

# METAL+CNT COMPOSITE

- ▶ Lowest Cost & High Productivity
- ▶ Excellent Mechanical Properties
- ▶ Low Weight Structure Material
- ▶ Base Metal : Pure & Alloy metal

## Generals

### Features

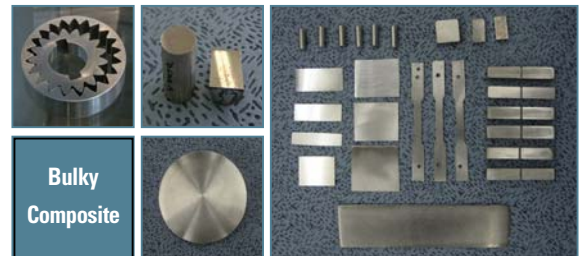
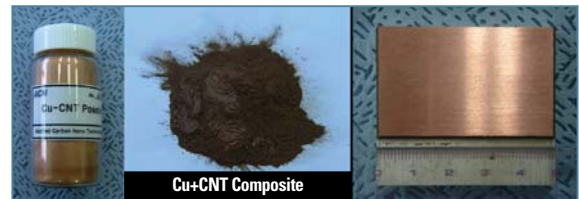
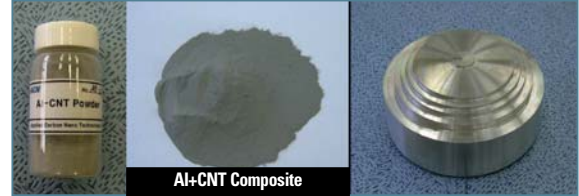
- Excellent Dispersibility of CNT in Metal Matrix
- Improved Strength by Metal-based Nano-crystalline
- Improved Strength & Toughness by Mechanical Properties of CNT
- Improved Conductivity by Electrochemical Properties of CNT
- Improved Abrasion Resistance by Nano-crystalline & CNT
- Light weight compared with the Existing High-strength Composites
- Low Cost Metal+CNT Composite compared with High Strength Composite
- Various Grade can be Manufactured depending on Application Fields

### Type

- Metal+CNT : Al+CNT, Cu+CNT, W+CNT etc.
- Alloy+CNT : Al Alloy+CNT, STS+CNT, W alloy+CNT etc.
- CNT Contents : ~10 wt.%

### Applications

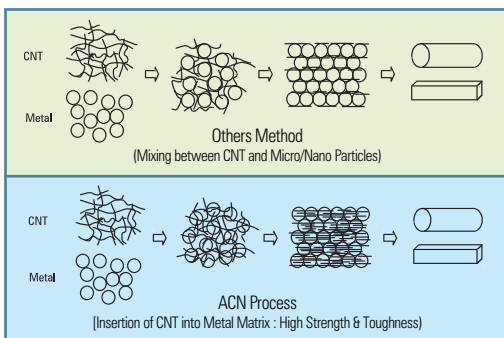
- **Light Weight Structures with High Strength & Toughness**  
: Aerospace, Automobiles, Vessels and Leisure/Sports Apparatuses
- **Abrasion-resistant Light Weight Materials**  
: Aerospace, Automobiles, Tools and Machine
- **Excellent Thermal and Electric Conductivity**  
: Electronics, Computer, Automobiles, Aerospace and Precision Equipment



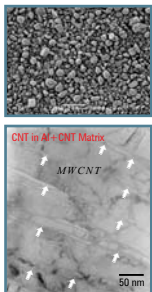
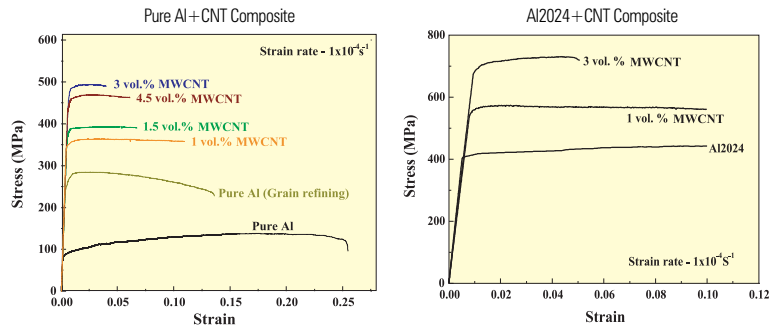
## Characteristics

### Comparison of Manufacturing Process

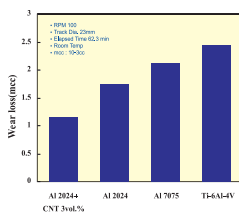
ACN Process : Lowest Price & Mass Production



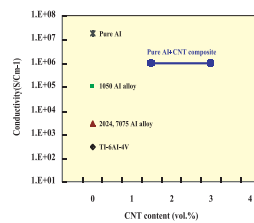
### Excellent Mechanical Properties



### Abrasion Property



### Electrical conductivity



### Comparison of Mechanical Properties

	Yield Strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness (HRB)	Specific strength (MPa)	Electrical conduct. (IACS%)	Wear loss (10 <sup>-3</sup> cc)
2024 Al Alloy	324	469	19	70.5	174	12	1.74
7075 Al Alloy	435	505	13	80.5	181	9	2.13
Ti-6Al-4V	880	950	14	260~	198	-	2.45
Pure Al+CNT (CNT 3 vol.%)	440	475	5~10	83.2	176	55	-
Alloy Al+CNT (CNT 3 vol.%)	715	720	4	93.7	265	-	1.16

• Tension test : ASTM E8  
• Wear test : RPM100, Track Dia. 23mm, Elapsed time 62.3min, Room Temp



# POLYMER+CNT COMPOSITE

- ▶ Uniform Dispersibility & Conductivity
- ▶ High Conductivity with Low Loading of CNT
- ▶ Excellent Physical Properties
- ▶ Maintain the Resin Physical Properties
- ▶ Extremely Low of Particle Sloughing

## Generals

### Features

- Improved Conductivity by Electrochemical Properties of CNT
- Improved Strength & Toughness by Mechanical Properties of CNT
- Uniform Dispersibility & Conductivity by using Metal+CNT Composite
  - Insertion of CNT into Metal particle : Control Length of CNT in Metal
  - Prevent Segregation of CNT in Extrusion
- Role : CNT (Conductivity), Metal (Dispersibility & Conductivity)
- Realization of High Conductivity with the Minimum Addition of CNT
- Maintaining the Properties of the Base Material's own
- Decreased Particle Sloughing
- Extended Lifetime

### Type

- PC+CNT, Nylon+CNT, PET+CNT, PE+CNT etc.
- CNT Contents : ~20 wt. %

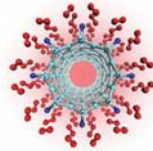
### Applications

#### Shielding Material (ESD & EMI)

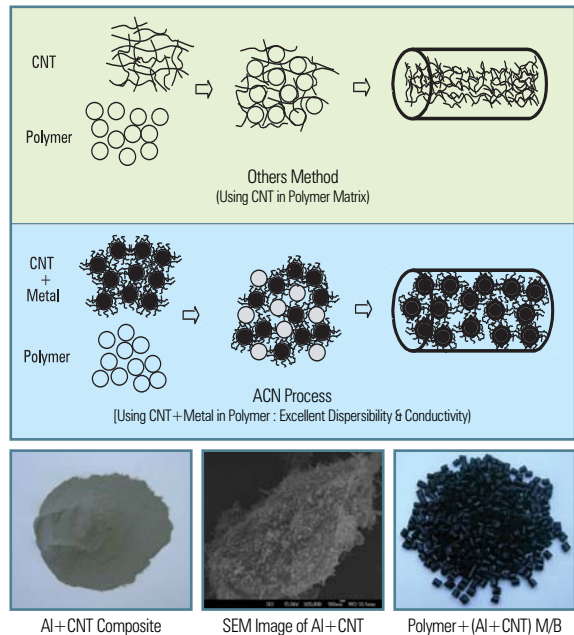
: Mobile, Cloth, Computer, Glove, Shoes, Matt, Tile, Tray, Tape, Box, Bag, Film etc.

#### Engineering Plastic, Heat sink

: Aircraft, Automobile, Aerospace, Electronic, Medical, Vessel Sports equipment, etc.

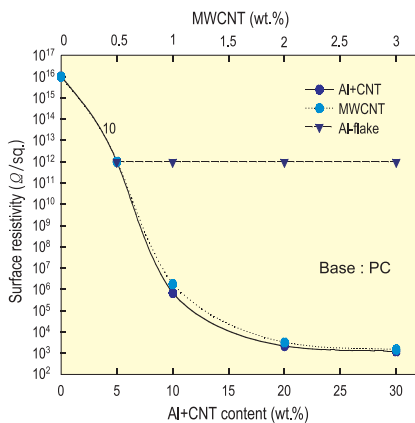


### Comparison of Manufacturing Process

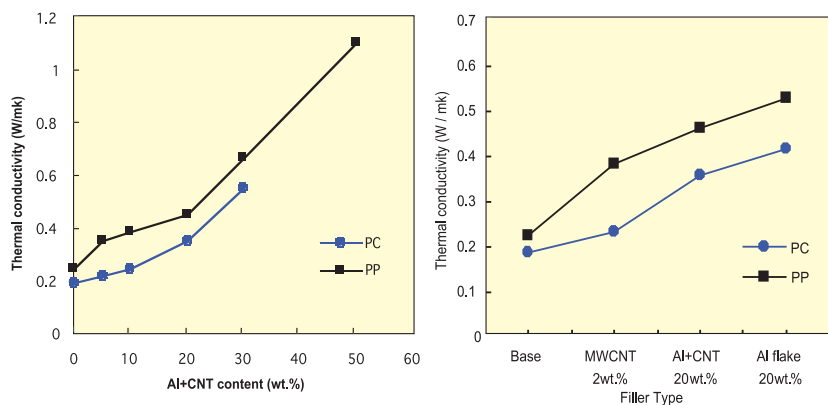


## Characteristics

### Surface Resistivity of Polymer+CNT

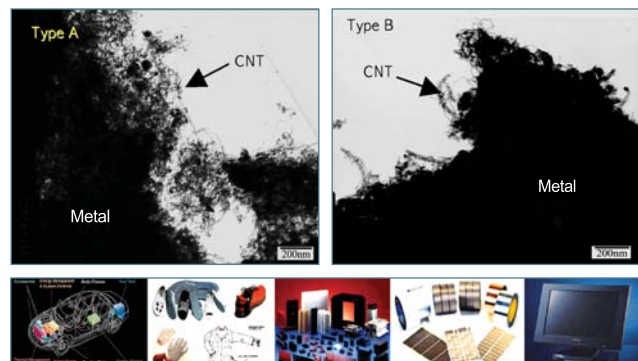
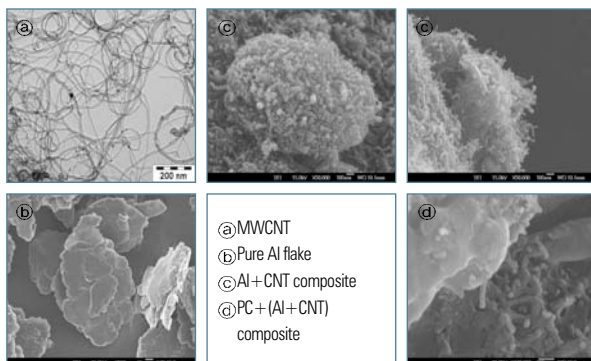


### Thermal Conductivity of Polymer+CNT



### Outer Length of CNT in Metal+CNT for Polymer+CNT Composite

(Conductivity : A > B)



# CERAMIC+CNT COMPOSITE

- ▶ Uniform Dispersibility & Conductivity
- ▶ High Conductivity with Low Loading of CNT
- ▶ Excellent Physical Properties
- ▶ Maintain the Ceramic Physical Properties

## Generals

### Features

- Improved Conductivity by Electrochemical Properties of CNTs
- Improved Strength & Toughness by Mechanical Properties of CNTs
- Improved Abrasion resistance by Appearance Properties of CNTs
- Realization of High Conductivity with the Minimum Addition of CNT
- Maintaining the Properties of the Base Ceramic's Own
- Decreased Particle Sloughing
- Extended Lifetime

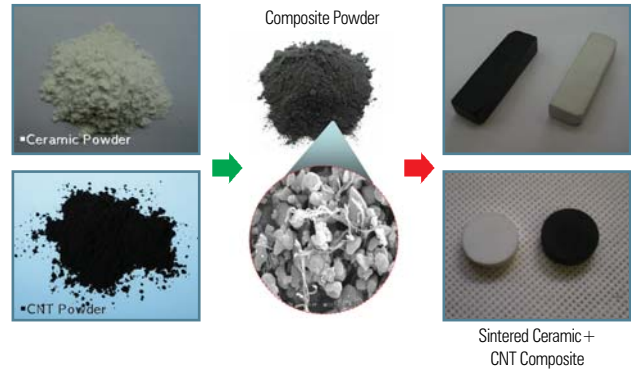
### Type

- ZrO<sub>2</sub>+CNT, Al<sub>2</sub>O<sub>3</sub>+CNT etc.
- CNT Contents : ~ 10 Vol.%

### Applications

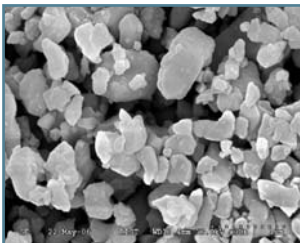
- Ceramic coating materials with high strength and high toughness
- Industrial materials requiring electric conductivity and heat dissipation
- Ceramics for shock absorption Abrasion-resistant ceramics

### Manufacturing Process of Ceramic+CNT Composite

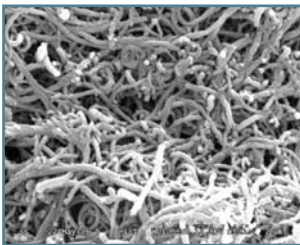


## Characteristics

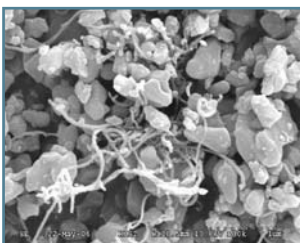
### SEM Image of Ceramic+CNT Composite



Raw ceramic powder

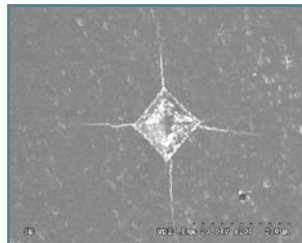


Carbon Nanotube (MWCNT)

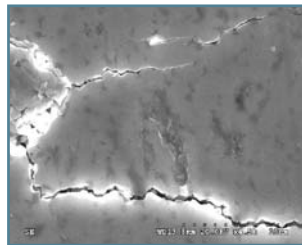


Ceramic+CNT Composite

### Crack Propagation Behavior of Ceramic+CNT Composite



Vickers hardness press mark

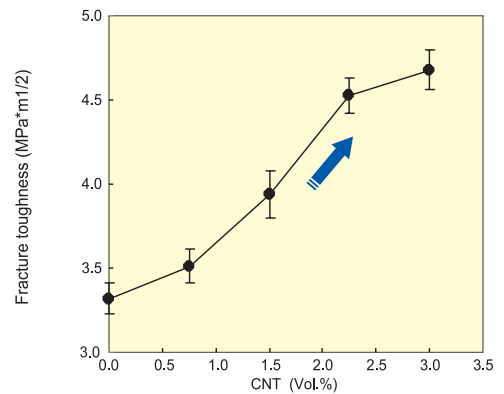


Prevent Crack propagation

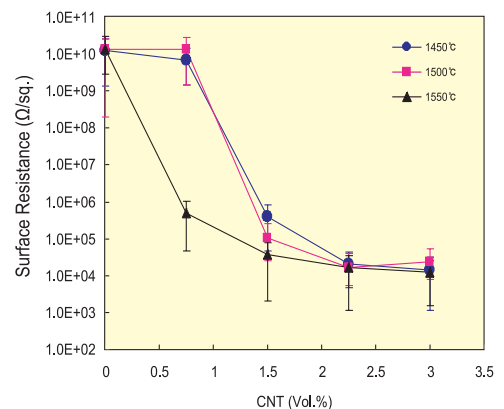


Crack bridging by CNT

### Fracture Toughness of Ceramic+CNT Composite



### Surface Resistance of Ceramic+CNT Composite





- ▶ Uniform Dispersibility & Conductivity
- ▶ Highly Electric/Thermal Conductivity
- ▶ Excellent Dispersibility of CNT
- ▶ Highly Photocatalyst Property

## Generals

### Features

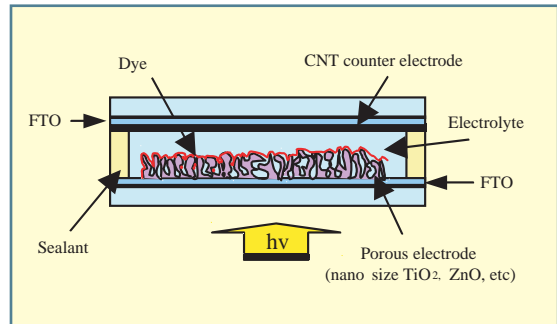
- CNT-used Liquid high conductive paste & ink
- Low cost CNT for expensive Pt & Ag
- Excellent electric conductivity & thermal emission property
- Environmental-friendly materials with conductivity & photocatalyst
- Various grade can be manufacturing depending on application fields
- Convenient usage : Spray, coating etc.

### Type

- CNT Paste :  $10^1 \sim 10^2 \Omega/\text{sq}$ .
- CNT Ink :  $10^2 \sim 10^5 \Omega/\text{sq}$ .

### Applications

- ESD, EMI
- Dye-sensitized solar cell counter electrode
- Adsorption of harmful gas, Pollution decomposition



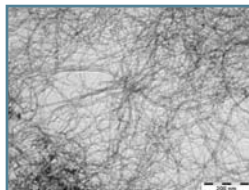
DSSC modules with CNT counter electrode



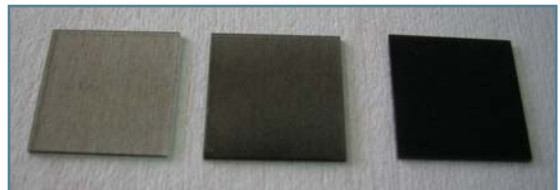
CNT Ink



CNT Paste



High Dispersibility CNT for Liquefied CNT



CNT Counter Electrode of DSSC

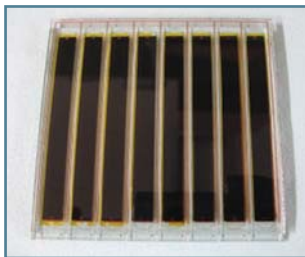
## Dye-sensitized Solar Cell CNT Counter Electrode

### Features

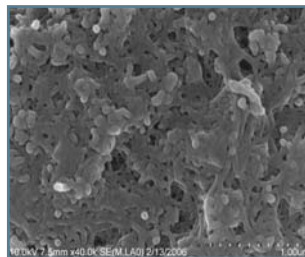
- Low cost CNT counter electrode for expensive Pt counter electrodes
- High photo-electric conversion in low level illumination
- High efficiency and stability in comparison with Pt DSSC



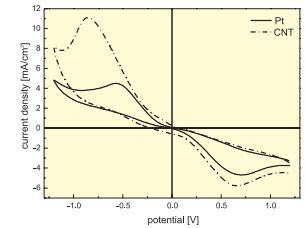
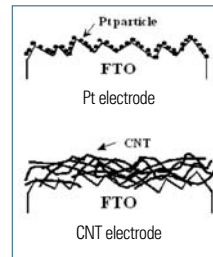
DSSC modules with CNT counter electrode (KERI-ACN)



DSSC modules with CNT counter electrode



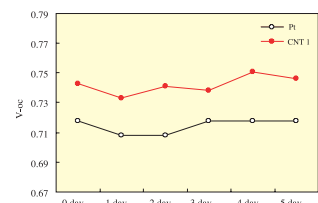
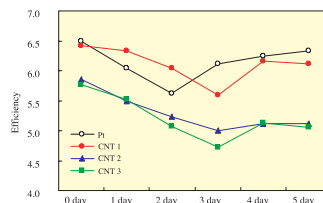
SEM image of CNT electrode



Cyclic voltammogram of Pt and CNT (Scan rate : 100 mV/s)

### Property

- Sheet resistance
  - : CNT electrode  $\approx$  Pt electrode (Excellent Conductivity)
- Electrochemical properties
  - : CNT electrode > Pt electrode (CV & impedance spectrum)
- CNT Electrode
  - : Excellent performance & Simple Process
  - CNT : Low resistance, Excellent electron emission
  - Large surface area, Low cost



Comparison of efficiency & V-oc between Pt and CNT electrode



# CARBON NANOTUBE

- ▶ Mass production and Lowest price
- ▶ Excellent mechanical/Electrical/Thermal property
- ▶ High chemical stability
- ▶ Various technological applications

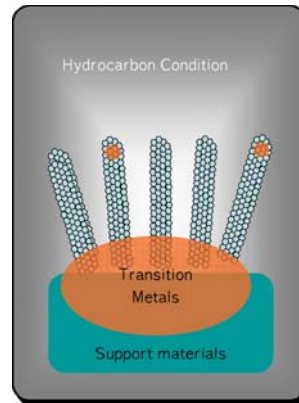
## Generals

### Features

- New dreamy material in the 21st century
- Tubular material with hexagonal honeycomb structure
- Remarkable electronic/thermal and mechanical properties
- Mass production and lowest price
- Wide use and various technological applications
- Environmental-friendly materials with conductivity & strength

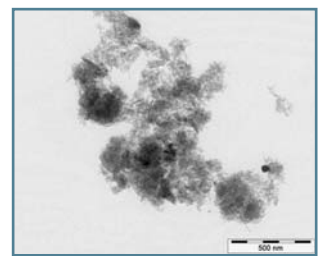
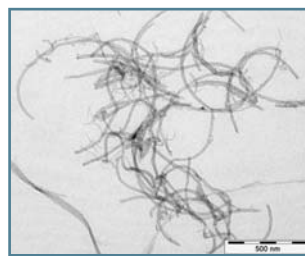
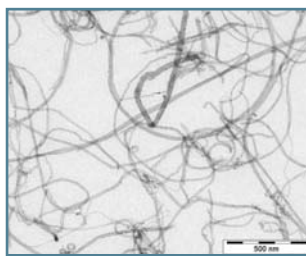
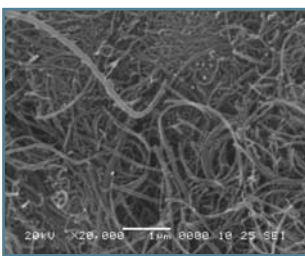
Typical Properties of MWCNT

Properties	Value	Remarks
Electrical Resistivity ( $\Omega \cdot \text{cm}$ )	0.1	Pure Cu (1.67)
Thermal Conductivity (W/mK)	~2,000	Pure Al (236)
Elastic Behavior	Young's Modulus (MWCNT)	1.28 TPa
	Maximum Tensile Strength	~100 GPa SUS 304 (0.6 Gpa)



## Properties and Qualities

Type	Purity (wt.%)	Diameter (nm)	Length ( $\mu\text{m}$ )	Remarks
CNT 85, CNT90	85, 90	5~20	~10	Catalyst CVD
CNT97	over 97	5~20	~10	Purified CNT90
Chopped CNT	85, 90	5~20	~1, 1~3	Various Length



### Applications

- Electron emitter, light source
- Electromagnetic interference (EMI), Electrostatic discharge (ESD)
- Solar cell electrode, Fuel cell electrode
- Rechargeable battery
- Metal/Ceramic/Polymer composite
- CNT paste & ink
- Removal sick house syndrome, adsorption of harmful gas, pollution decomposition

