The effects of CNTs for lithium-ion batteries as additives

(USE Of VGCF™ (Vapor Grown Carbon Fiber) Additives For Lithium Ion Batteries)

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1. Review the history of Lithium Ion Battery (LIB)
2. Properties of VGCF™
3. Application of VGCF™ for LIB as additives
4. New applications of LIB in future
5. Safety issues on VGCF™
6. Summary

The history of LIB applications

1991～ (900 mAh) ⇒ **2000～** (2000 mAh) ⇒ **2008** (2800 mAh) ⇒ Future

Longer cycle life

Larger capacity

Higher power

Quick charge

Short life time

Smaller capacity

Improvements; Cell design, Electrolyte, Active materials, Additives, etc.

VGCF™ has been employed as additives of LIB for more than ten years.

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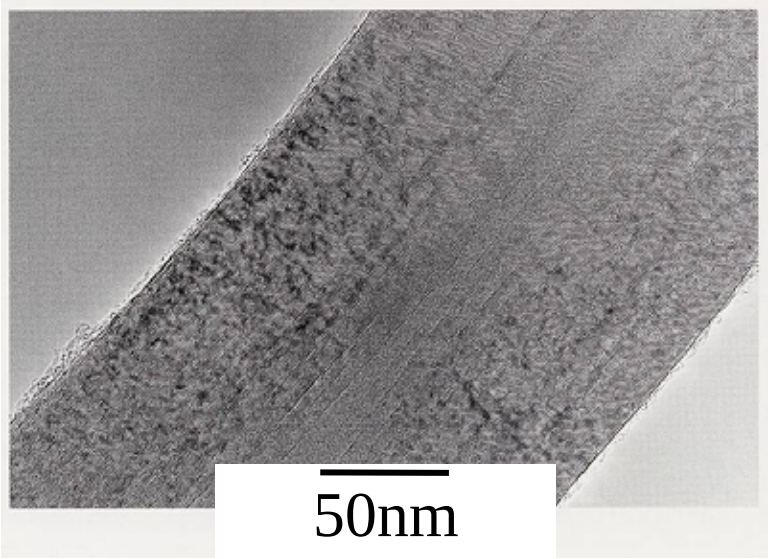
Typical properties of VGCF™

Multi Wall Carbon Nano-Tube



Fiber Length (Ave.)	8	μm
Fiber Diameter (Ave.)	150	nm
Real density	2.19	g/cm^3
Specific Surface Area	13	m^2/g
Conductivity	0.1	mΩ·cm

VGCF™ has graphene layers like tree rings and possesses excellent electric conductivity along to the fiber axis.

C. Sotowa, M. Takeuchi, ***LLIBTA in AABC 2008.***

C. Sotowa, M. Takeuchi, 2A17, ***Battery Symposium in Japan 2007.***

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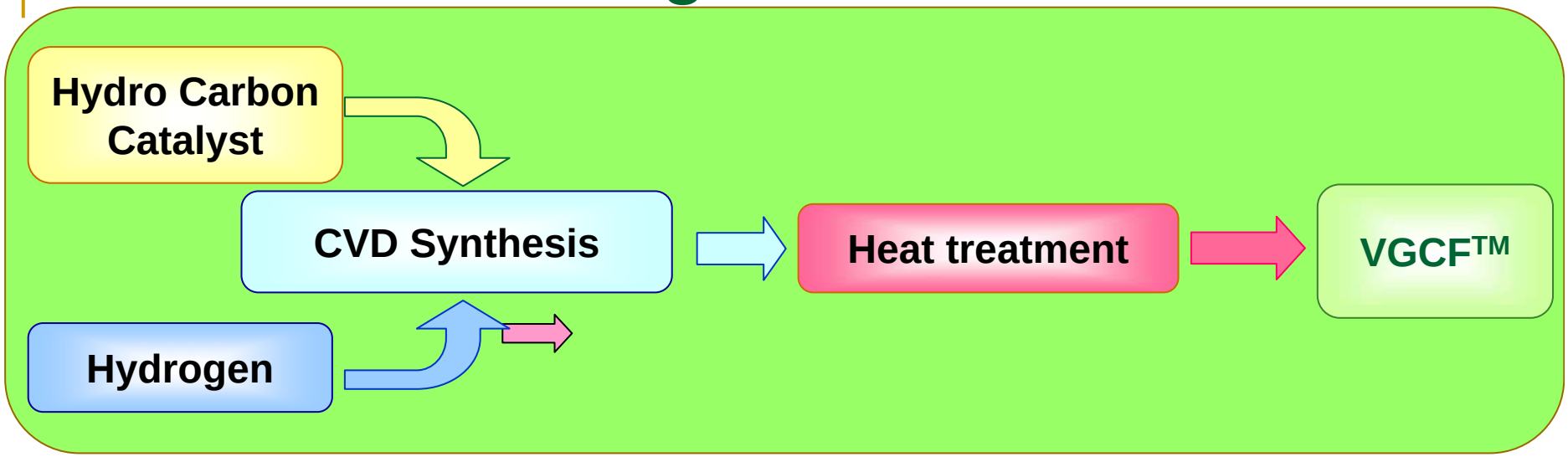
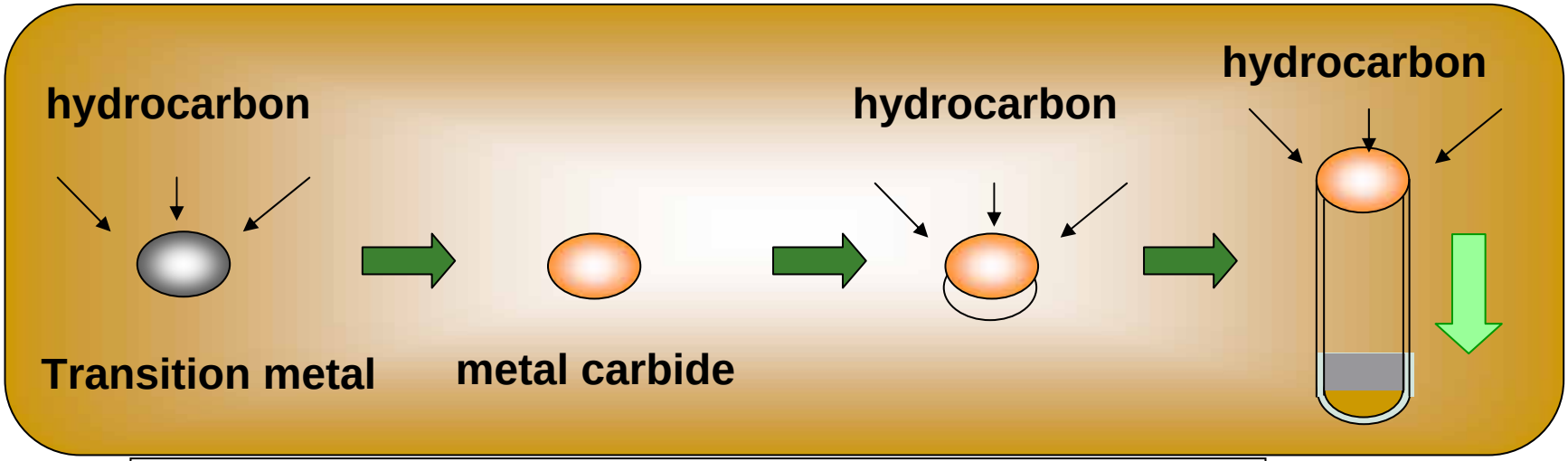
The Manufacturing Method of VGCF™





A.Oberlin, M.Endo, T.Koyama; *J.Cryst.Growth*, 32, 335 (1976)

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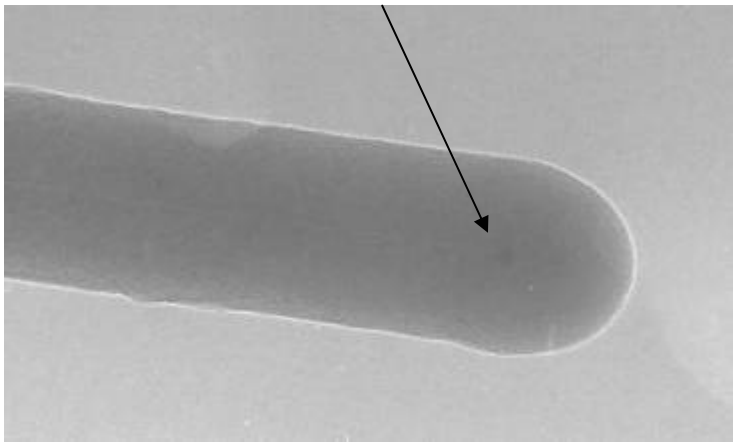
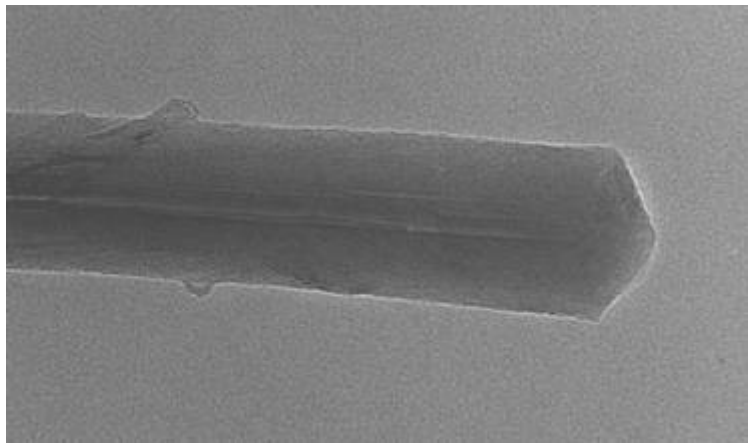
TEM images of VGCF™

Catalyst particle



Before heat treatment



After heat treatment

Basic idea of VGCF™

Powder resistance

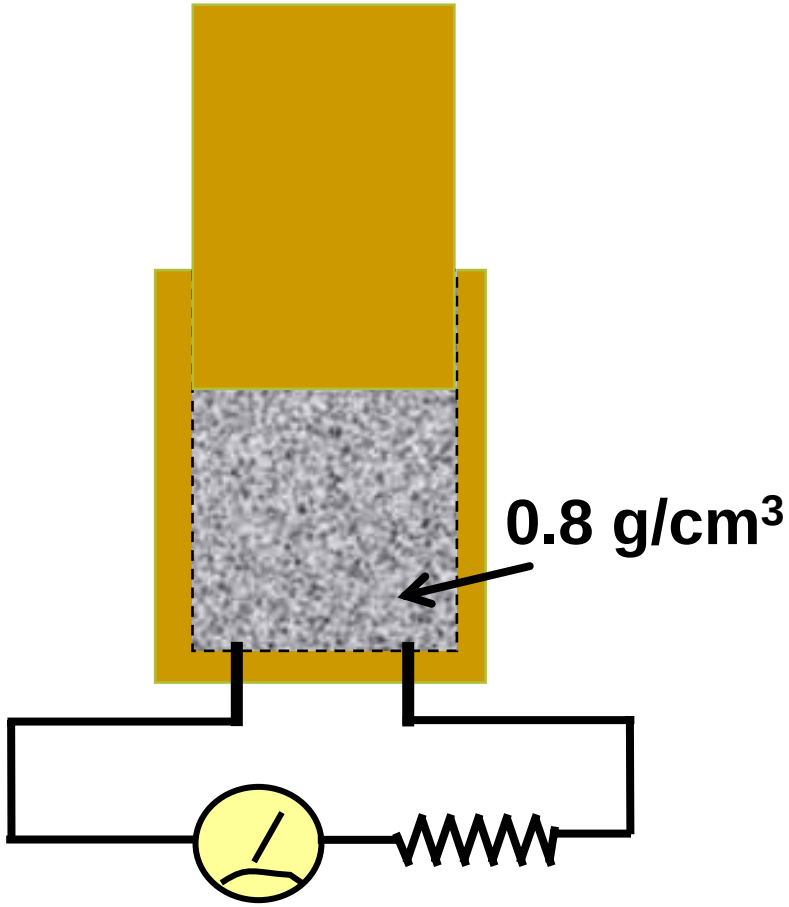


Table 1. Powder resistances

	(Ω·cm)
VGCF™	0.010 ～0.015
Acetylene black (AB)	0.07 ～0.08
Ketchen black (KB)	0.03 ～0.04

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SEM images of electrodes with VGCF™

VGCF™ has been employed as additives of LIB

for more than 10 years.

Effective on LIB ***Improve High Power Ability***

Prolong Life Cycle Time

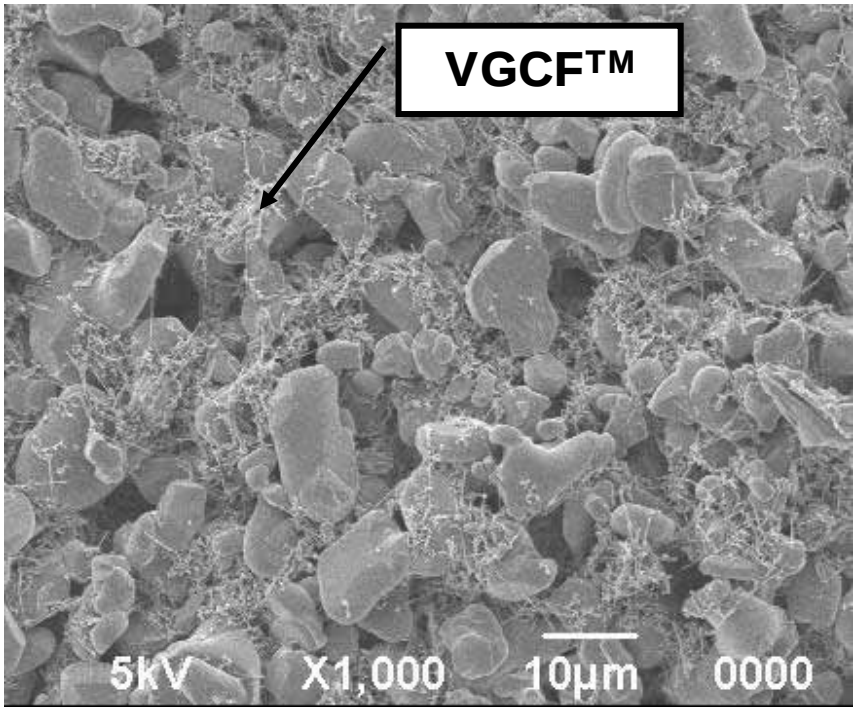

Fig. 1. Cathode ($LiCoO_2$)

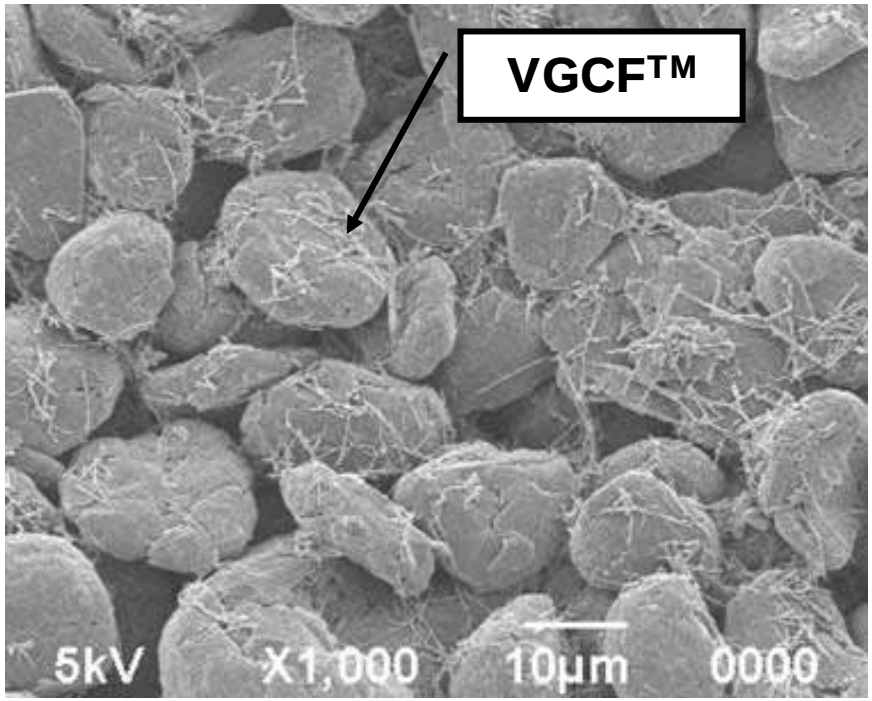

Fig. 2. Anode (graphite)

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High Power ability

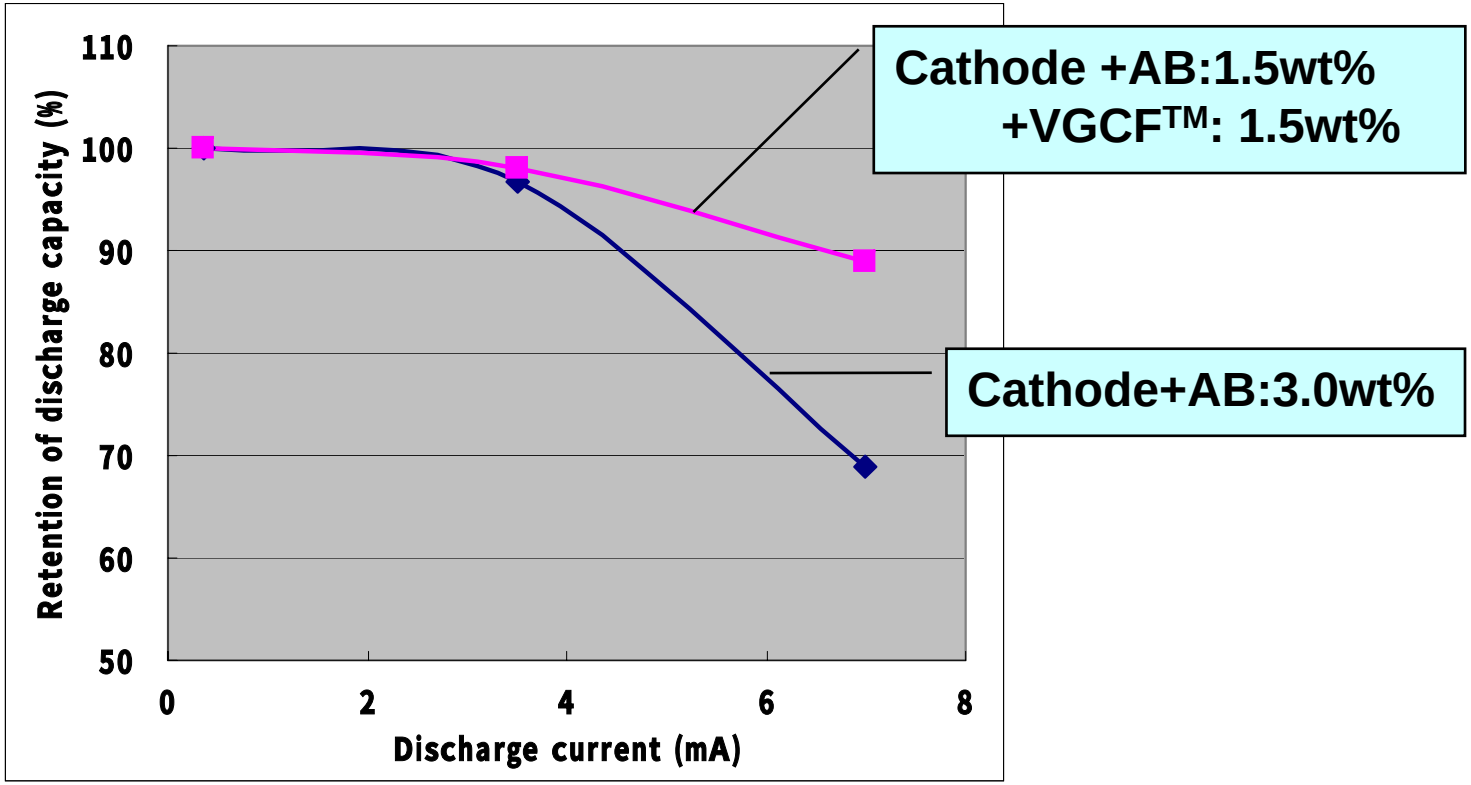


Fig.4. Discharge at higher current rates.

VGCF™ improved high power ability of LIB.

(Coin cell 2032 (3.5mAh))

Conductivity of cathode electrode

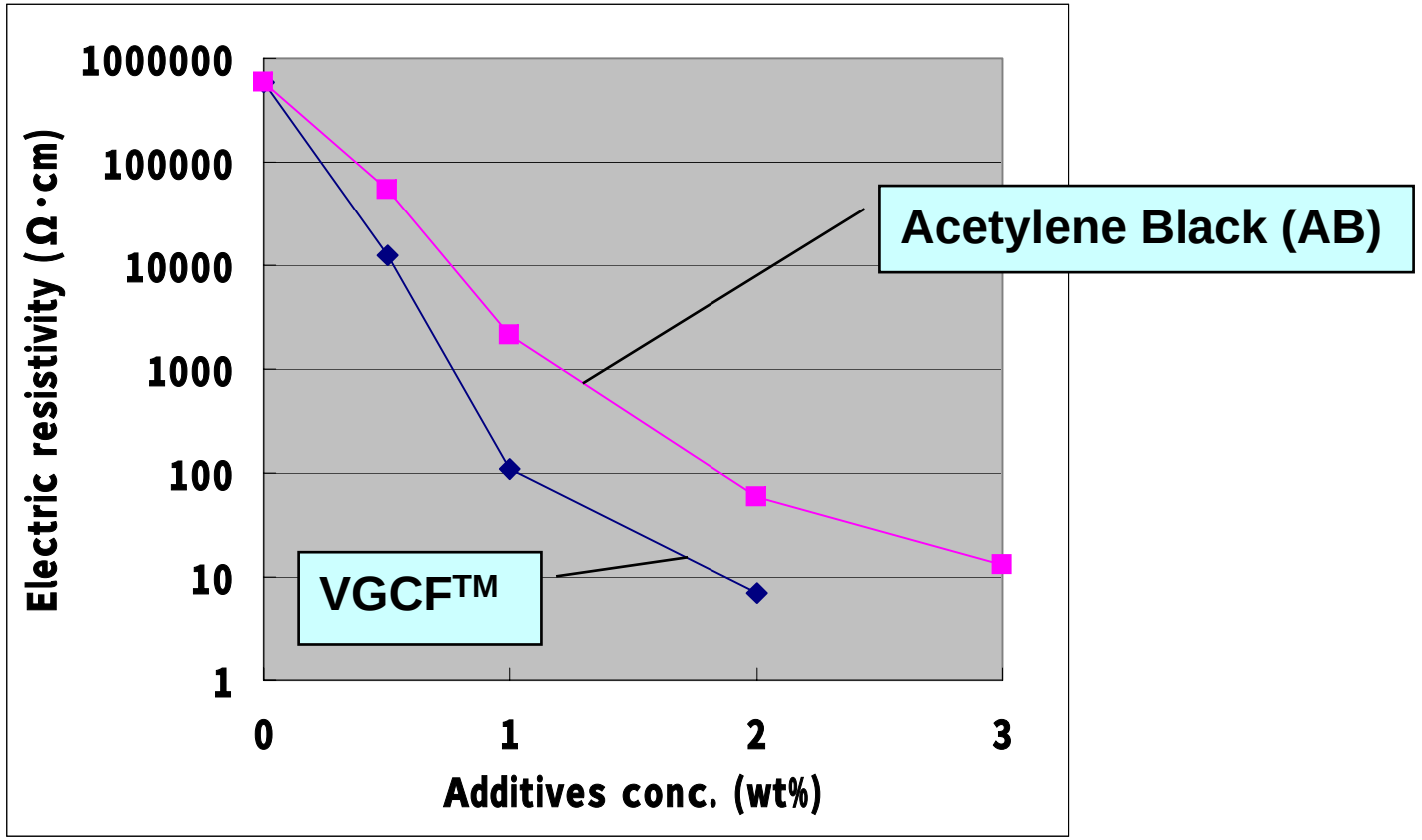
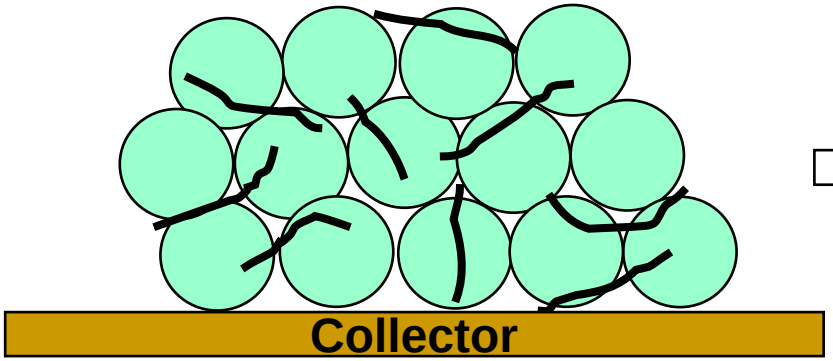


Fig. 3. Electric resistivity of Cathode electrode.

(Four points probe method)

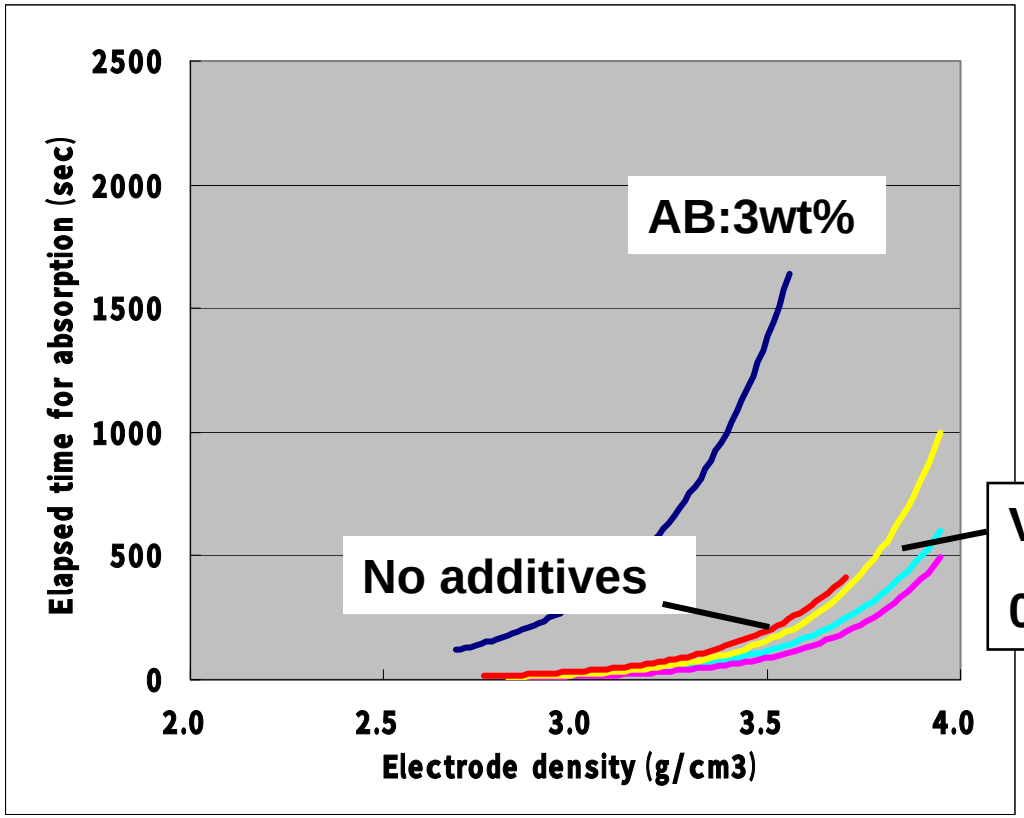
Improve conductivity of electrode



⇨ higher power ability

VGCF™ improves conductivity of electrode .

Electrolyte absorption into electrode

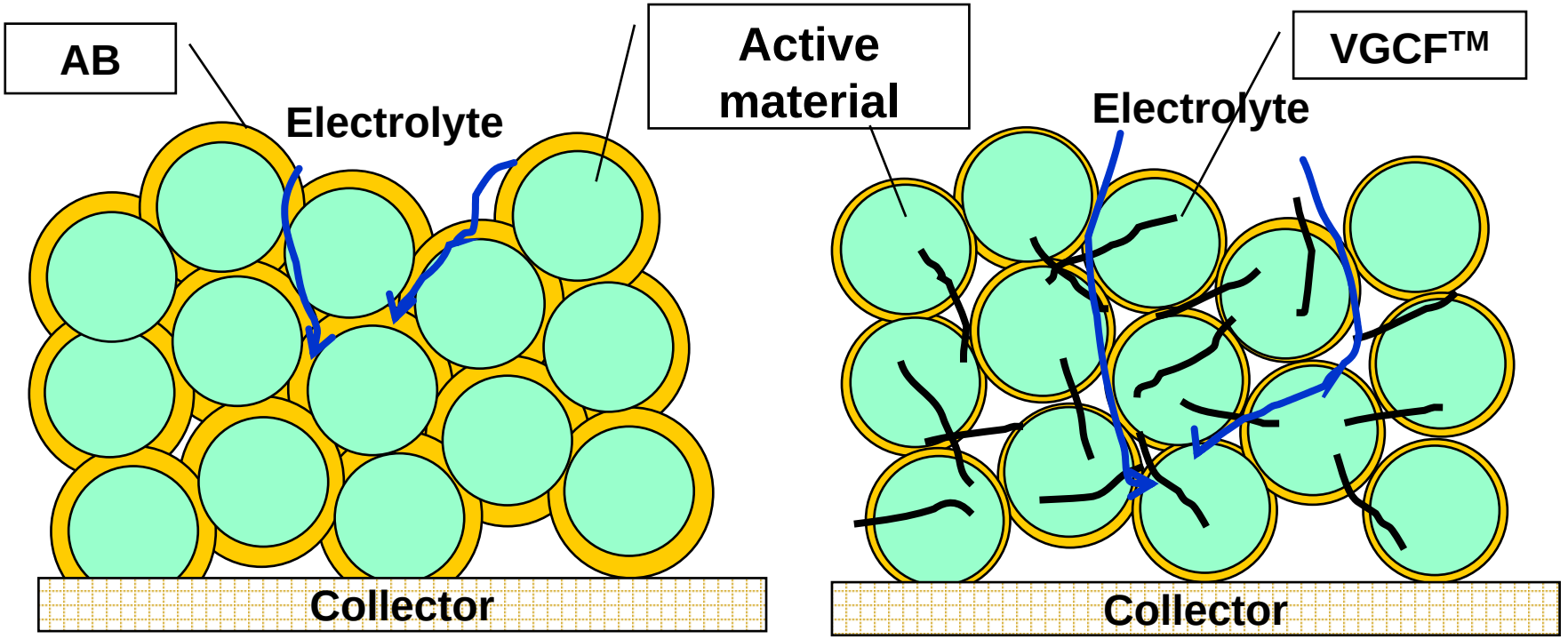


Elapsed time was measured from putting 3 μL propylene-carbonate on electrode to complete absorption into the electrode.

PVDF: 3wt%

Fig.5. The electrolyte absorption into cathode electrodes.

Electrolyte absorption



AB or KB may fill out vacancies among active materials.

VGCF™ may remain the vacancies.

Higher mobility of electrolyte in electrode raises the performance of LIB.

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Cycle Life Time of LIB

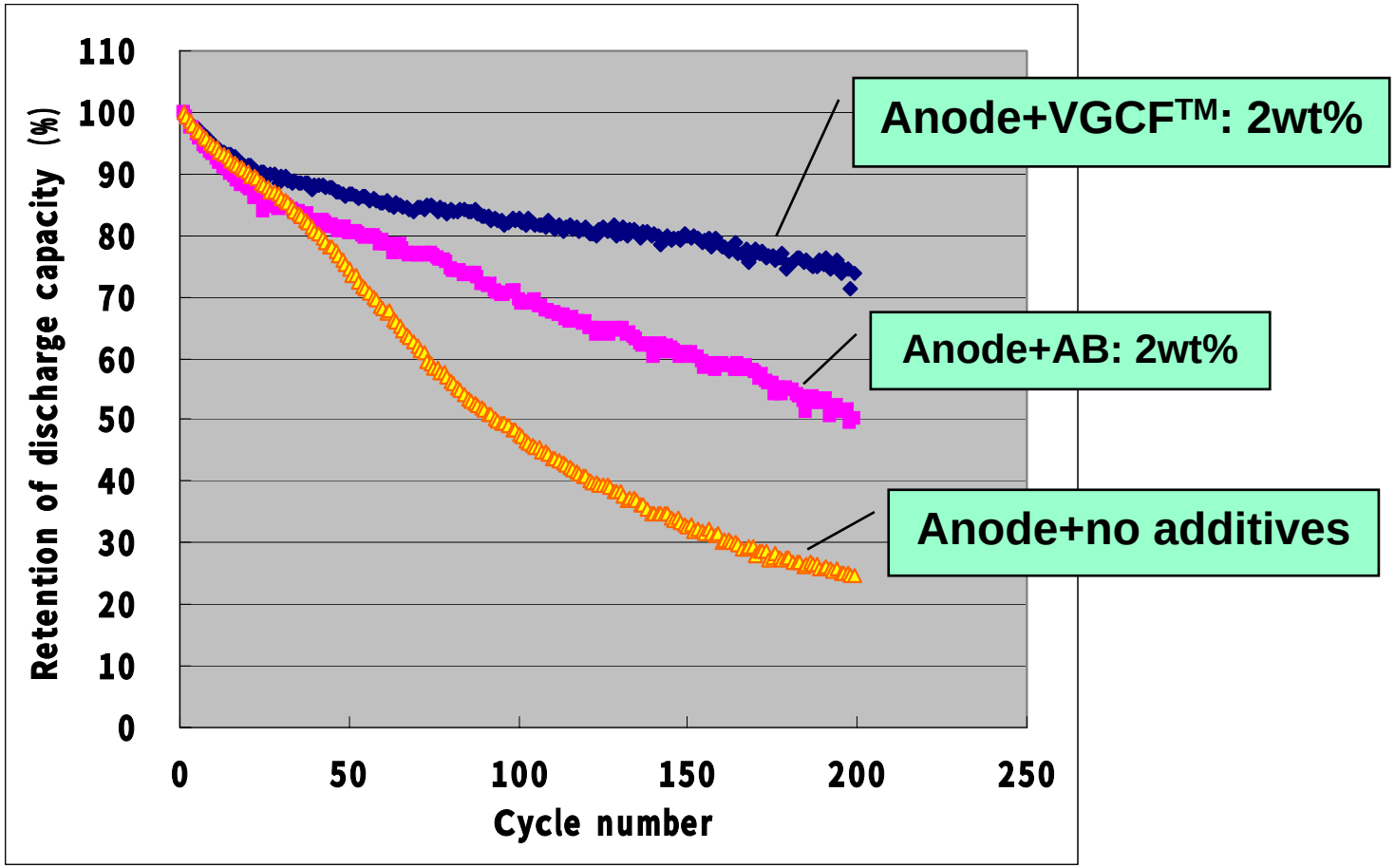

Fig. 6. Cycle performances. (Coin cell 2032 (3.5mAh))

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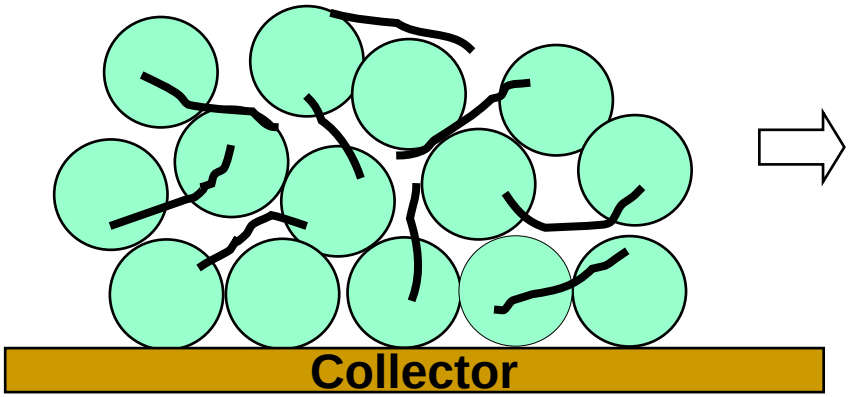
VGCF™ prolonged cycle life time of LIB.

Keep connections between active materials



⇨ **Longer cycle life time**

VGCF™ keeps connections between active materials.

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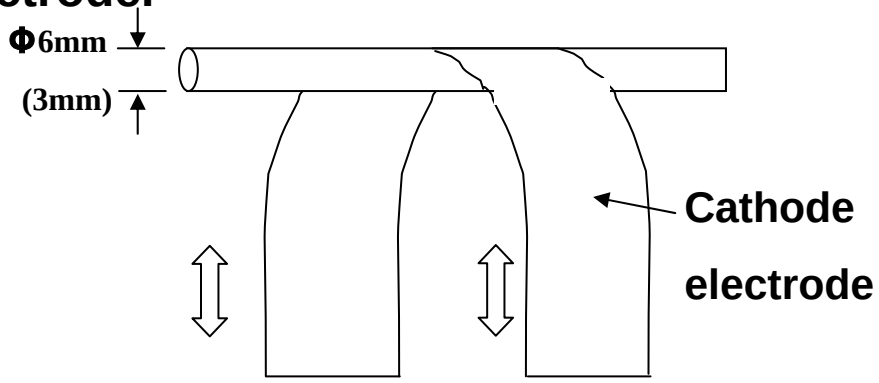
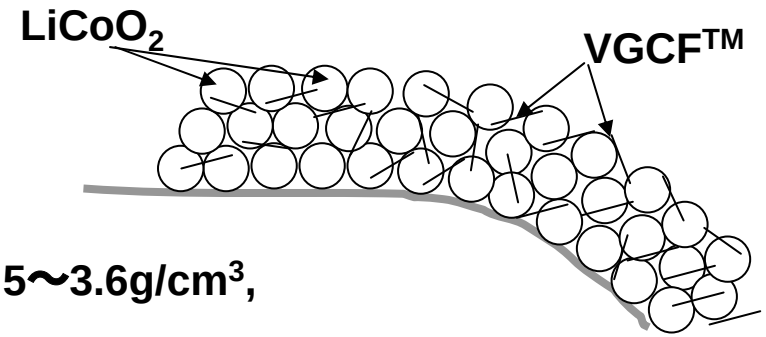
Flexibility of electrode

Table 2. Flexibility Test of cathode electrode.

Contents of additives	ϕ6mm	ϕ3mm
AB:1.0wt%	×	×
VGCF™:1.0wt%	○	○
AB:2.0wt%	×	×
VGCF™:2.0wt%	○	○
AB:1wt%+VGCF™:0.5wt%	○	○

×：Crack, ○：No Crack





Binder: PVDF 5wt%, Density of electrode: 3.5～3.6g/cm^3,

Loading level: 40～45mg/cm^2, Thickness of electrode: 115～120μm

A sturdy electrode with VGCF™ contributes to durability.

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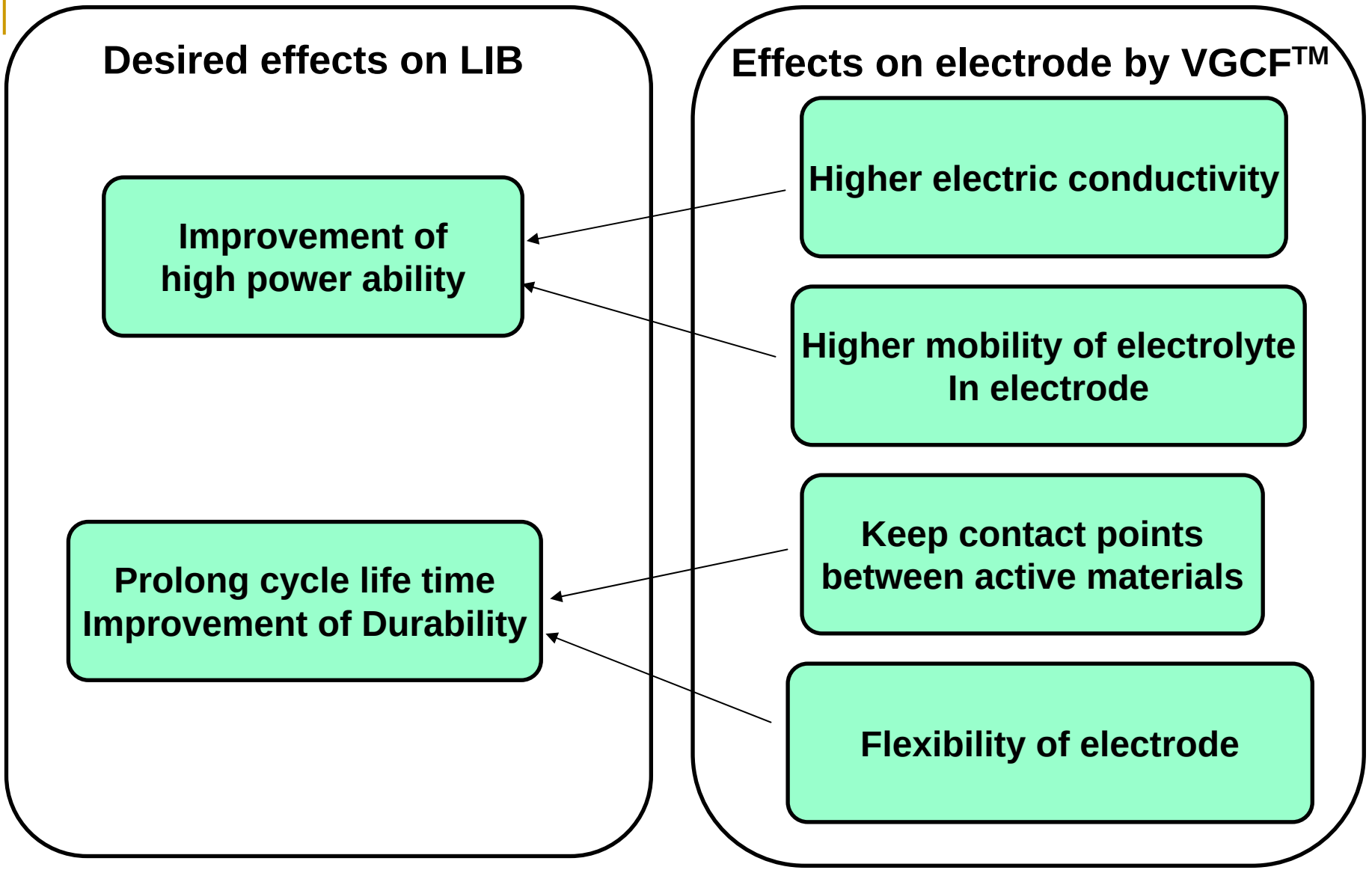
Desired effects on LIB
Improvement of high power ability
Prolong cycle life time Improvement of Durability
Effects on electrode by VGCF™
Higher electric conductivity
Higher mobility of electrolyte In electrode
Keep contact points between active materials
Flexibility of electrode

New applications in future

20%

Major parts of CO_2 emission from our society

1. Vehicles; Battery EV, Plug-in HEV, HEV

30%

2. Electric power generation systems;

Accumulator combined with Solar power and Wind power.

Durability for more than 10 years is required in new applications.

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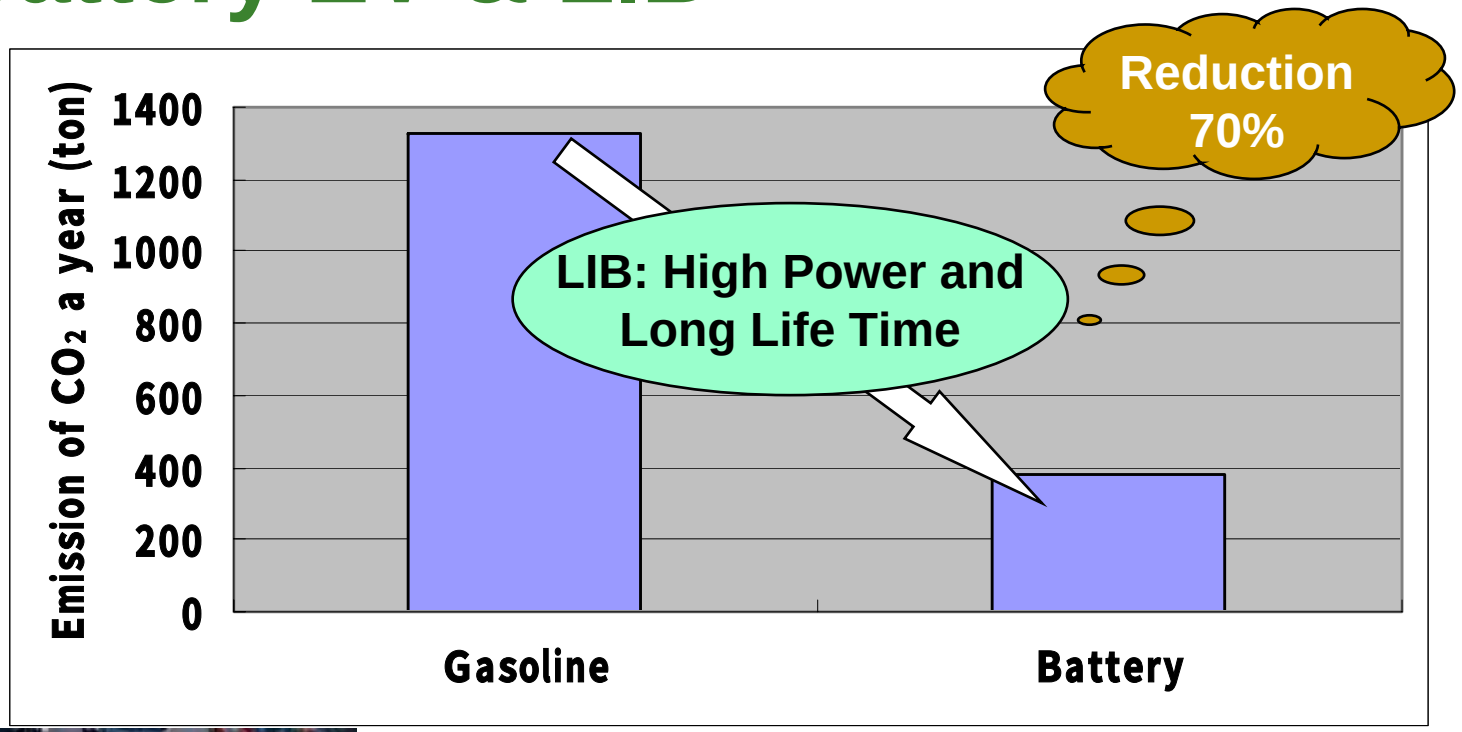
Battery EV & LIB



Travel distance: 10,000km/y

25M light motor cars in Japan

→ Reduction CO_2 of 23,000,000 t

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(Ref.; Web site of Tokyo and Kansai electric power company)

Natural Energy Source & LiB

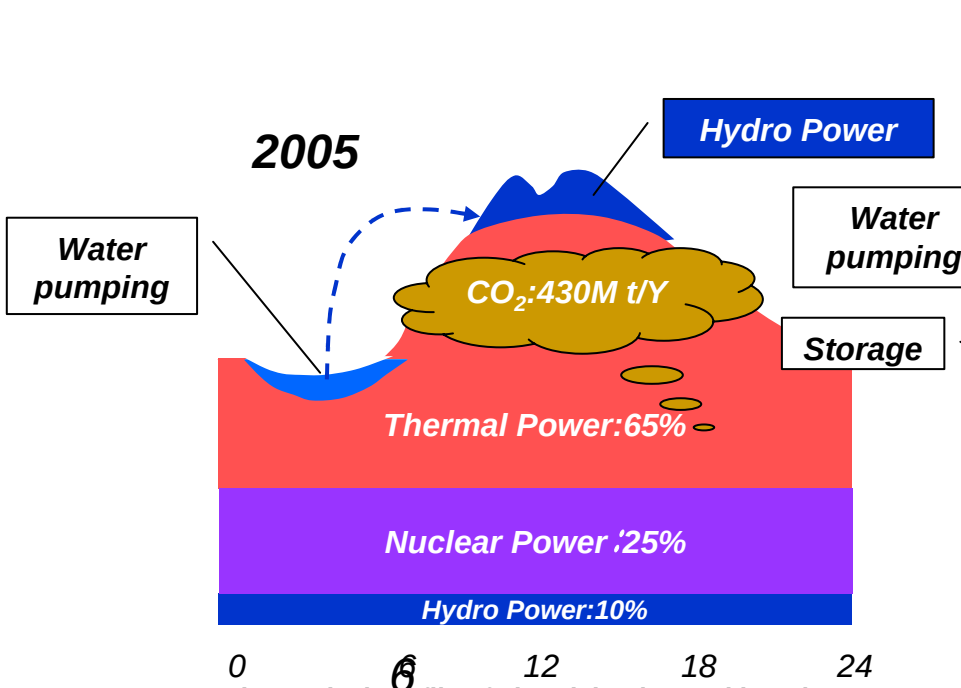

Fig. Typical profile of electricity demand in a day.

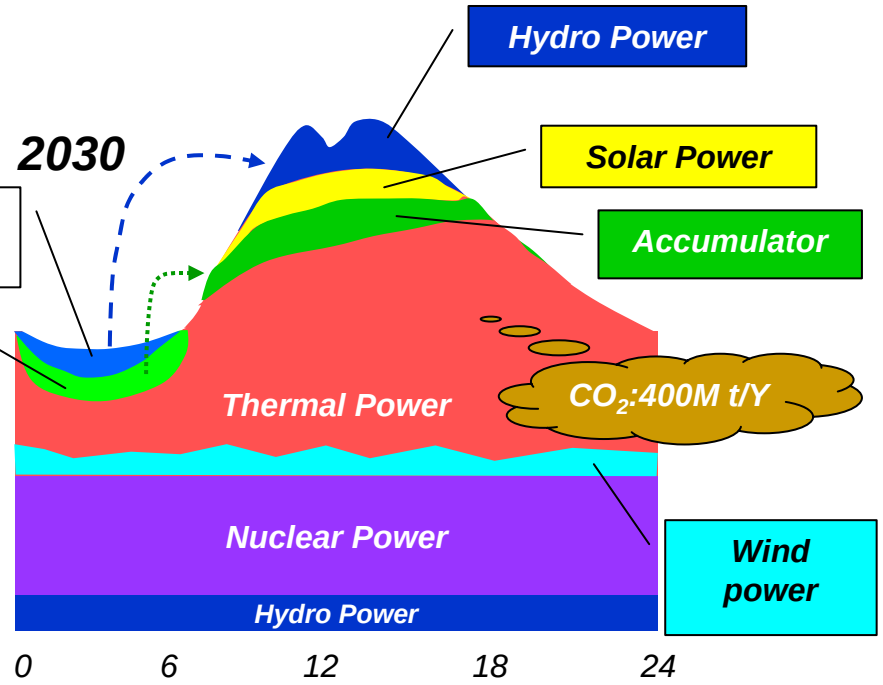

Fig. Electric generation system in future.

Place for new building of Hydro Power is becoming restricted.

⇨ **On-site generation; *Solar power, Wind power***

Planned Solar power: 56MW(40 times of 2005) in 2030 → CO_2 reduction: 6% and more

Natural Energy Source & LiB

Unstable electricity supply might cause serious frequency fluctuation.

Solar power

Wind power

Unstable supply

Accumulator

(Battery; LIB)

Consumers

Stable supply

Long Life Time
High Power ability

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Potential Benefits for environment

LIB with VGCF™

High Power Ability

Long Life Time

Reduce waste

Use energy and resources at higher efficiency

Becoming wide use in vehicles and power generation systems

Reduce emission of CO_2

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Safety issues on VGCF™

Safety control at Production site

- **Environmental aspect**
- **Human health effects**

Environmental aspect

- **Closed system of the production equipment**
- **Local and Total Ventilation system with high performance filter**

Human health effects

- **Personal protection equipments**
- **Education to worker**

Communications with users

- **show the latest informations and maintain it so that it is updated**

Conducting the exposure assessment on the whole supply chain of VGCF™.
Cooperation with Governments or International Organization.
SDK participates in Nano Materials stewardship Program conducted by US-EPA.

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Life of VGCF™

Production ➡ **Customer** ➡ **LIB**

(Battery Maker)

Risk: Exposure for

Worker and Environment

Closed production system

Ventilation system

Education for safety

Recycle

VGCF™ → Flammable

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Summary

1. **VGCF™ is a kind of Multi Wall Carbon Nano Tube, and has fibrous shape and higher electric conductivity.**

2. **VGCF™ improved high power ability and life cycle time of LIB.**

3. **LIB with VGCF™ will be a candidate technology contributing to more clean environment.**

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