Global Focus on Knowledge

The Production and Application of Matter

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Prof. Yasushi Suto — The Origin of Matter

Prof. Yasuhiro Iye — The Character of Material

Prof. Masakatsu Shibasaki — Material and Living Organisms

1. The Structure and Properties of Matter

The property depends on its structure

Materials of the same crystalline phase can show different properties

Hard and soft irons

Colorless, Yellow, and Black Diamonds

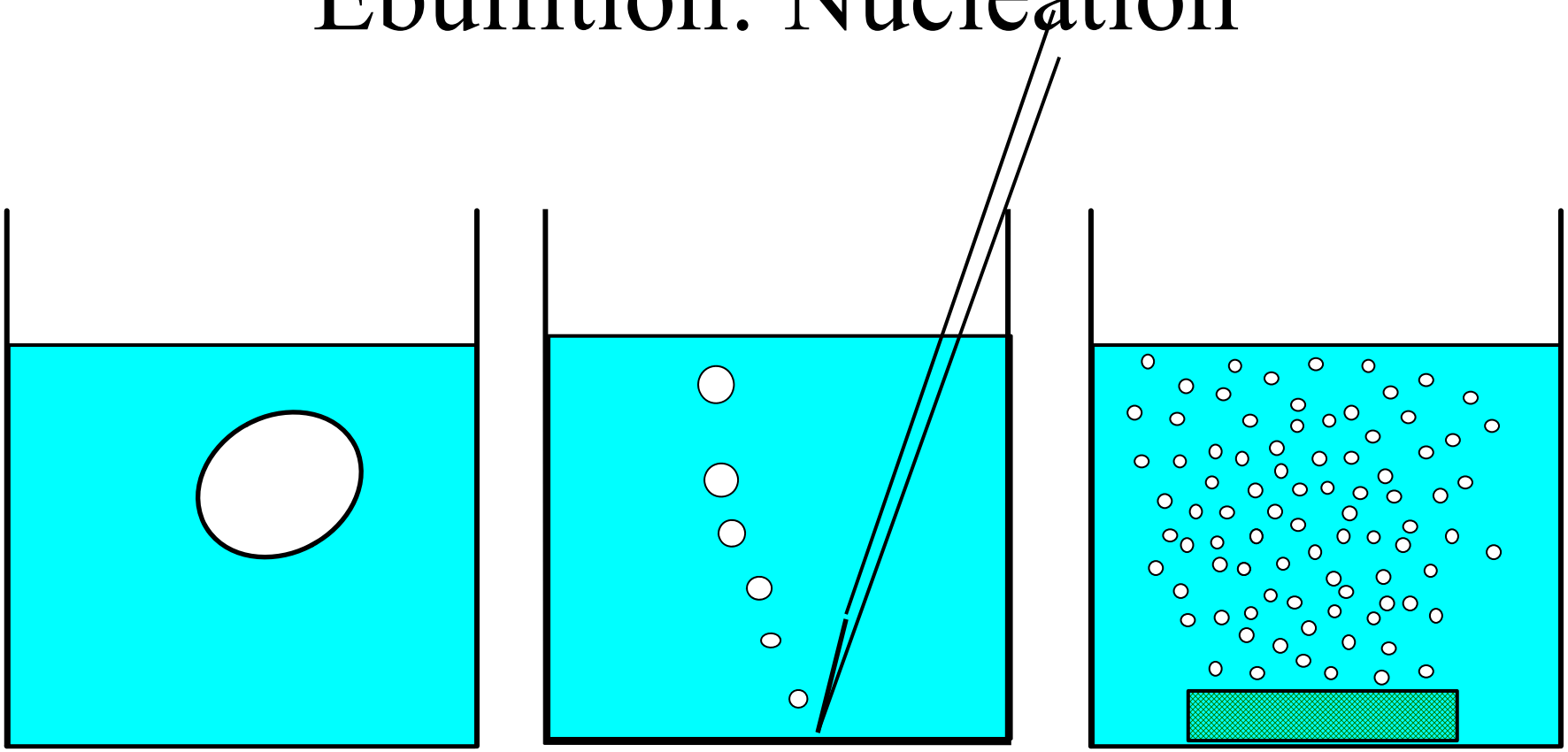
Ductile, powdery, and smooth split silicon.

1.1 Dynamic Characteristics

Water does not start boiling at 100 ° C.

Water does not start freezing at 0 ° C.

Dynamic Models of Liquid Ebullition: Nucleation

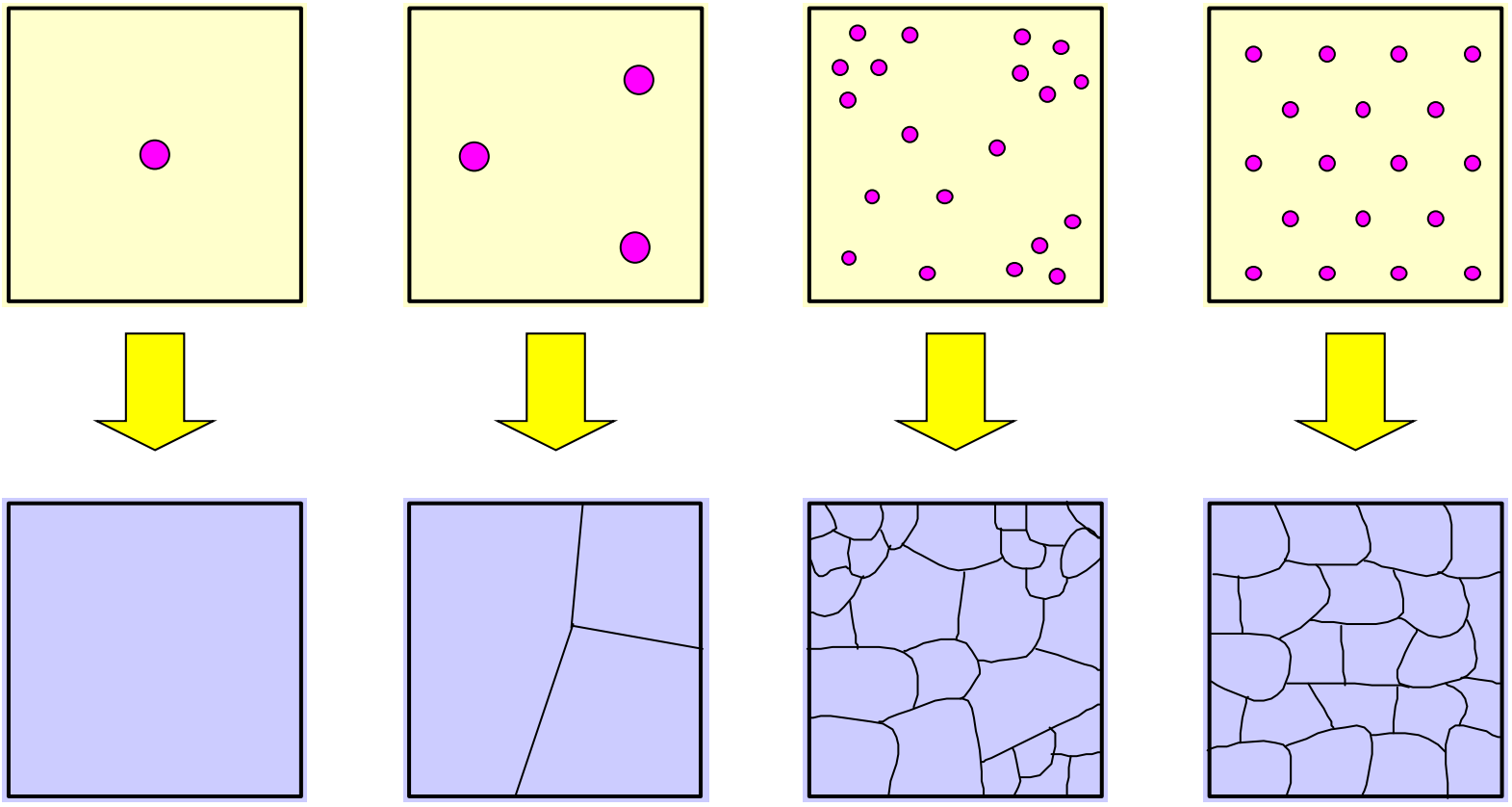


Bumping

Capillary Tube

Madreporite

1.2 Diversity of structure: nucleation -> crystal



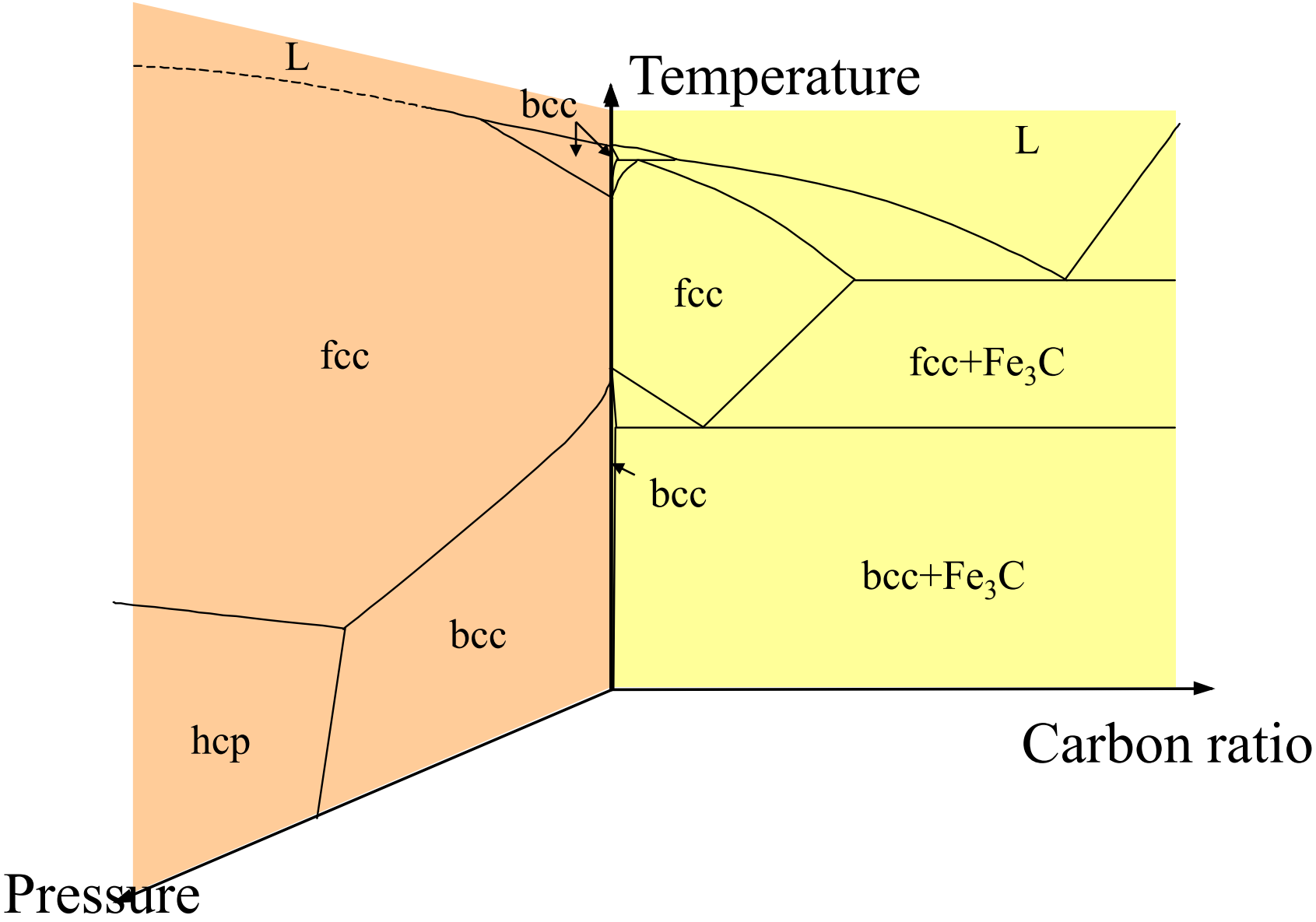
monocrystal

Polycrystal

Uniform structure

Uneven structure

Diversity of Structure : Phase diagram of iron



1.3 Almost all of substances on the earth Are in non-equilibrium state

Liquid water at 120℃ or -10℃

Diamonds are in equilibrium state under high pressure

Iron should be in the form of iron oxide in equilibrium state on the earth

Calcium carbonate in the ocean Is supersaturated

1.4 the properties of Matter are attributed to its structure

The same material can have infinite kinds of structure

(distribution of crystal forms and their scales)infinite

×(Phase types) infinite

×(structures at phase boundaries)infinite

→infinite

Natural phenomenon mediates structure control

(The formation and the growth of nuclei)

1.5 **The definition and elements of the Production Process of Matter**

Definition: to realize a structure in a particular range out of all the structures of infinite possibility by making a phenomenon in a particular range proceed out of all the phenomena of infinite possibility.

Four elements of the production process

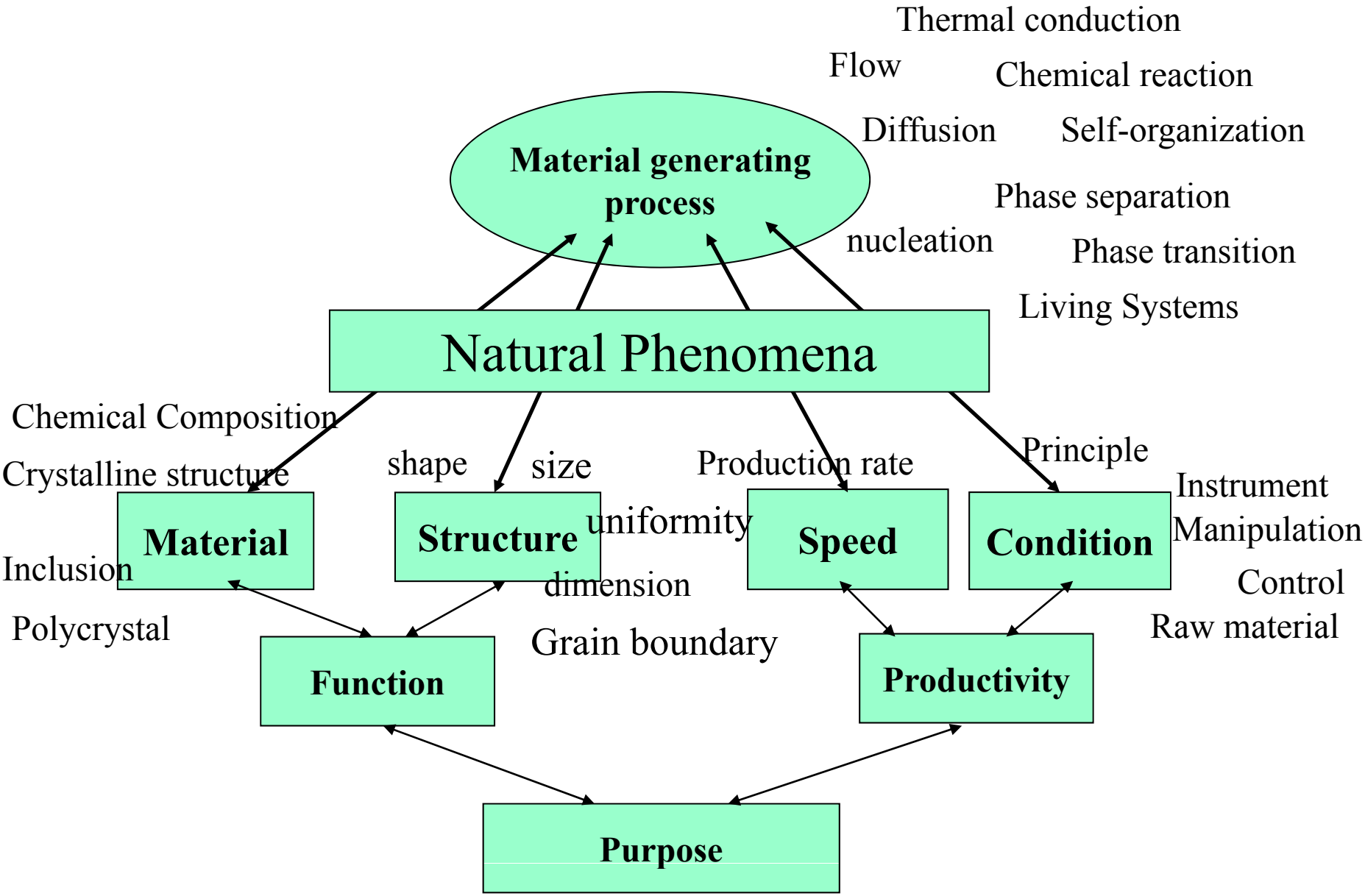
Material: Chemical composition, Crystalline(amorphous) phases, impurities(inclusions)

Cf. Prof. Iye's lecture

Structure: Polycrystalline (amorphous) structure… form, size, uniformity, dimension

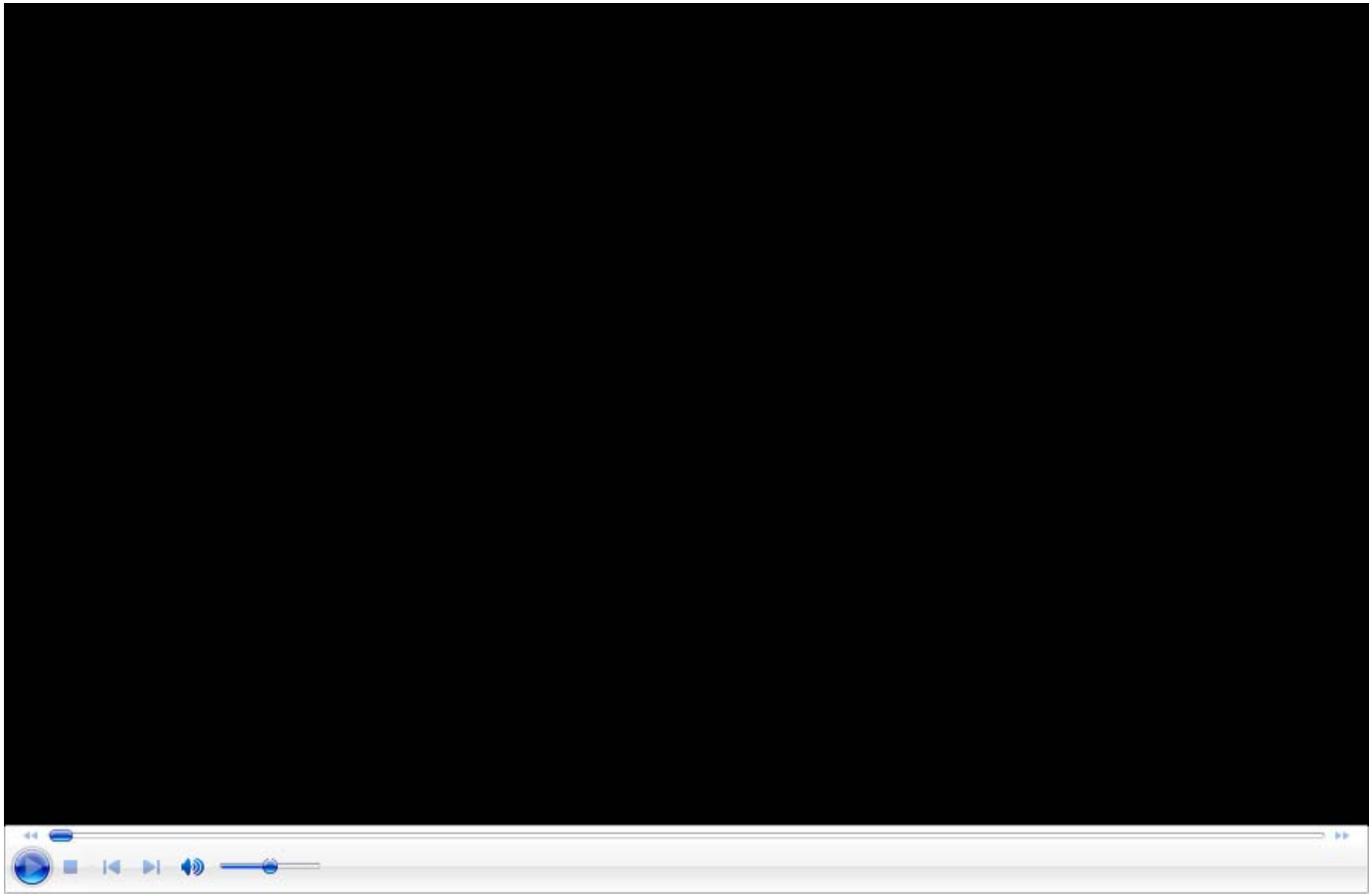
Speed: generation rate

Condition: Principles, Instruments, Operations, materials, and control


Thermal conduction
Flow
Chemical reaction
Diffusion
Self-organization
Material generating process
Phase separation
nucleation
Phase transition
Living Systems
Natural Phenomena
Chemical Composition
Crystalline structure
shape
size
Production rate
Principle
Instrument
Manipulation
Material
Structure
uniformity
Speed
Condition
Inclusion
Polycrystal
dimension
Grain boundary
Control
Raw material
Function
Productivity
Purpose

Steel is used in many ways

2.1 pig iron(a blast furnace): iron ore Fe_2O_3→deoxidized→Fe



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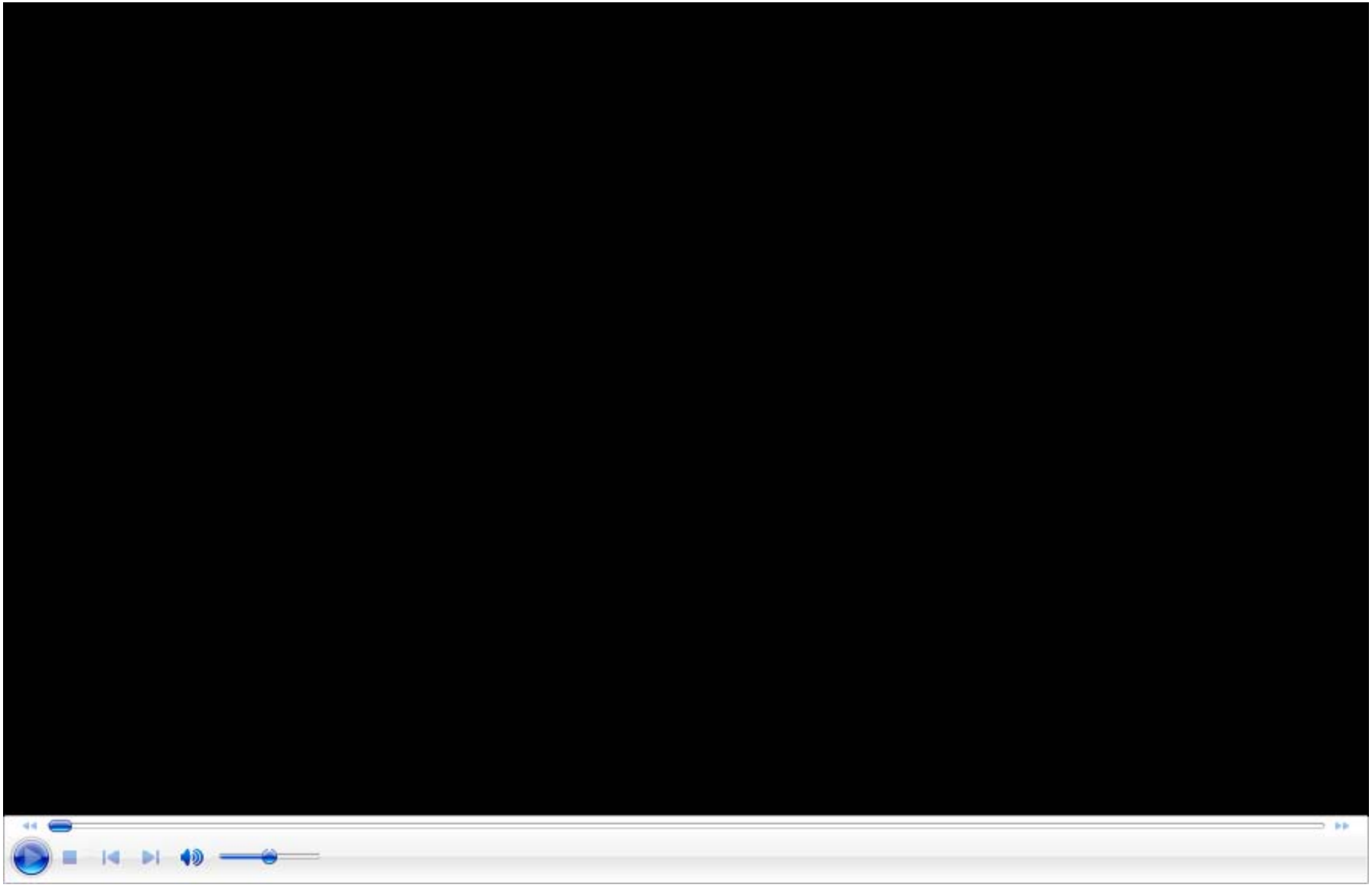
2.2 Steelmaking（converter furnace）



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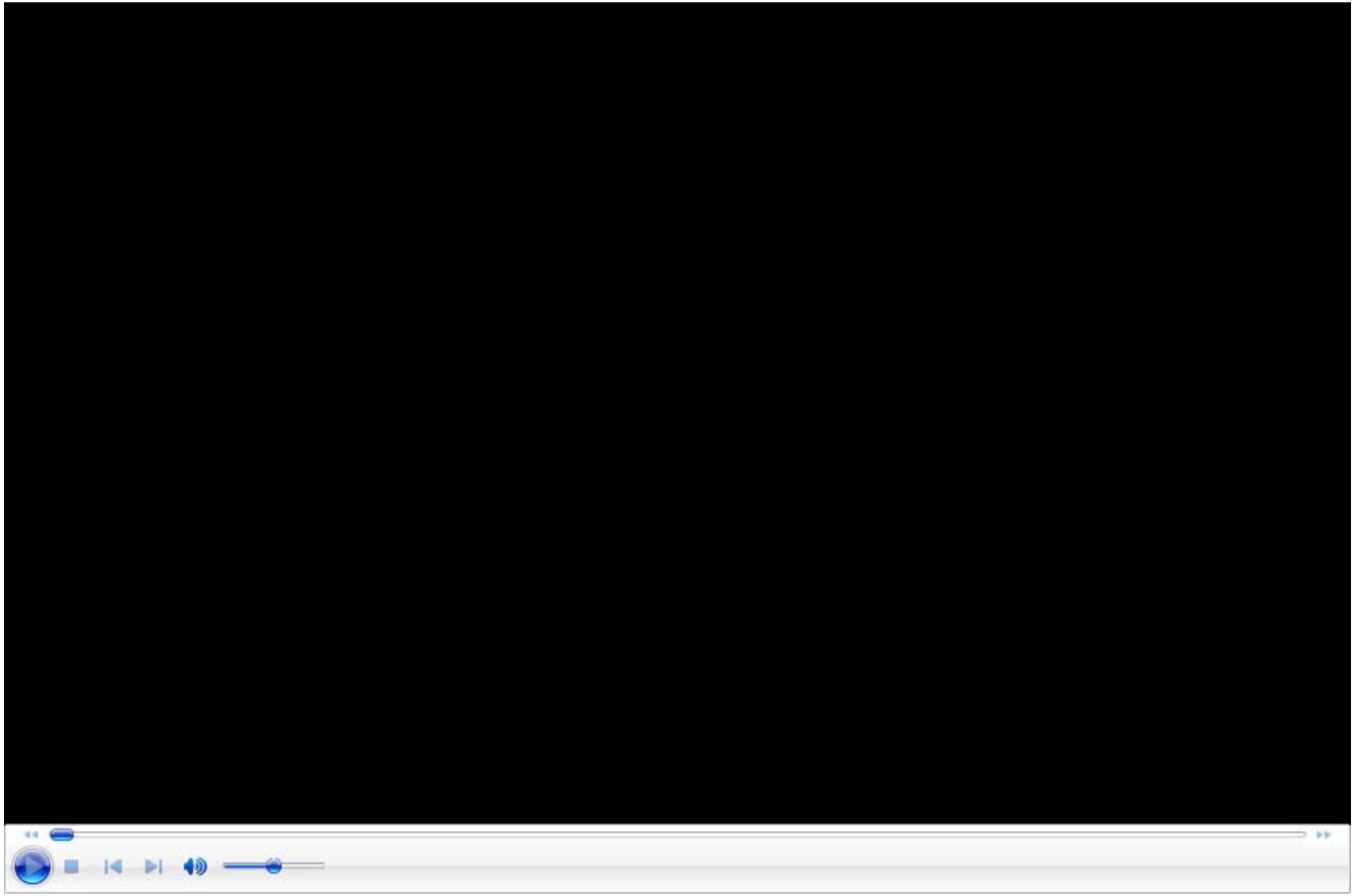
2.3 Continuous Cast (CC)



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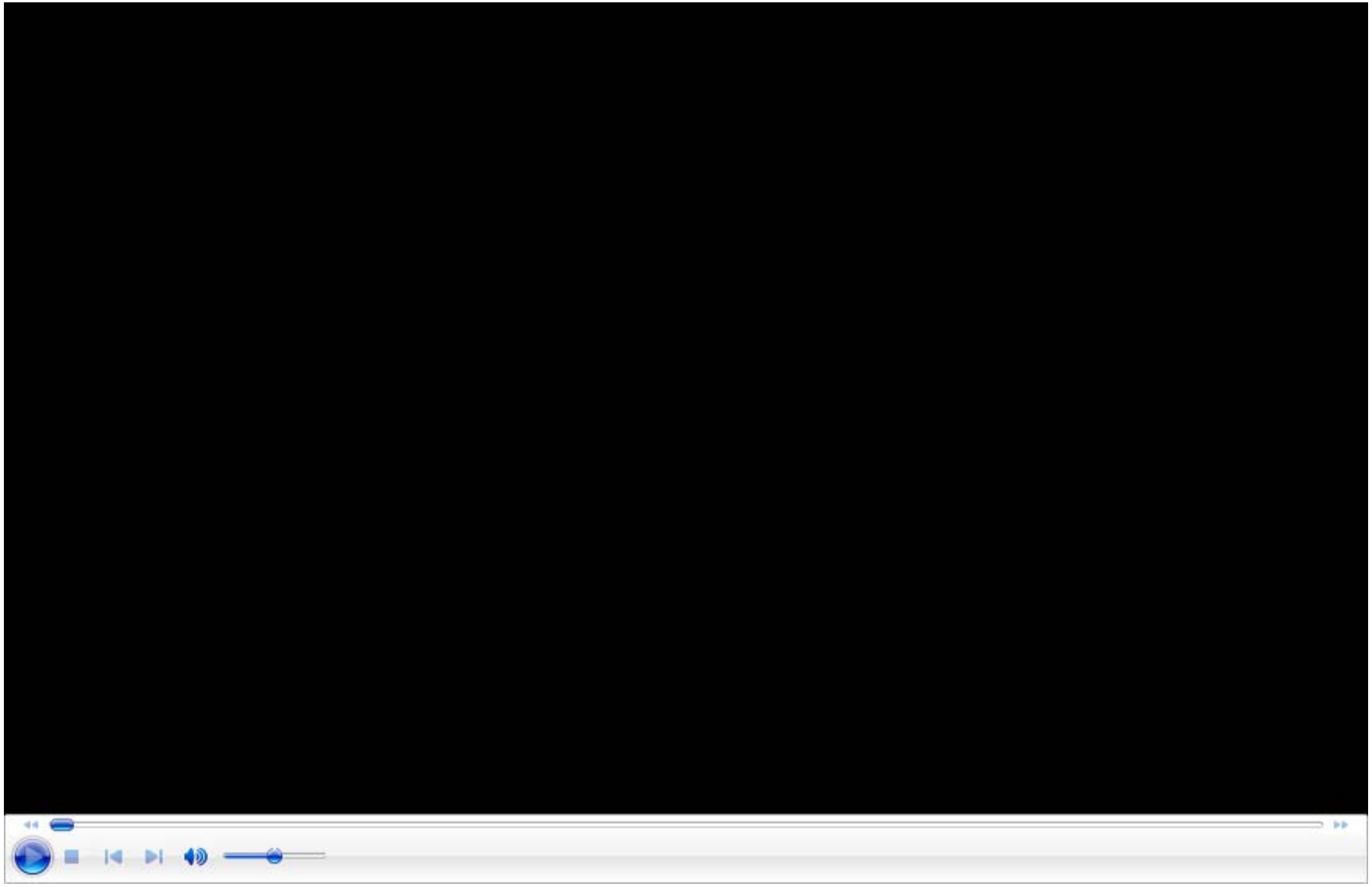
2.4 hot rolling

rolling ()（deformation driving, solid small-size crystal particle



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2.5 Outline of an iron-making process

- Shaft furnace（deoxidizing iron oxide）
- Converter furnace（removing impurities）
- Casting（Liquid → Solid）
- Rolling（crystal fine grain）
- Control：When Rolling

  Pressure, Temperature, Speed of Roll

  Uniformity (μm to km)

  Feedback, Feedforward

2.6 Four elements in the production of matter

Material : Composition, Crystalline phase, impurities (inclusions)

Structure: polycrystalline structure, form, size, uniformity

Speed : rate of the process

Conditon : Principle of the process, instruments,

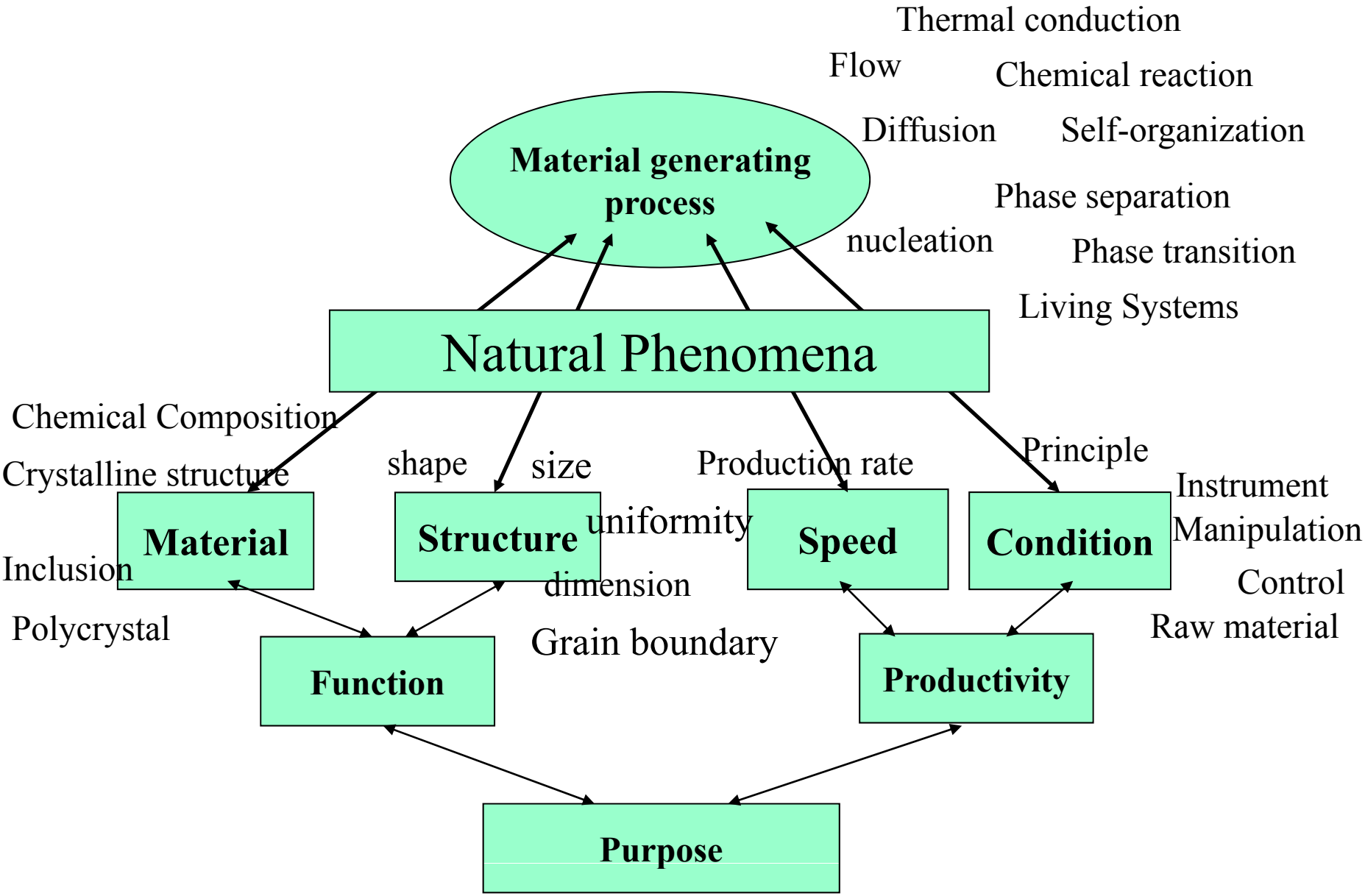
Operating condition (Temperature, Pressure, Concentration),

Control, Measurement

Matter and structure →function (property)

Speed and Condition →Productivity

Function and Productivity → Application range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Living Systems
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Chemical Composition
Crystalline structure
shape
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Production rate
Principle
Instrument
Manipulation
Material
Structure
uniformity
Speed
Condition
Inclusion
Polycrystal
dimension
Grain boundary
Control
Raw material
Function
Productivity
Purpose

3.Function and Applications (an example:Steel)

3.1 Thin plate for automobiles

High strength and elasticity thanks to controls over phase transitions

→weight saving, collision safety

3.2 Wire ropes for Akashi Kaikyo Bridge

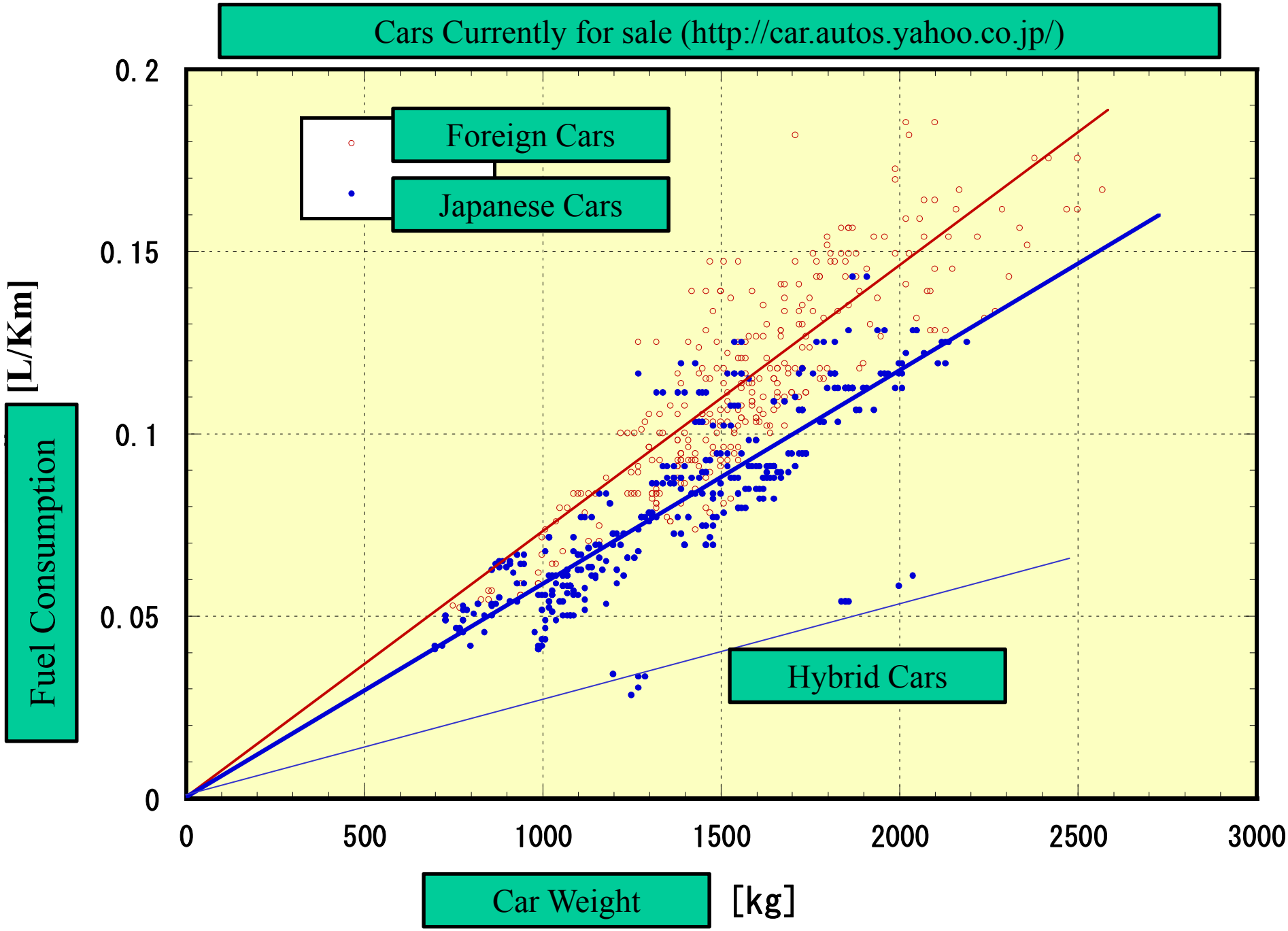
High strength thanks to nano self-organization

→long span structure

3.3 Supermetals

High strength thanks to superfine crystal grain

→high recyclability, high strength material


Cars Currently for sale (http://car.autos.yahoo.co.jp/)
Foreign Cars
Japanese Cars
Hybrid Cars
Fuel Consumption [L/Km]
0.2
0.15
0.1
0.05
0
0
500
1000
1500
2000
2500
3000
Car Weight [kg]

3.1 Structure and Energy absorption:

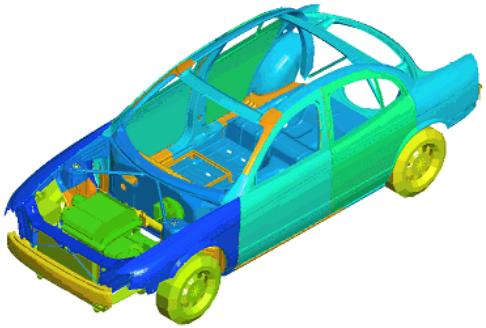
Pressure-Induced Structure Change and high strength steel

Car-to-car 50% front offset impact test (50km/h)

（http://www.toyota.co.jp/jp/tech/safety/）

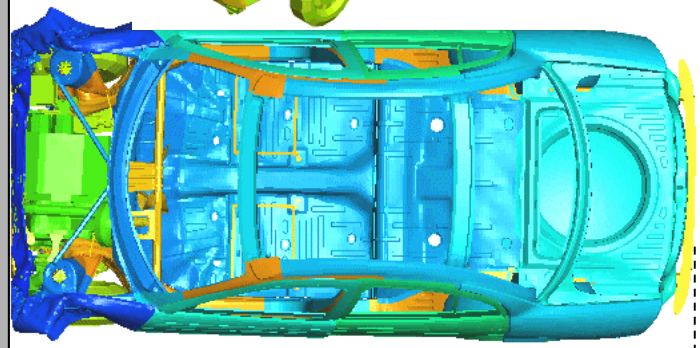
safe

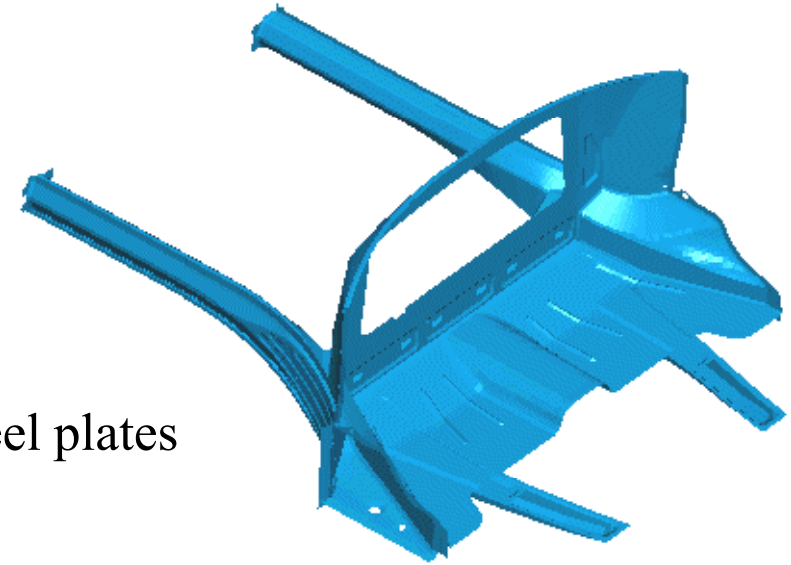
injured



Movie: Front frame transformation

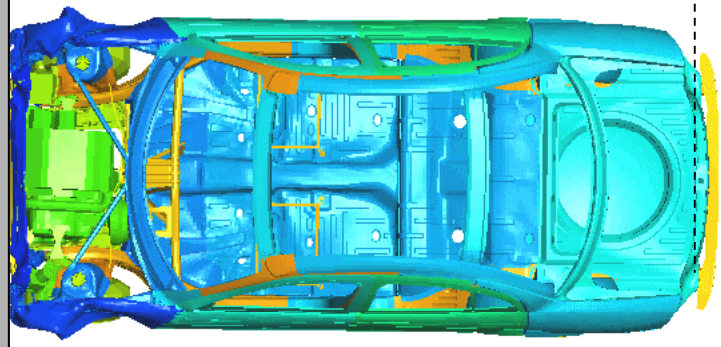
Equivalent to the plastic strain

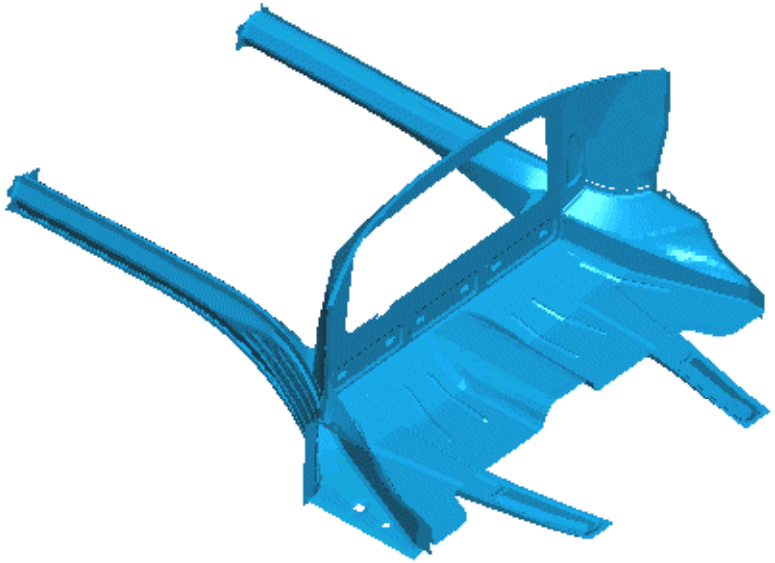




A frame that consists only of soft steel plates
(passengers are seriously injured)

Rigid Wall

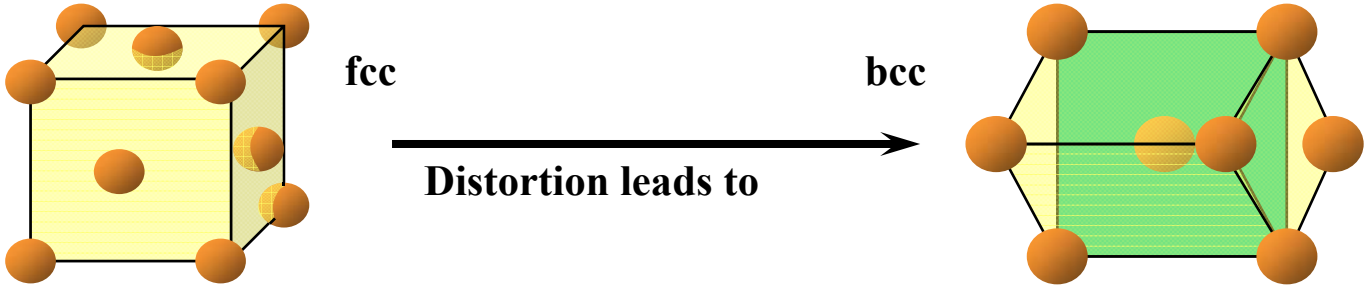




A frame with some high-strength
steel plates properly arranged
(passengers are safe)

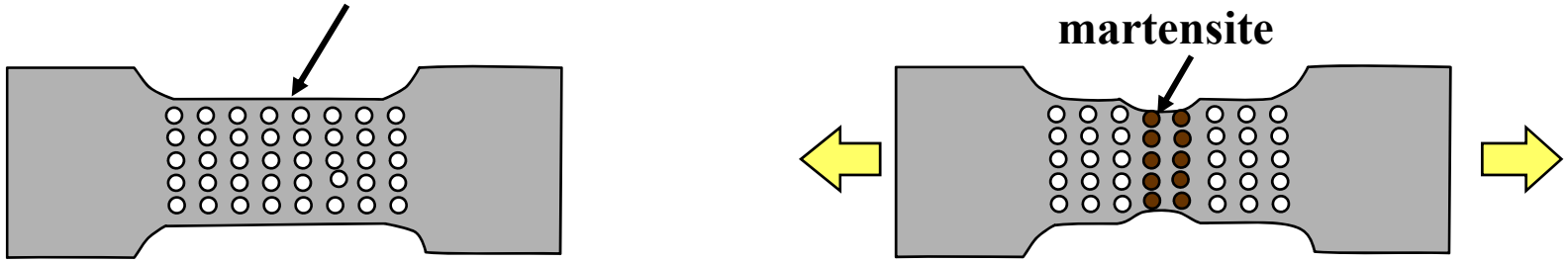
High-Strength Steel produced by Fabrication-Induced Structural Change (Process-Induced Transformation)

In no time, (distortion → transformation → hardening)
leading to martensitic transformation →hardening



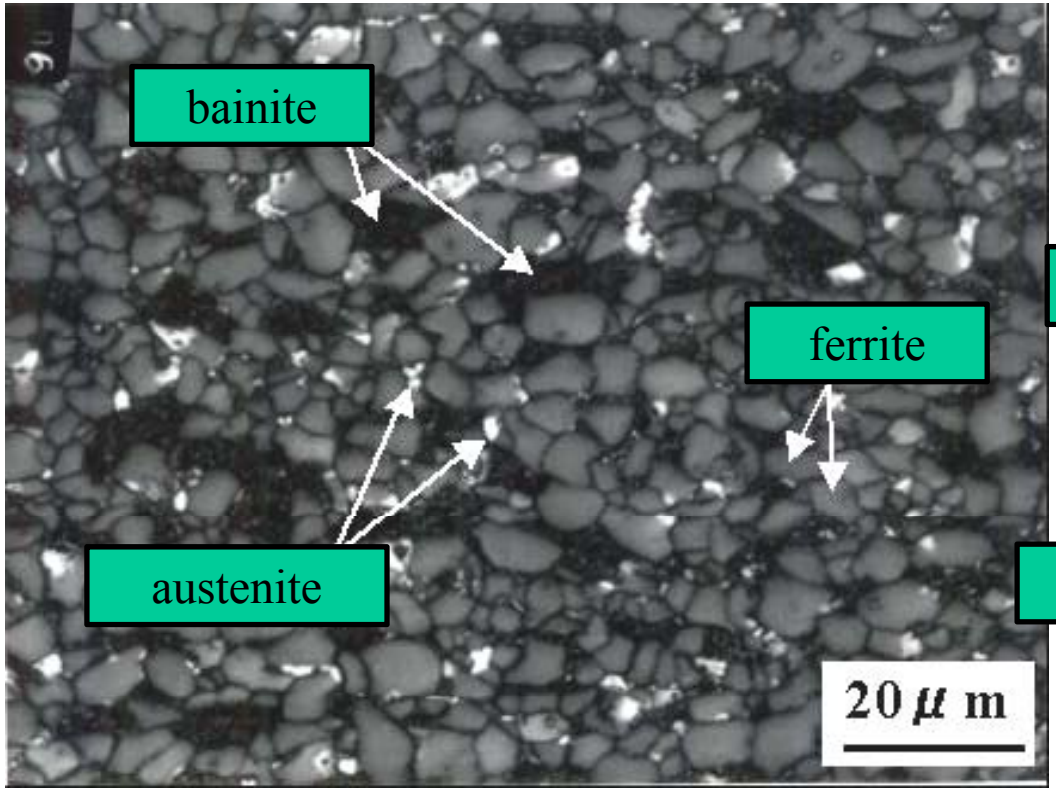
γ: austenite

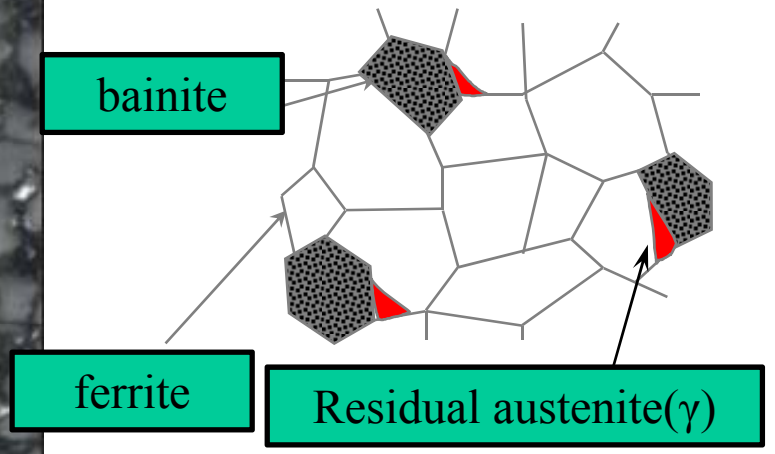
α': martensite（hard phase）



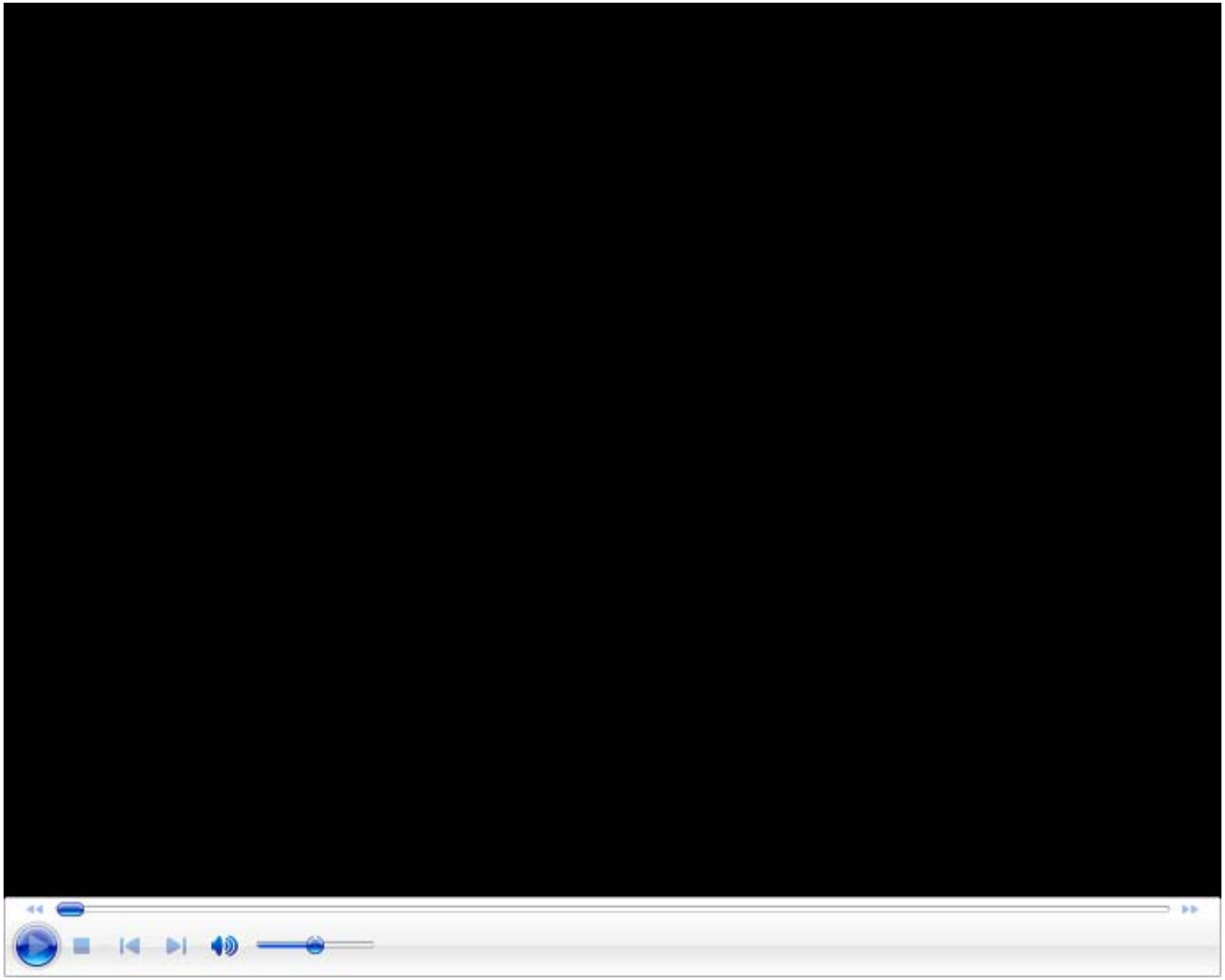
Remaining austenite (soft) is distorted, and transforms to hard martensite
Distortion propagates uniformly, and there are few local constriction,
Realizing high ductility

Structures of TRIP steel





○manufacturing automobile steel plates



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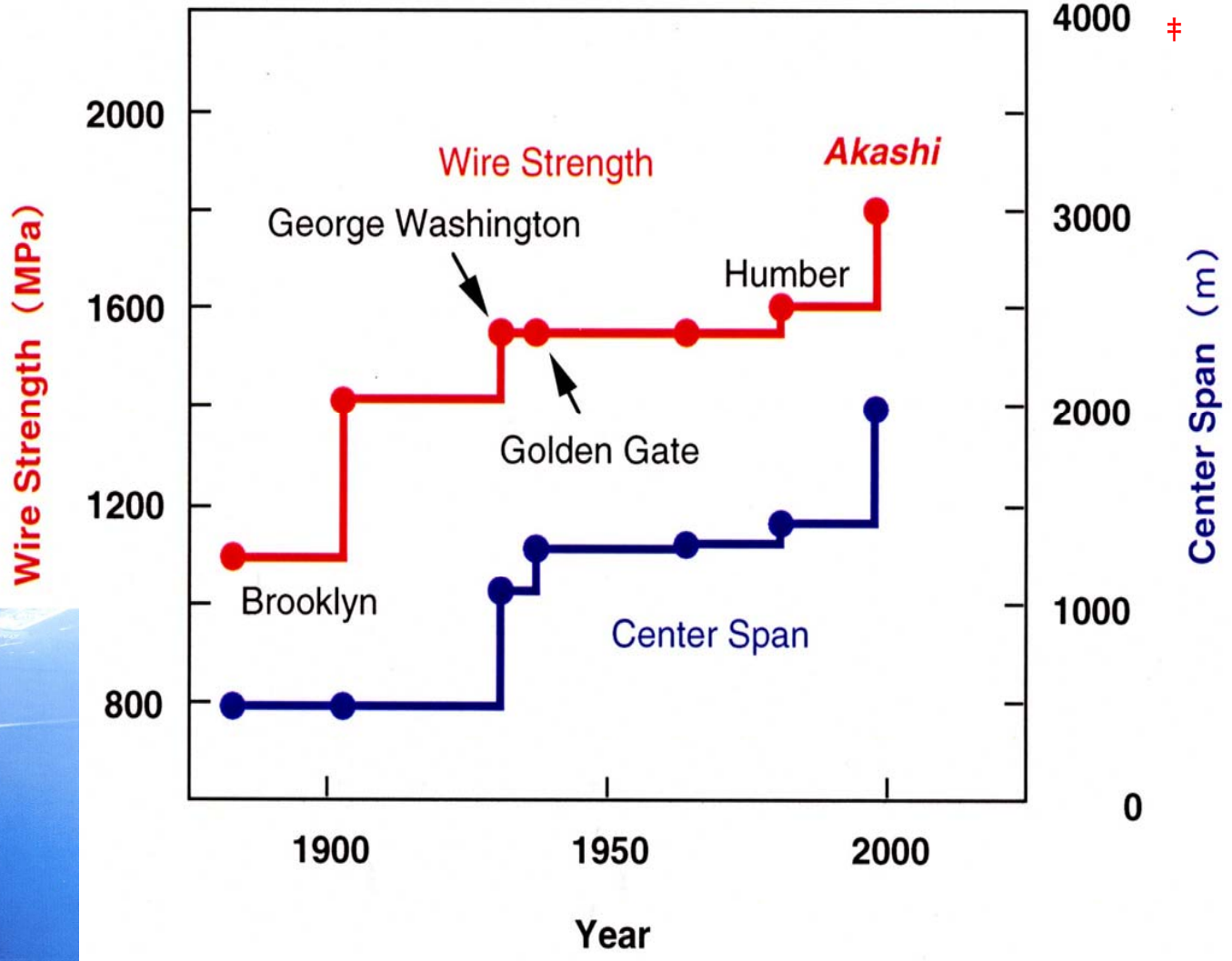
3.2 High-Strength Steel at Akashi Kaikyo Bridge:

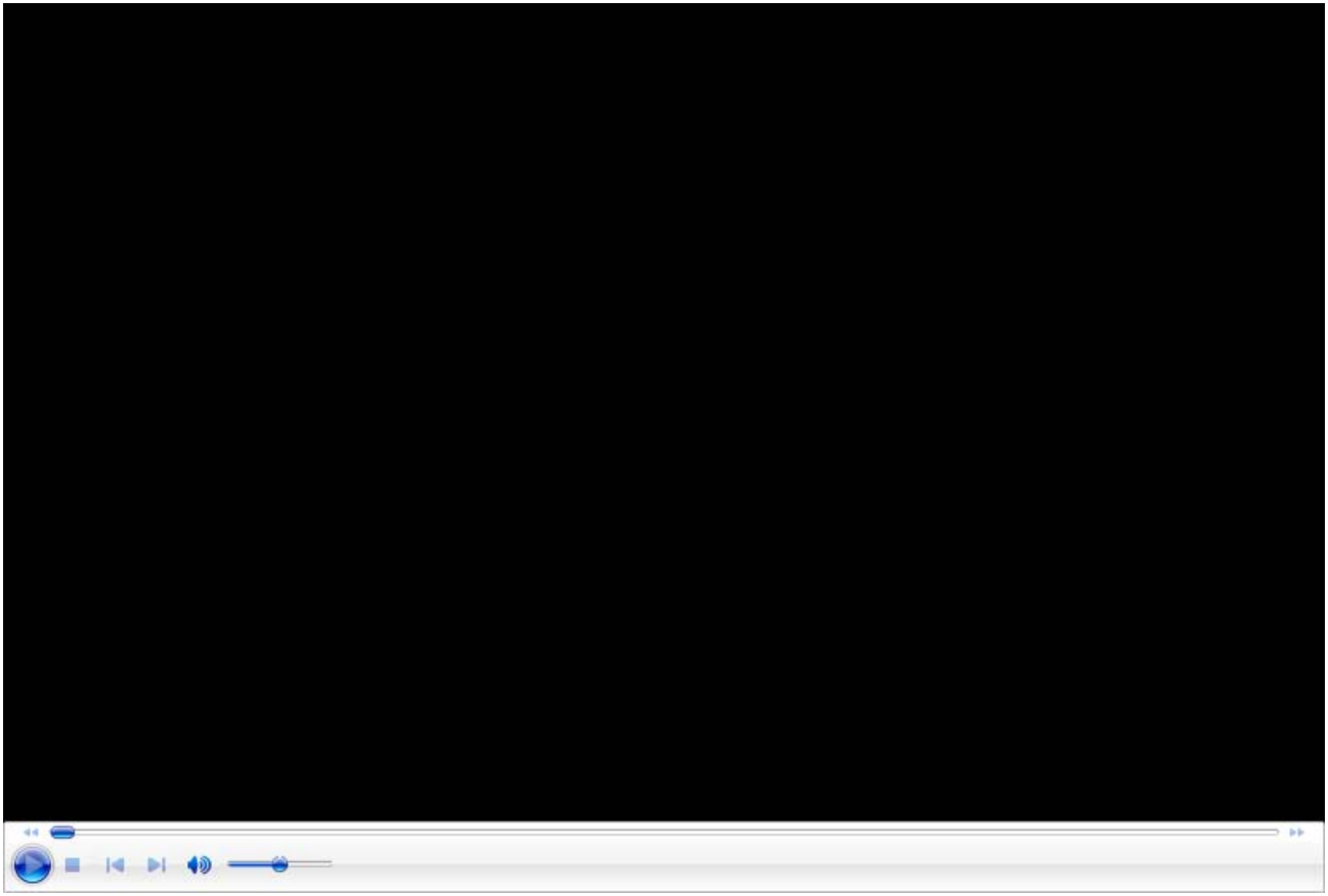
High-strength wire for bridges with texture control technology at atomic level

‡

Strength of zinc galvanized steel wire for bridges



○Akashi Kaikyo Bridge



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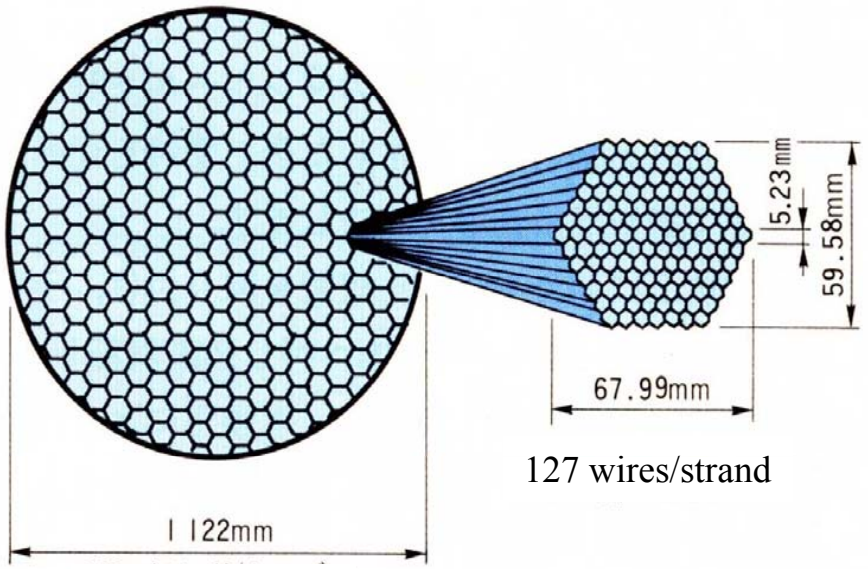
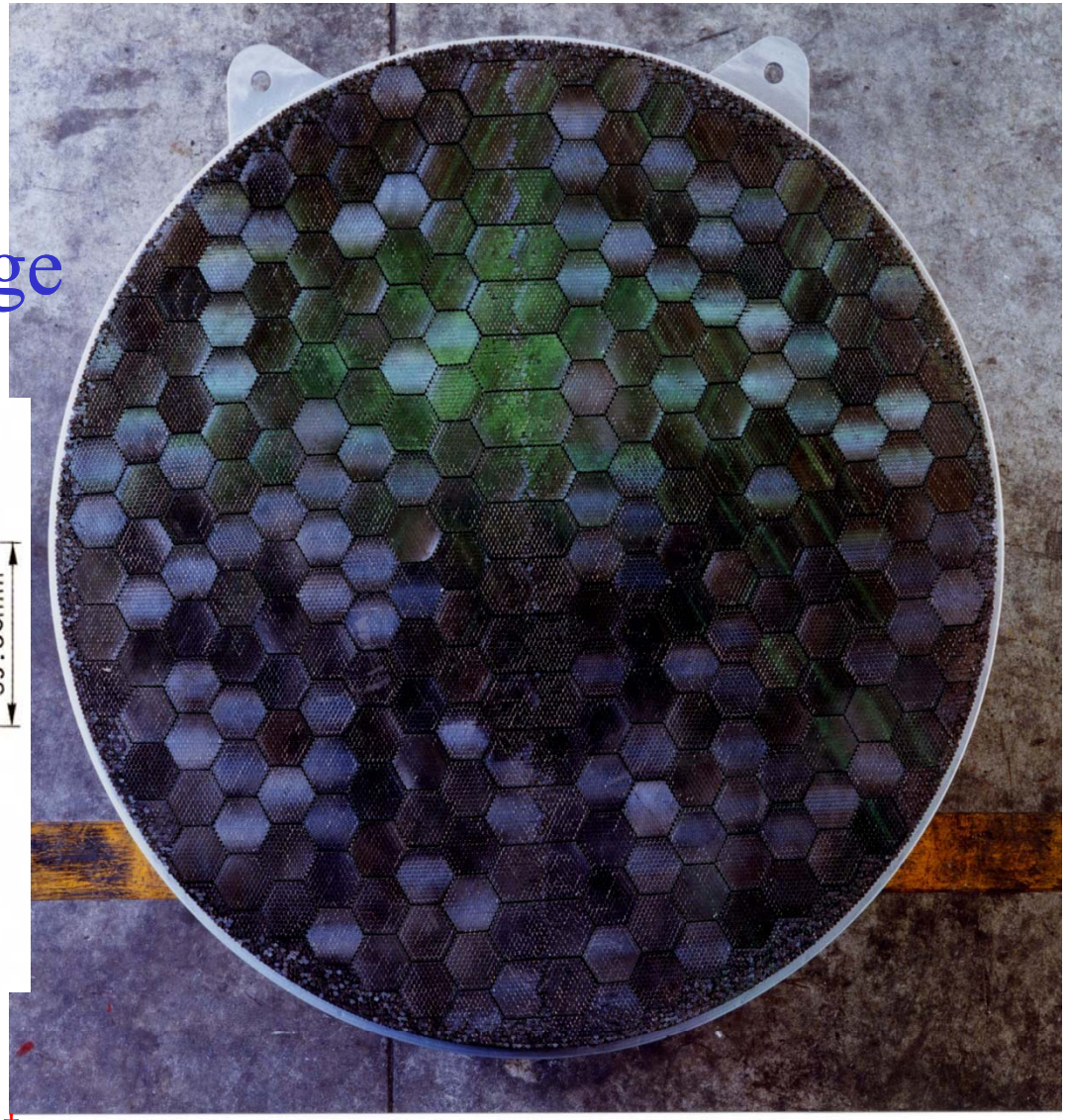
Cross-Section of Main Cable at Akashi Kaikyo Bridge



290 strand/cable

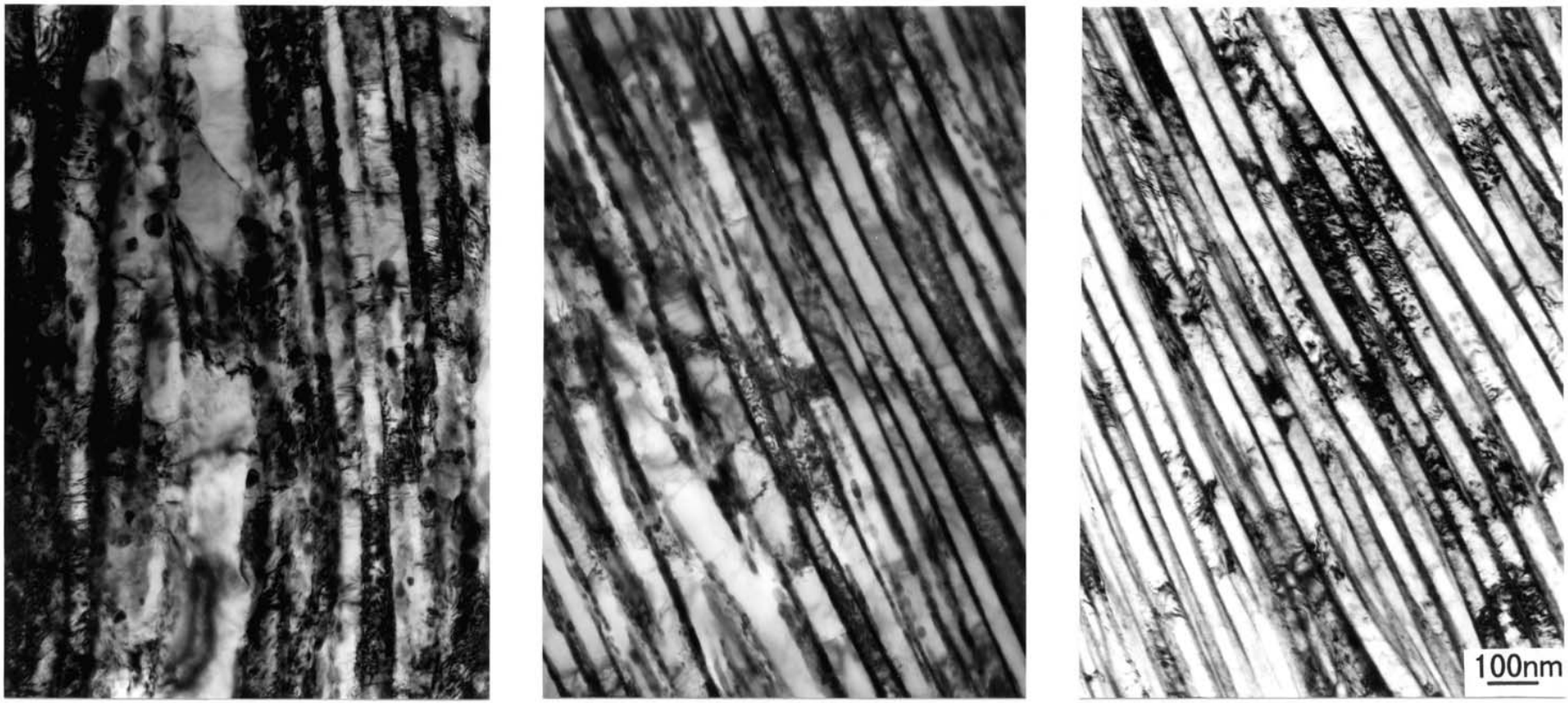


Cross section of main cable used for Akashi Strait Bridge.

Strength of galvanized wire	: 1800 MPa
Diameter of galvanized wire	: 5.28 mm
Diameter of main cable	: 1.12 m
Number of galvanized wire / cable	: 36,830
Weight of main cable	: 25,265 ton

Wires used previously and wires for Akashi-Kaikyo Bridge

after galvanization of Si,Cr-induced steel
(keeping the structure)



0.82%C　　0.82%C—Si　　0.82%C—Si—Cr

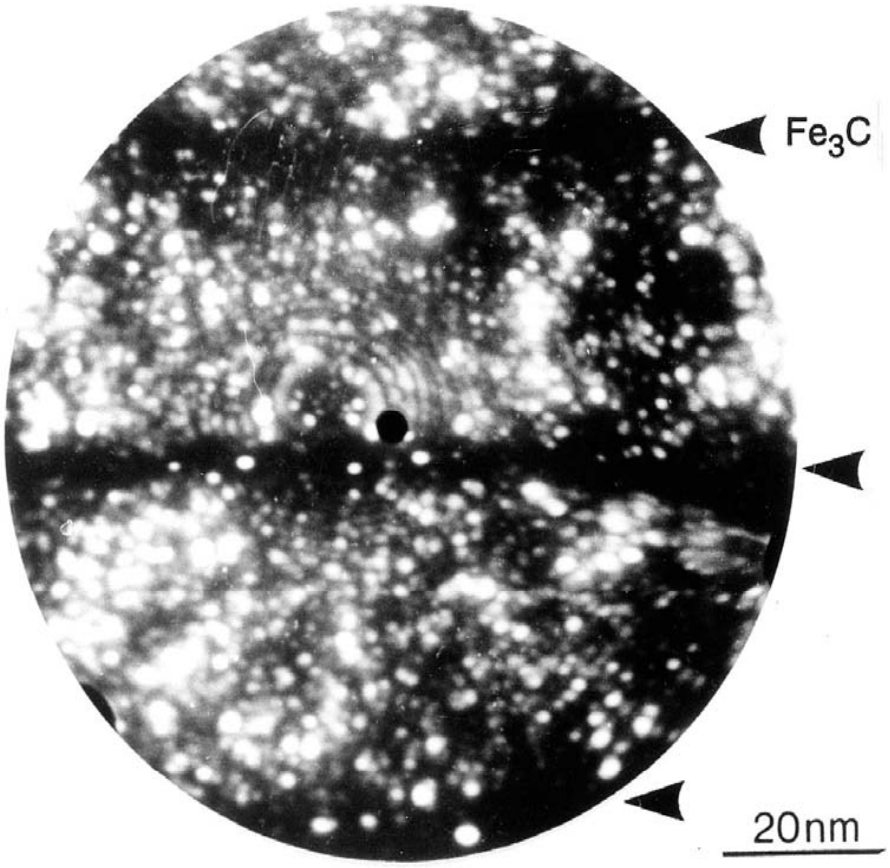
Previously used steel

Transmission electron micrographs of wire aged at 450℃

‡

AP-FIM of steel wire

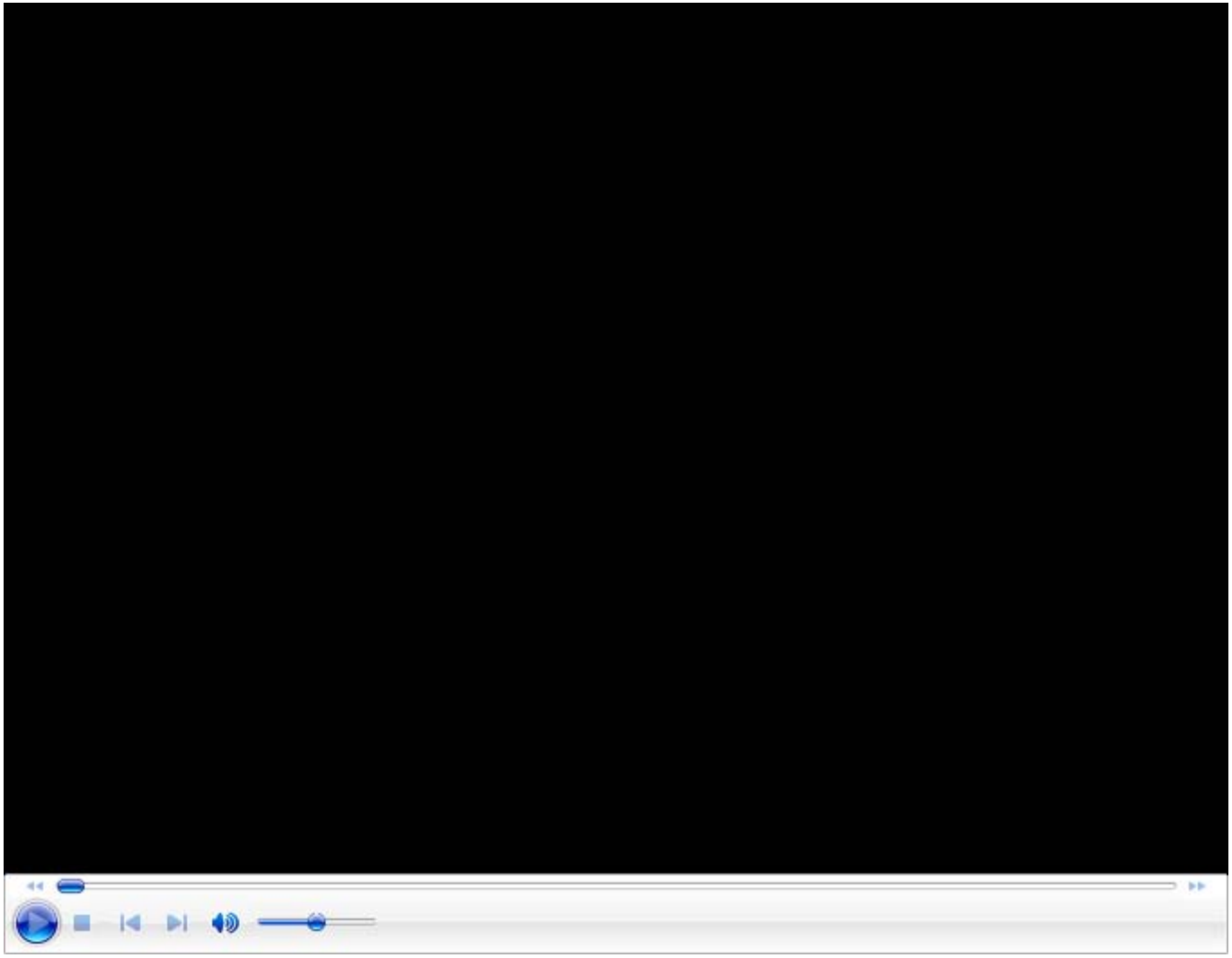
‡ TEM image of FIM sample

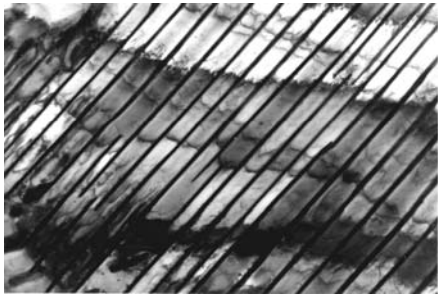


‡ FIM

○wire rod rolling

＜NSC/Kimitsu, Tokyo Rope MFG/Tsuchiura＞





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3.3 Supermetals

Transition of public demand

Mass production of ordinary products

Efficient production

Energy saving, resource saving,

Environment, Automation,

Highly-functional, high-tension, high-tenacity

Even higher function

New demands

Crash safety

Materials for a sustainable society:

Energy saving、horizontal recycling

Simultaneous achievements

Recyclability

Iron is recycled →electric furnace

400 million tons of steel out of 1.4 billion

Produced annually are for scrap metal

homogenization and degradation as a

Consequence of recycling

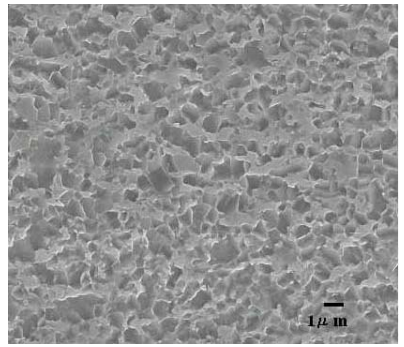
Now used as constructional materials

Supermetals

Controlling the structure of matter

Composed of only single element

○rolling experiment of ultra fine particle steel



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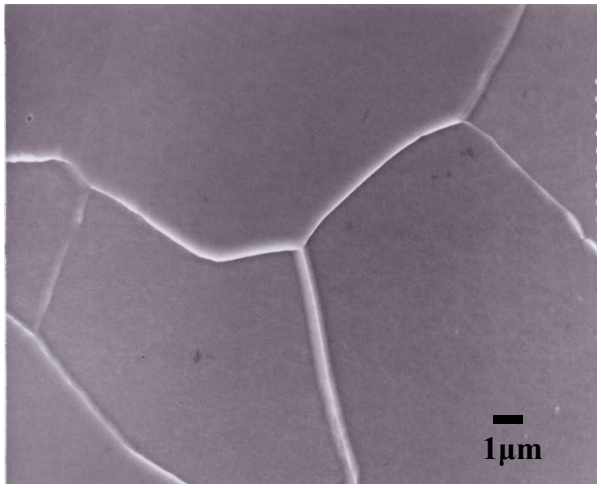
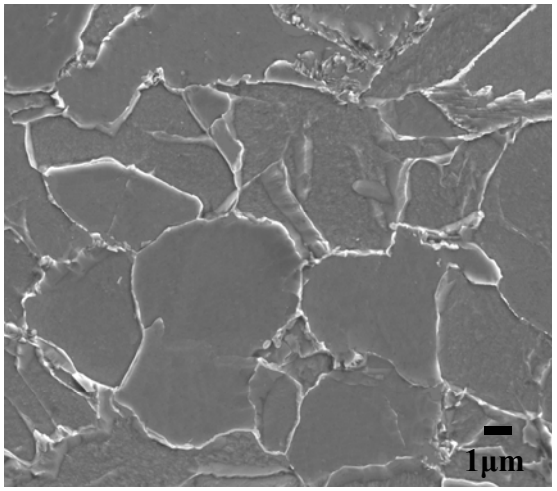
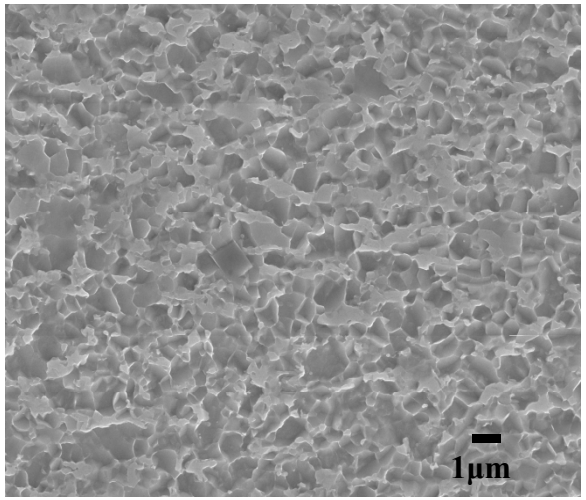
High strength thanks to small size of crystalline particles

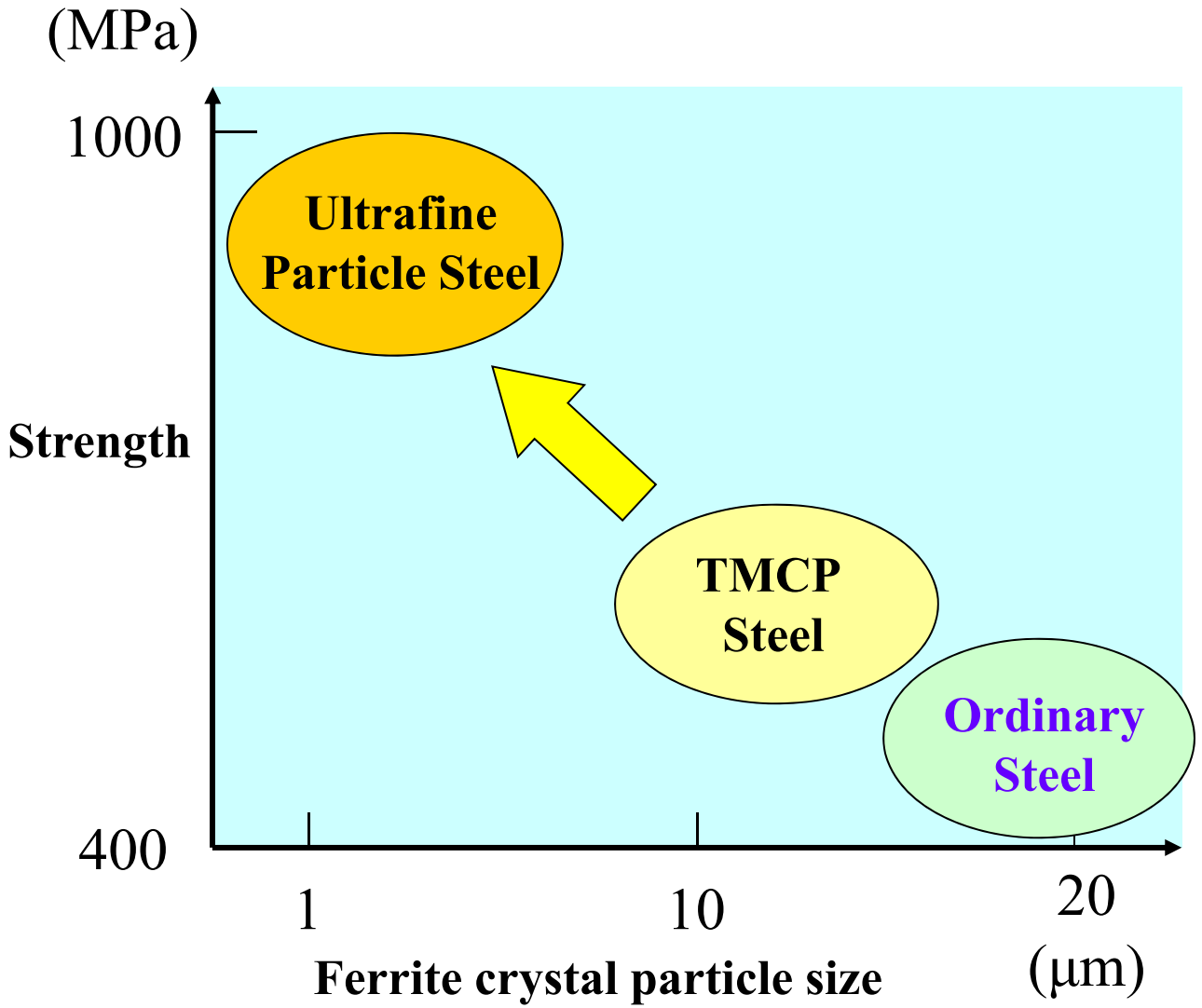






Previous（same as rolled）　　TMCP steel　　ultrafine particle steel

‡



‡ Figure 1.the increase of strength due to the size of crystalline particles (a frame format)

The definition and elements of manufacture

Definition

Causing selected phenomena Realizing selected structure

- Elements

  Material : Composition, Crystalline Phase Structure, impurities (contaminant)

  Structure : Various crystalline structure, form, size, uniformity, thickness

  Speed : Speed of the process..

  Conditions : Principle, Device, manipulation, heat control, measurement

4.Outline of this lecture

Lecture One：manufacturing processes　e.g. metal(steel)

Lecture Two: Conjugation (devices)

semiconductors, inorganic materials

soft matters, e.g., liquid crystals

Lecture Three：materials for a sustainable future

fuel batteries, microchips

End of Lecture One