Chapter 0. Introduction

0.1 What is powder?

Powders : Finely-divided solid matter

Wide ranges of size : from nanometers(10-9m) to centimeters(10-2m)

syn) Particulate matter, particles

분체(粉體), 분말(粉末), 입자(粒子)

Examples of Powder: important in most industries...

	업 종	관련되는 원료, 제품(중간제품포함)
자원	농업	토양, 종자, 사료, 곡물
	광업	원광, 분탄
가공산업	식품	소맥분 등, 화학조미료, 분유, 가루 차, 설탕, 소금, 인스턴트 커피
	섬유	색소제, 염료, 안료
	종이, 펄프	목재칩, 펄프, 톱밥, 도장재, 충전제, sizing제
	고무, 고분자	충전제, 안료, 고분자 pellet, 고분자가루
	안료, 충전제	안료, 카본블랙, colloidal silica, 인쇄잉크
	화학공업	농약, 비료, 촉매, 각종 화학약품
	요업	점토, 흑연, 금속산화물, 규사, 석회석, 알루미나, glass beads, 시멘트, 연삭재
	철강	분광, 궤광, 분진, 광석 pellet
	비철금속	분진, 알루미나, 소광분(燒鉱紛), 금속분
집적산업	금속, 기계	금속분, 분진, 연마재, 연삭재
	전기기기	형광재료, 텅스텐, 몰리브덴분, 실리카, 알루미나
	전자재료	산화티탄, 산화철, 알루미나 등, 티탄산바륨, 페라이트, 전도성재료
	의약, 화장품	전분, 활성알루미나, 젖당, 주약(主藥), 안료, 정제, 과립, 치약
	잡화	고분자 pellet, 약품
환경・재해	환경기술	슬러지, fly ash, 규석가루, 분진, 매연, fume, 생활먼지
	자연재해	꽃가루, 황사, 눈, 화산재

In chemical industries

DuPont 1985, 1992: 3000 products

62% : Powders, crystalline solids, granules, flakes, dispersions, slurries and pastes

18% : powder = key intermediate products

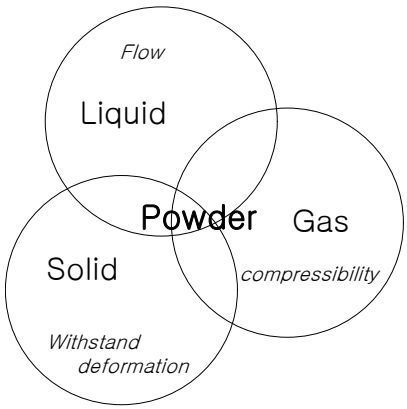
Characteristics of Powders

They differ from molecules, atoms and solids in:

- *They are finely divided, isolated solids*
- *They have probabilistic, statistical properties*
- *Their surface properties are important in their behavior.*

They differ from solids, liquids, and gases in:

- *As with solids, bulk powders can withstand deformation.*
- *As with liquids, they can flow.*
- *As with gases, they exhibit compressibility.*



0.2 What Is Powder Technology?

Science and technology related to the handling and processing of powders

Titles	*Contents*
Size analysis	*Size definition, size distribution, size and size-related properties of nanoparticles*
Particle movement	*Drag force, settling velocity, diffusion, phoresis*
Sedimentation	*Hindered settling, Thickner design*
Particle movement by fluid flow	*Fixed bed, liquid filtration, fluidized bed, particle transport*
Separation of particles from gas	*Cyclone, air filtration, electrostatic precipitation*
Storage and feeding	*Stress in powder bed, storage tank design*
Mixing and granulation	*Mixing, segregation, granulation*
Particle size reduction	*Crushing, grinding, milling*
Generation of particles by growth	*Nucleation, condensation, coagulation, monodisperse particles*
Particle-particle interaction and surface modification	*van der Waals force, liquid bridge, electrical double layer, DLVO theory*
Adverse effect of particles	*Dust explosion, respiration of dusts*

0.3 History of Powder Technology

Ancient Egypt:

- Thousands-year old powder technology

· Silts deposited: agriculture, raw materials for brick and ceramic handicrafts

· Winnowing and crushing of grains, followed by kneading of flour

· Physical liberation of precious metals and gems by crushing

· Colloidal rheology : mixing of black soot with water, vegetable gum for ink, production of bricks from mud, sand and straw

Leading industries for many generations :

· Production of pottery

· Milling of flour for bread

· Mining, mineral processing, metallurgy

· Soils in civil engineering

Industrial revolution and powder technology

- Powder industries in early U.S.(18C - 19C)

· Potash, indigo dye, salt, saltpeter, gunpowder, lamp black and white lead

Beginning of chemical engineering and powder technology

- Important role in birth of chemical engineering(early 20C)

· Strong ties between chemical engineering and powder handing industries

· Important part of unit operations

☞ Early Texts in Unit Operations:Walker(1923), Badger and McCabe(1931) : devoted 40 % to particle processing

Neglected powder technolgy

- Following World War II, petrochemical industries: main stream of chemical engineering☞ gas-liquid, and liquid-liquid systems

· U.S.: neglect on powder technology

☞ lag behind Japan, Germany and U.K.

· Treated as "low-tech"

: Mathematical interpretation : not completely available

☞ Scale-up depends on empiricism

: Messy to handle and store

So, powder technology has been underdeveloped...

- Two-year study by the Rand Corporation(1986)
  - Recently built plants perform no better than those built in the 1960's.
  - Operate at only 50% of design capacity(1/5 : less than 20%)
    cf. average: 90-95% of design capacity
  - Start-up time : 6 times as long as liquid/gas processing plants
    (though 3.5 times expected)

Solutions

- Needs on basic research on solids behavior
  - Background theory
  - Equipment performance
- Needs the development of scale-up strategy
- Needs information feedback from plant engineers to designers and R & D departments.

Recently

- Inclusion of aerosol technology + beginning of nanoparticle technology

Trend in powder technology

	Powder in mass production (since '60s)	Particles as a source of air pollution (since '70s)	Particles as advanced materials (since '80s)
Process interested	Comminution (breakdown) Size enlargement Transportation Storage Collection (recovery)	Collection (removal) Growth (buildup) Transport	Growth (buildup) Dispersion Sintering Characterization Applications
Powders interested	Cement; fertilizer; flour; sugar; mining products; pharmaceuticals; pigments	Particles related with public health Meteorology and aerosol research Indoor air quality	New materials with new born properties: semiconductors, metals, ceramics, polymers, biomaterials
Size interested	$\geqq 10\mu m$	Down to submicron sizes	Nanoparticles

History of Nanoparticles

- 4c, Roman glassmakers, glasses containing nanosized metal particles: Lycurgus cup ☞ Explained by Michael Faraday(1857) and Gustav Mie(1908)..

- 18-19c, H.Davy, C.Maxwell(1861), G.Eastman(1883), Photographic films using silver halide photochemistry (silver nanoparticles)

- 1958, Richard Feynman, a lecture entitled "There are plenty of room at the bottom." ☞ predicted the existence of electron beam lithography, scanning tunneling microscope and building circuits on the scale of nanometer for powerful computers

- 1960s~1970s, preparation of nanoparticles by gas evaporation-condensation method ☞ Quantum confinement (Kubo) effect

- 1981-1986 Japan, Ultra-Fine Particle Project under the auspices of the Exploratory Research for Advanced Technology program (ERATO)

☞ preparation, characterization, properties, applications

- 1981 G.K. Binnig H. Roher(IBM Zurich): invented scanning tunneling microscope (1985 Nobel prize)

☞ obtained atomic-scale three-dimensional profiles of surfaces

- 1985 R.Smalley, R.Curl and H.Kroto discovered C_{60} (Nobel Prize in 1996).

☞ officially known as buckminsterfullerene (exactly like a football).

*- 1991, Iijima made **carbon nanotubes** (multi-walled), Single-walled(1993)*

*- 1996 NSF et al., **assessed current worldwide status of nanoscience and nanotechnology***

*- 2000.2 B. Clinton, **National Nanotechnology Initiative***

☞ Followed by Japan, EU and other countries..

- 2003, Prototype solar cells (Nanosolar Inc.) with conducting polymers and nano-based particles.

☞ much cheaper and easier to make.

☞ produced in flexible sheets, making them suitable for many applications