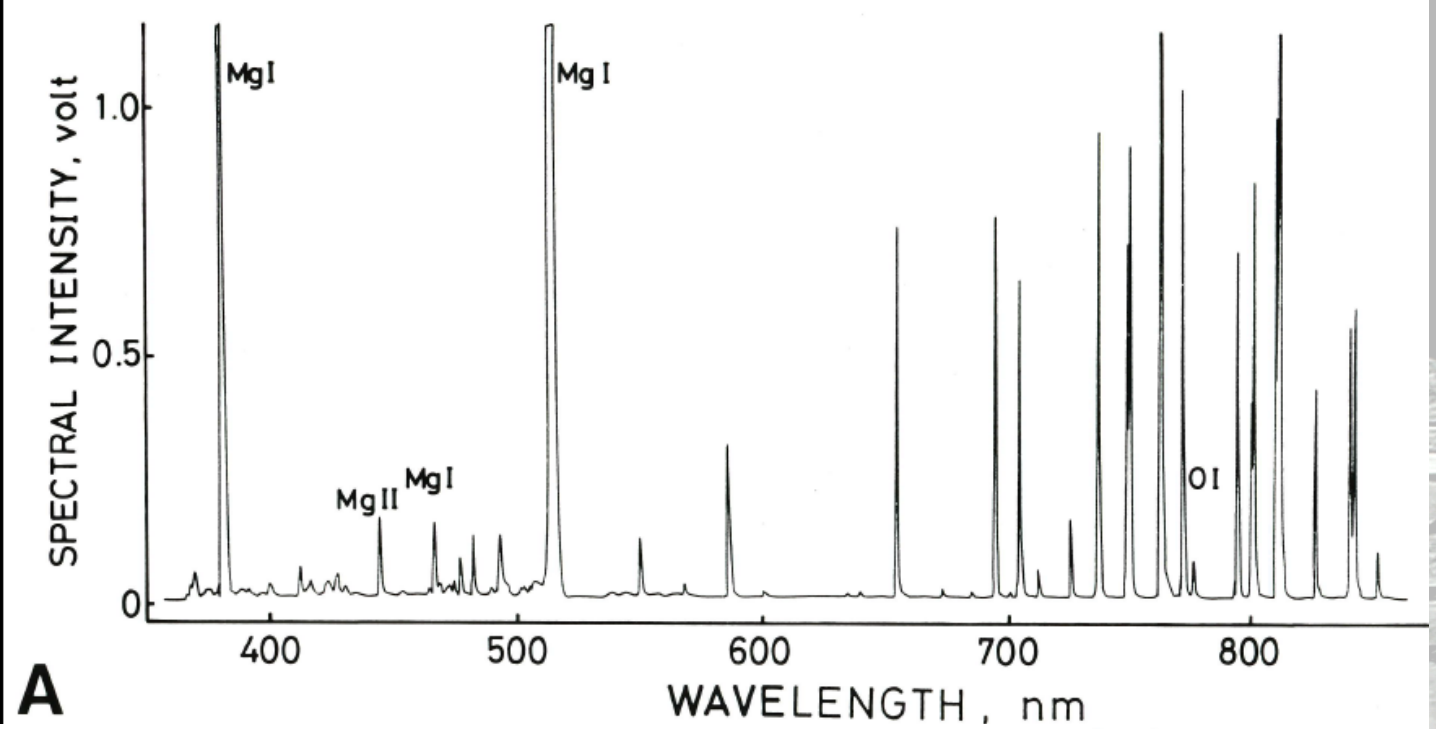
A: SiO2
B: SiO2
C-E: Magnetite
F-H: Ag
I: Fe
condensed in Ar 20 kPa

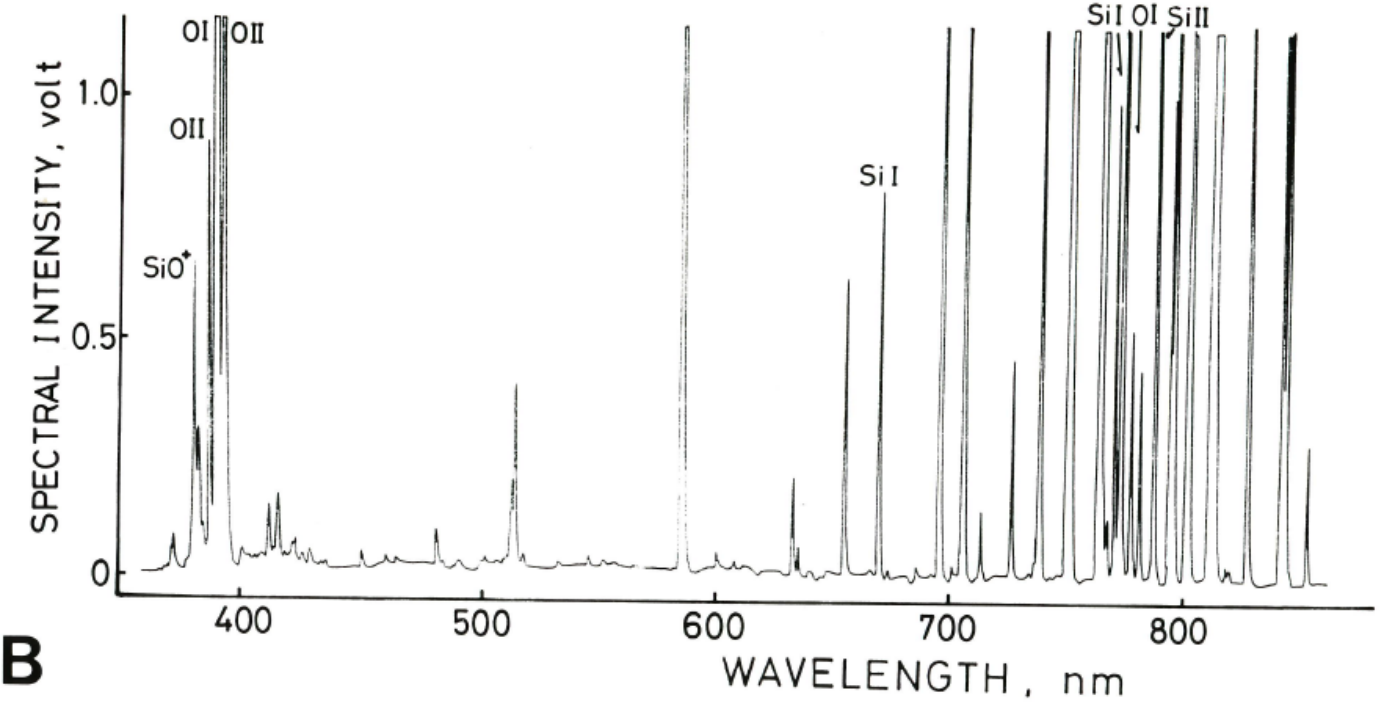
Scale Bars: 100 nm

Argon 5 kPa Plasma Spectrum

12000 ± 1500 K by Boltzmann Method



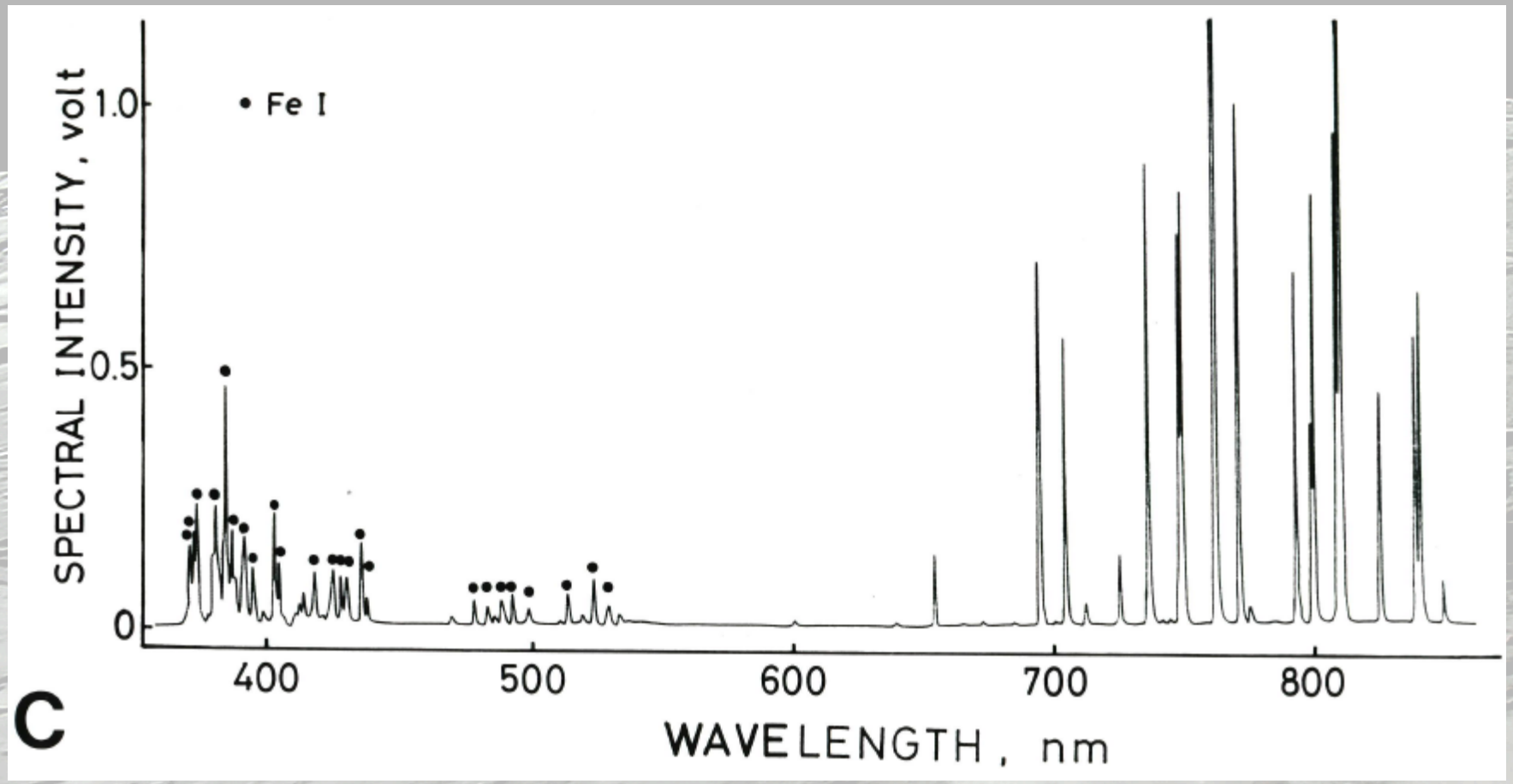




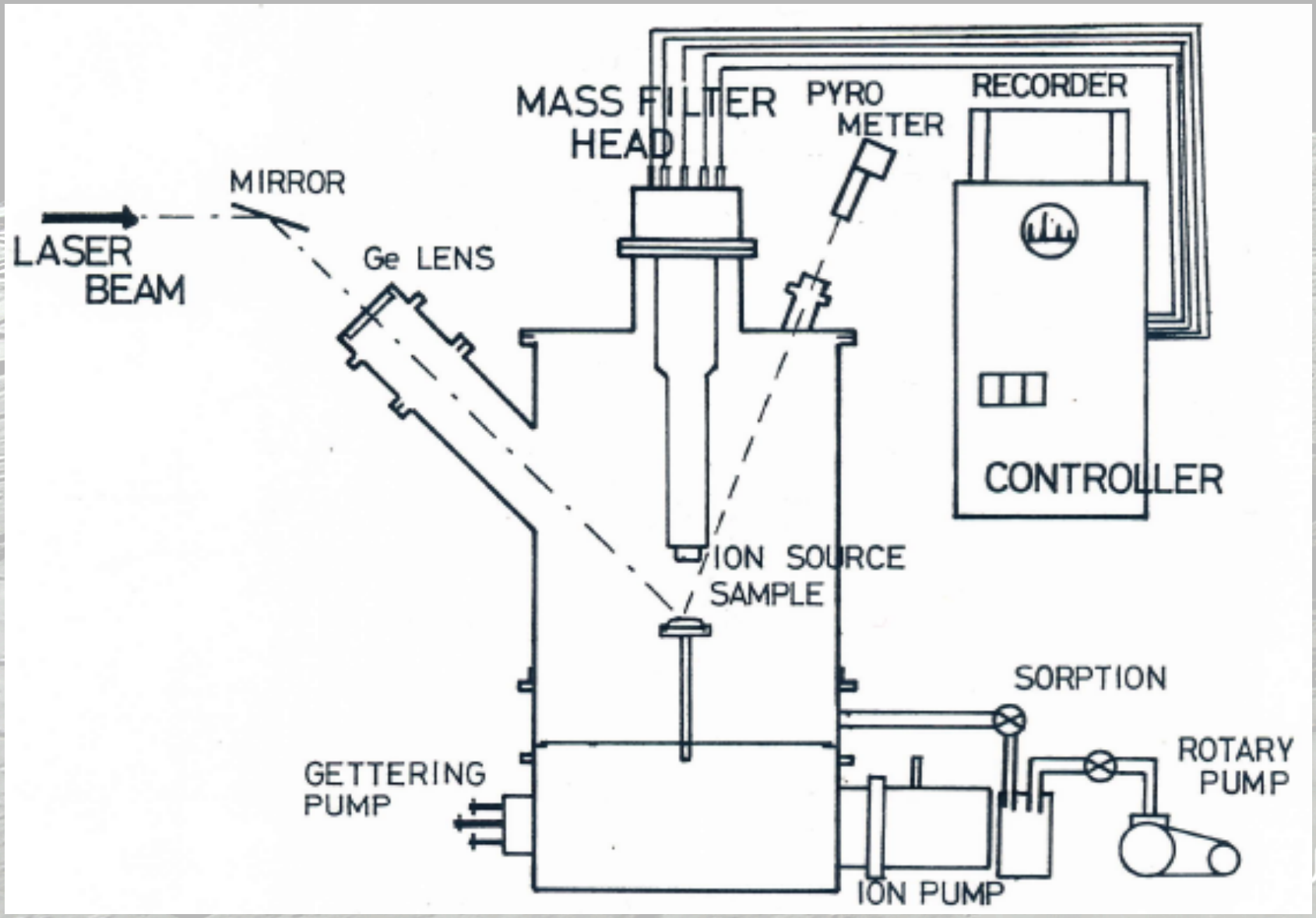
Plasma Spectrum
MgO evaporated in Ar
30 Torr

SiO_2

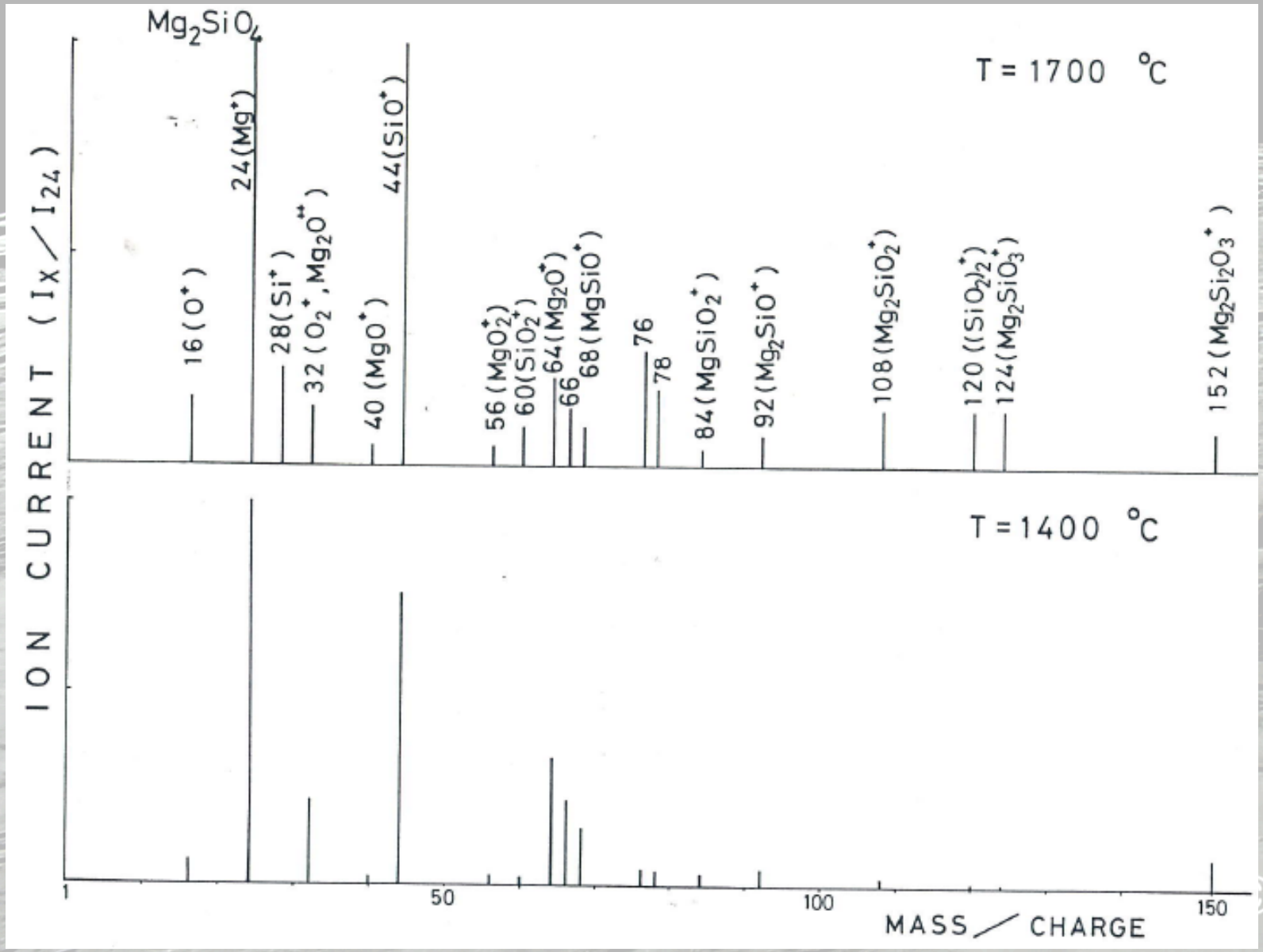
Fe


• Fe I
SPECTRAL INTENSITY, volt
1.0
0.5
0
400
500
600
700
800
WAVELENGTH, nm
C

Mass Spectrometry of Vapor



Vapor Species in Mg_2SiO_4 Evaporation

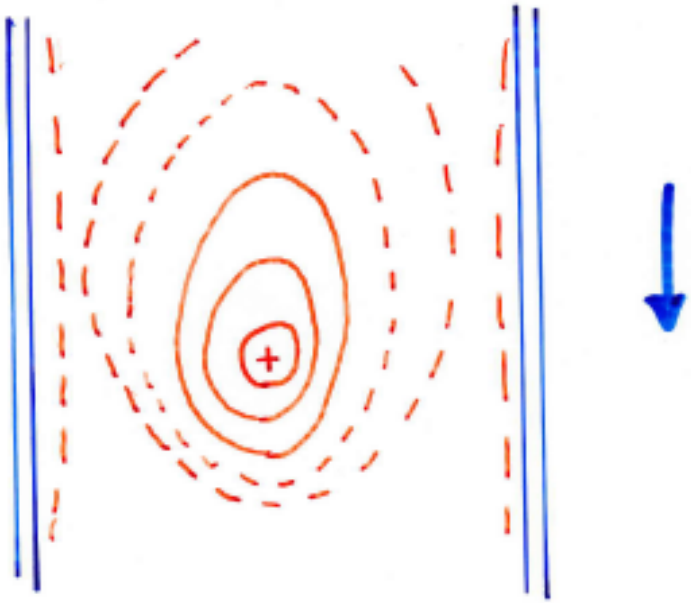


Temperature Distribution of Argon Plasma

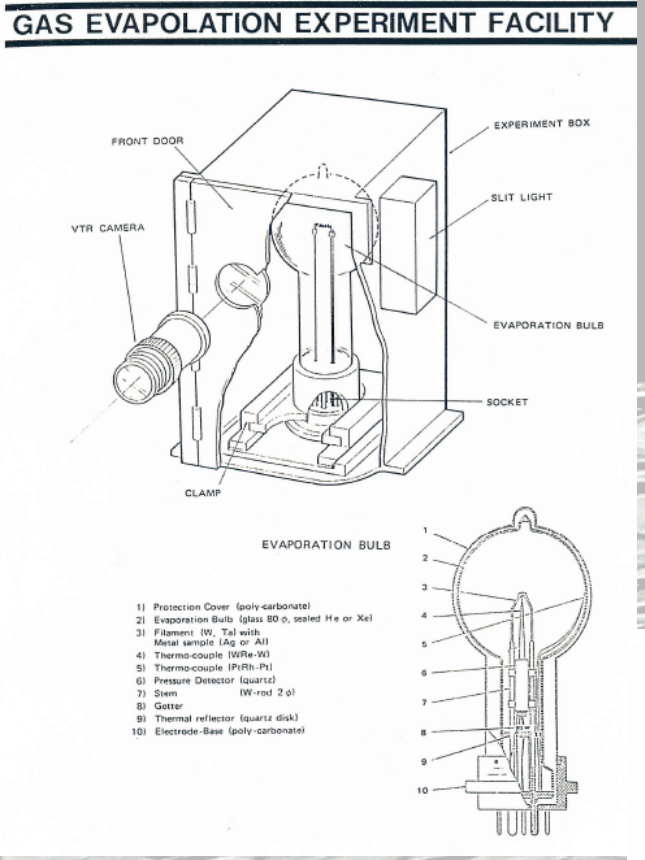
プラズマ 温度分布

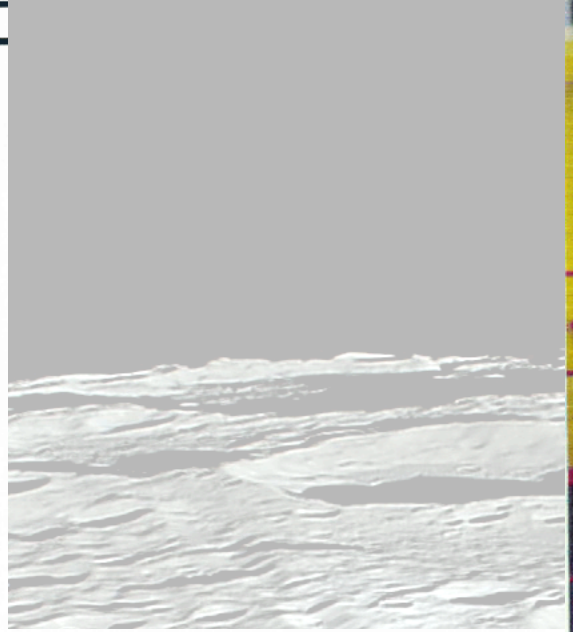
+40mm	6800 K
+20	7500
0	8300
−20	6800
−40	6600

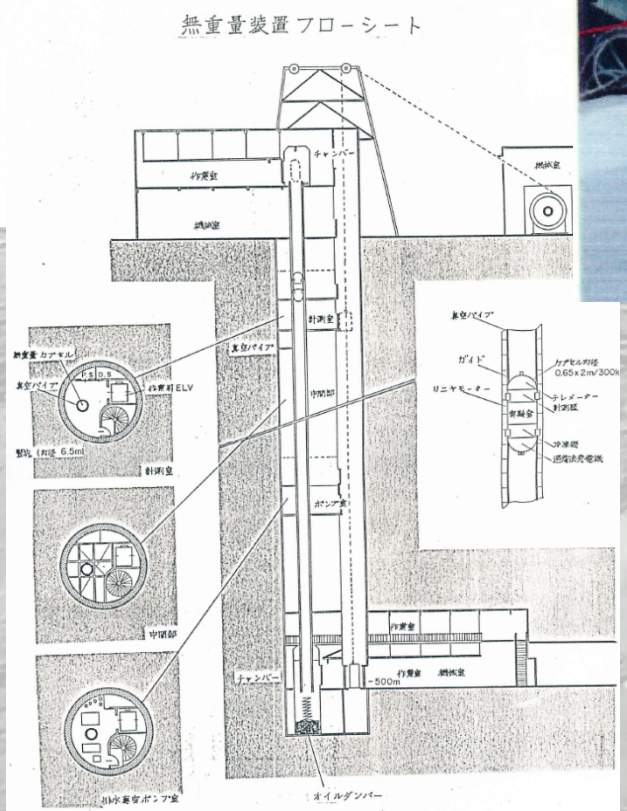
40Torr Ar
NO.2 cavity



	cavity NO. 1	NO. 2
20 Torr Ar	15800 K	12500 K
40 Torr Ar	13600 K	8300 K
100 Torr Ar	7200 K	5000 K







FMPT in Space Shuttle

MG Lab in Mizunami