

Innovative Coating Materials That Overturns Conventional Wisdom

NANOTECT®-A

Abrasion-resistant coating

Outstanding mechanical properties in all characteristic tests
Abrasion resistance 10 times higher than conventional resin coatings

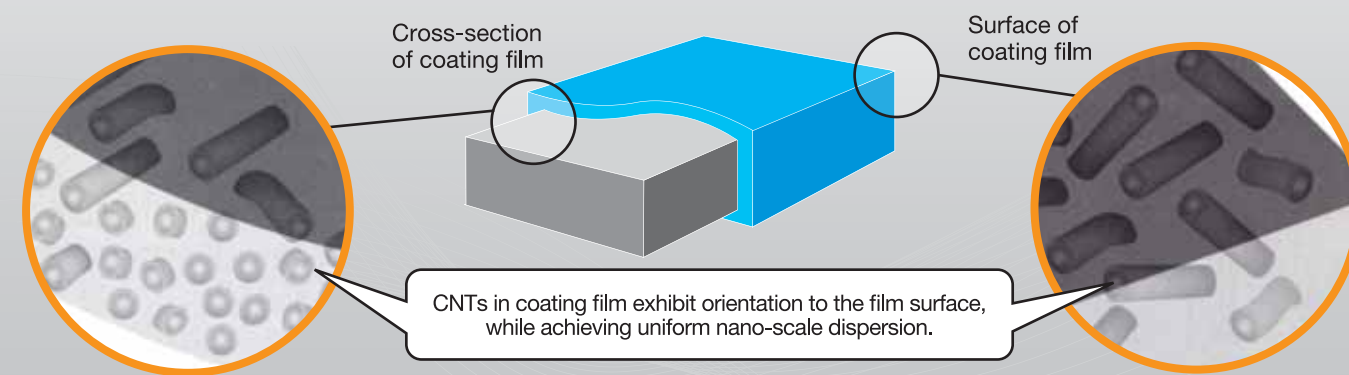
NANOTECT®-C

Corrosion-resistant coating

Superb mechanical strength and chemical resistance
World's first composite coating with CNT to exhibit 3,000-hour resistance in salt spray tests

Succeeds in Uniform Dispersion of Carbon Nanotubes in Composite Resin Coating

Dispersion and orientation structure of CNTs in coating film



CNT dispersion in solution

CSCNT¹ chemically treated using our proprietary grafting technique enables uniform CNT dispersion in resin polymers.

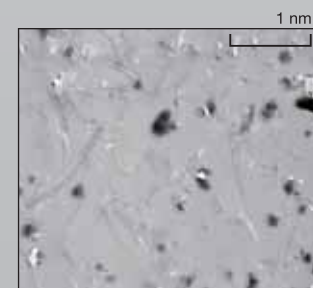


Grafted CNTs

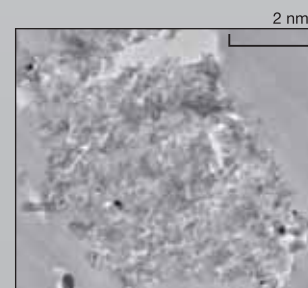


Non-grafted CNTs

CNT dispersion in resin coating



Grafted CNTs



Non-grafted CNTs
(CNTs dispersed in aggregates)

Unlimited Potential for Wide Array of Applications

Our high performance coating materials protect product surfaces from scratches, rust, corrosion, burns and other damage, offering great promise for a wide range of applications including airplane parts, construction materials and automotive and other transport vehicle parts.



▲ Large structures/bridges, subways, buildings, offshore plants



NANOTECT® series holds great promise in various application fields



▲ Nuclear power plants



▲ Chemical plants/complexes



▲ Passenger/cargo aircraft

NANOTECT®

1. Nanotect® is a registered trademark of Takenaka Seisakusho Co., Ltd.
2. Patents applied in Japan, Europe, the U.S. and Taiwan jointly by Prof. Emeritus Inagaki of Institute for Chemical Research, Kyoto University; and GSI Creos Corporation (under the guidance of Prof. Emeritus Fukuda, Institute for Chemical Research, Kyoto University).



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TAKENAKA SEISAKUSHO Co.,Ltd.

World's First Composite Technology That Combines Carbon Nanotubes (CNTs) with Resin Coating

Super-hard CNT-resin composite coating

NANOTECT®

Nanotect®: The first organic resin paint hybridized with carbonnanotube (CNT)

Recipient of a merit award and special award for technology management in the 2009 small and medium-size enterprise outstanding new technology and product award program

Selected as an R&D project commissioned by the Ministry of Economy, Trade and Industry under the 1st strategic core technology sophistication assistance program in 2006-2008

TAKENAKA SEISAKUSHO Co.,Ltd.



Innovative Technology for Fabricating Coating Composition with Carbon Nanotube (CNT)

Fabricated by combining organic polymers with carbon nanotubes that are pretreated using a unique grafting technique, the **NANOTETECT** series coating materials offer dramatically increased toughness and ductility—two properties that are usually incompatible in organic polymers. The coating films are also highly resistant to impacts, shear and abrasive wear, and also have a highly lubricative surface. Moreover, our grafting technique effectively blocks the electrical conductivity of carbon nanotubes, providing coating films with excellent corrosive resistance.

Feature 1
With excellent abrasion resistance, Nanotect® helps decrease abrasion loss even in the heaviest friction conditions.

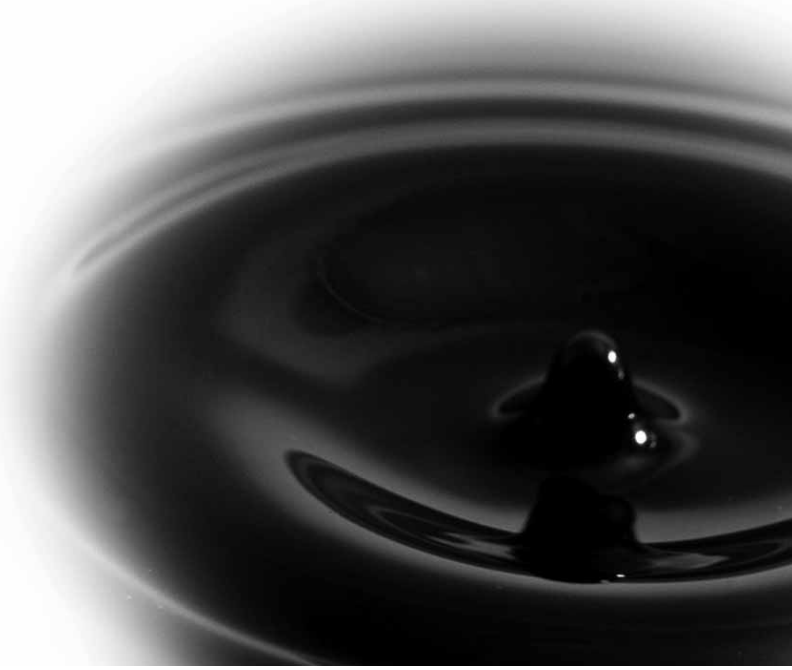
Feature 4
With its heat-resistant performance, Nanotect® is suitable for use especially on drive members and rotating parts and many other similar applications.

Feature 2
Suitable for use on products under severe service conditions. Nanotect® coating film can withstand high impact from outside sources to protect products.

Feature 3
Our proprietary grafting technique effectively blocks CNT conductivity, providing the coating film with high corrosion resistance.

Sophisticated Coating Composition Fabrication Technology Achieves a Breakthrough in Coating.

| Characteristics/resistance by product | Feature 1 Abrasion resistance <small>Weight loss (Load of 1,000 g/500 rpm)</small> | Feature 2 Impact resistance <small>DuPont method (100 g/50 cm)</small> | Feature 3 Corrosion resistance <small>Salt spray test</small> | Feature 4 Heat resistance | Coating film hardness <small>Knopp hardness test</small> |
|--|--|--|---|----------------------------------|---|
| Typical organic polymer coating | 30-50 mg/4,000 cycles Substrate surface appears (Coating flakes off) | φ 6.35 mm Film cracking/peeling | 500 hours Spot rusting | ~180°C | Hk10 |
| Abrasion-resistant coating NANOTETECT®-A | 3.0-4.5 mg/85,000 cycles 4.5 mg/2,000 mm ² No abnormality | φ 1.58 mm No change/abnormality | 1,000 hours No change/abnormality | 220°C | Hk80 |
| Corrosion resistant-coating NANOTETECT®-C | 5.0-10 mg/70,000 cycles 10.5 mg/2,000 mm ² No abnormality | φ 3.17 mm No change/abnormality | 3,000 hours No change/abnormality | 220°C | Hk50 |
| 耐熱用 NANOTETECT®-H | High heat-resistant coating (up to 600°C) under development | | | | |



Feature 1 Abrasion resistance evaluation

Taber's abrasion resistance test

Among the Nanotect® series, Nanotect®-A offers the highest abrasion resistance, with more than 14 times higher durability than typical organic polymer coatings in Taber's abrasion resistance tests.



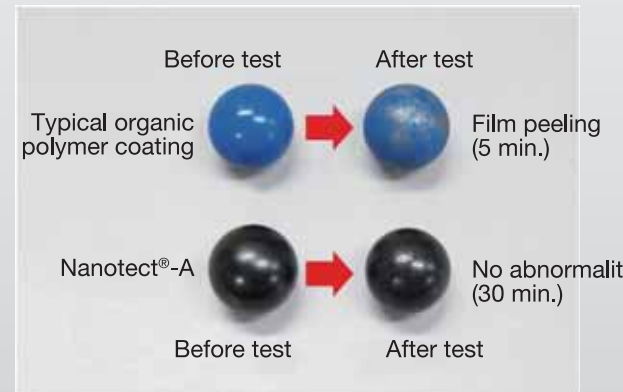
NANOTETECT®-A
(85,000 cycles)



Typical organic polymer coating
(4,000 cycles)

Impact wear test

Shaking tests demonstrate that Nanotect® offers remarkably higher impact wear resistance than typical organic polymer coatings.



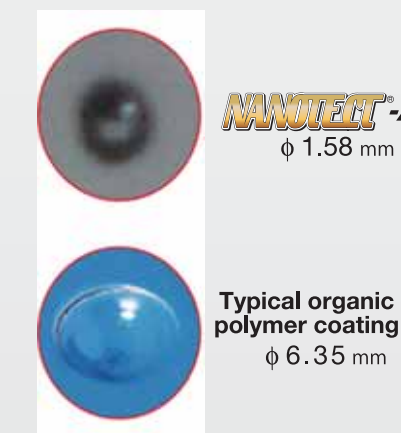
Feature 2 Impact resistance evaluation

Instantaneous impact resistance test

This test demonstrates that Nanotect® coating films withstand more than 15 times larger impact force than typical organic polymer coating films.

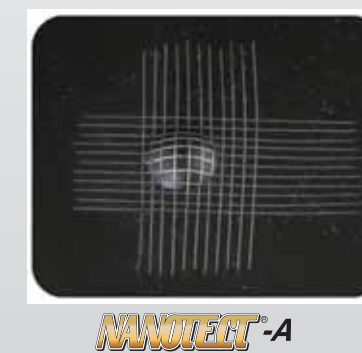


Loading weight: 1,000 g
Drop height: 50 cm

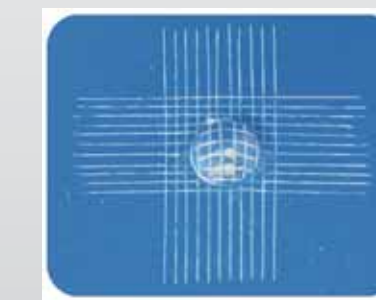


Multiple adhesion tests

Impact test and cross-cut test show that Nanotect® has superior adhesiveness compared with typical organic polymer coatings.



NANOTETECT®-A



Typical organic polymer coating

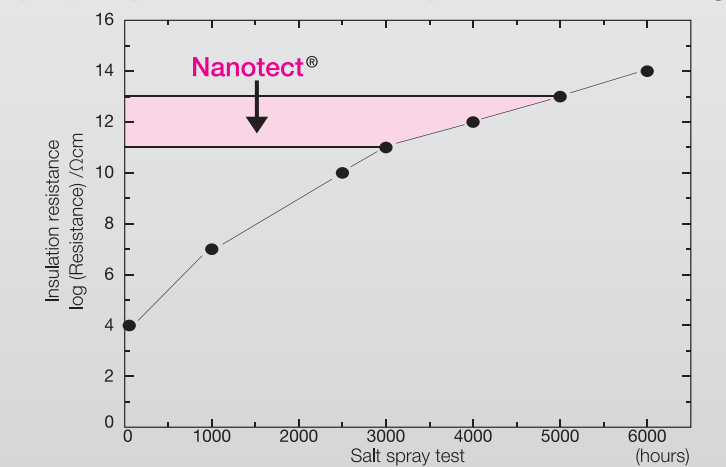
Feature 3 Corrosion resistance evaluation

Salt spray test

Using our grafting technique, CNT surfaces are coated with an insulating polymer coating to effectively block CNT conductivity. As a result, the Nanotect® series gives superb corrosion resistance to coating films. Nanotect®-C, above all, exhibits corrosion resistance after more than 3,000 hours exposure to salt spray tests.



Correlation between insulation resistance and salt spray exposure time of composite resin coating with CNT



The First Polymer Coatings Compositated with Carbon Nanotube

NANOTECH[®]

TECHNICAL INFO



Without CNT



With CNT

Carbon nanotubes (CNT) has made it this strong!



With untreated CNT



With surface-tailored CNT

Even corrosion resistant coatings with CNT!



TAKENAKA SEISAKUSHO CO., LTD.

What IS NANOTECT®?

Nanotect is a composite coating comprising selected polymer resins, lubricants, corrosion inhibitors, and carbon nanotubes (CNTs), the last of which distinguish *Nanotect* from all other coatings available to date in the market. A special technique of surface modification of CNTs developed with the collaboration of Kyoto University, Japan, has made us the first maker to develop and put on the market a line of *Nanotect* coatings in which CNTs are finely (molecularly) composited with polymer matrices. These polymer/CNT molecular composites have proved to show extraordinarily superb properties, as partly predicted by theory.

Nanotect is tailored to provide specific properties for specific applications. These properties include:

- * *Good adhesion.*
- * *Low and steady friction.*
- * *Excellent resistance to wear and abrasion.*
- * *Remarkable impact strength.*
- * *Strong resistance to corrosion.*
- * *Good Resistance to the elements.*
- * *Wide range of working temperatures.*

Pretreatment of the matrix is essential to achieve the best performance in corrosion resistance. Color is all the black of CNT, fortunately or unfortunately.

Nanotect is best used on steel products, while it can be effectively applied on many other matrices. When used on steel bolts and nuts, for example, it will provide incomparable performance in resistance to corrosion, chipping, and break and ease of maintenance, for many decades in heavy-industrial environments, for example.



Some products coated with *NANOTECT®*

What Technology IS NANOTECT[®] Based On?

Indeed carbon nanotubes (CNTs) have long been expected to be promising building blocks for next-generation composite polymers, but their extremely low solubility in solvents and polymers has prohibited their commercial applications in this field. We had the idea that a thin layer of a suitable polymer densely grafted on the CNT surface would help CNT particles finely disperse in the matrix polymer to be reinforced and, at the same time, work as an insulating barrier to prevent electric circulation through CNT particles. The electric conductivity of CNT is obviously undesirable for our purpose, since it even accelerates corrosion. This idea along with collaboration from Kyoto University has led us to develop a simple, industrially acceptable grafting method to surface-modify CNTs.

The mentioned method of CNT modification was found to be particularly effective to a selected CNT, which is supplied by GSI Creos, Corp. and in fact used in *Nanotect*. As the photos given below show, thus treated CNTs give excellent dispersion in the polymer (Photo d) as well as in the solvent (photo b), while the untreated materials form large aggregates in the solvent (a) and polymer (c). The nearly molecular dispersion of CNT in the polymer matrix as shown in Photo c has never been achieved before, and is responsible for the excellent properties of the *Nanotect* coatings.



Photo a



Photo b

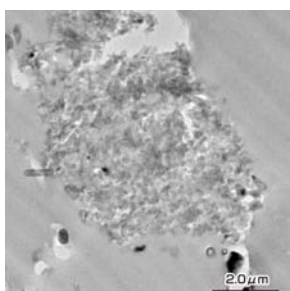


Photo c

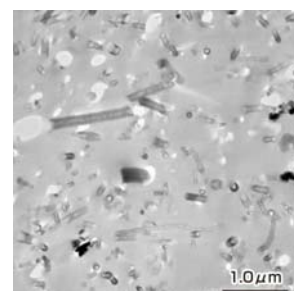


Photo d

The NANOTECT[®] Coatings

1. Nanotect-A

Among the most notable properties of this coating are **excellent resistance to wear and abrasion** (ca. 10 times more resistant than zinc coating) plus **high impact strength** (undamaged by the 1.6mm ϕ /1kg/50cm Du-Pont test).

It is also characterized by remarkable ductility (undamaged by the 2mm ϕ bend test), low friction (0.02 to 0.14, depending on methods of measurements), good resistance to corrosion (about 1000h by the salt spray test) and to UV (about 2000 h by the Dew cycle sunshine weather meter test) and wide range of working temperatures (from below -190°C to 240°C).



Nanotect-A after a 500,000r of abrasion test (left)
and a 1.6mm ϕ /1kg/50cm Du-Pont test (right)

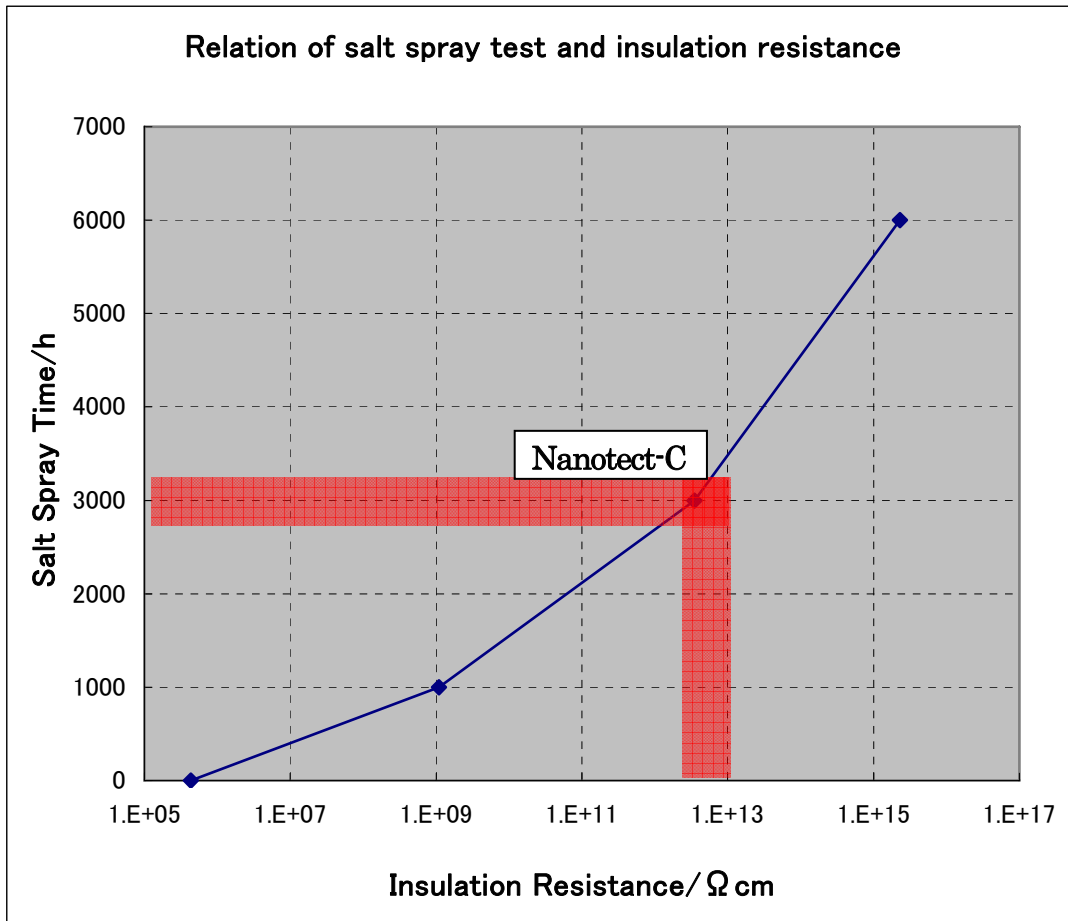
2. Nanotect-C

This coating is best characterized by its **excellent resistance to corrosion** (3000h by the salt spray test) plus **high impact strength** (undamaged by the 1.6mm ϕ /1kg/50cm Du-Pont test).

Other notable features of *Nanotect-C* include remarkable ductility (undamaged by the 2mm ϕ bend test), low friction (0.10 to 0.15, depending on methods of measurements), resistance to wear and abrasion (ca. 6 times more resistant than zinc coating), good UV resistance (about 3000 h by the Dew cycle sunshine weather meter test), and wide range of working temperatures (from below -190°C to 220°C).



Nanotect-C after 3000h of salt spray test



Relationship between the corrosion resistant time (salt spraytime) and insulation resistance of CNT composited coating films ($\sim 40 \mu$ m thick)

Selected Properties of The Nanotect and Some Other Coatings (All 30 μ m Thick)

| | Nanotect-A | | Nanotect-C | | Zinc Plate | Hard Chromium Plate |
|---|----------------|--------------|----------------|--------------|--------------|---------------------|
| | Nanotect-A | without CNT | Nanotect-C | without CNT* | | |
| Knoop Hardness | Hk80 | Hk20 | Hk70 | Hk10 | Hk120 | Hk180 |
| Abrasion Resist. (A 1kg/500rpm relative test**) | 500,000r | 75,000r | 300,000r | 4000r | 50,000r | 500,000r |
| Ductility (Bend resistance) | < ϕ 2mm | ϕ 2mm | < ϕ 2mm | ϕ 2mm | ϕ 2mm | < ϕ 2mm |
| Impact Resist. (A Dupont 1kg/50cm test) | < ϕ 1.6mm | ϕ 1.6mm | < ϕ 1.6mm | ϕ 3.2mm | ϕ 1.6mm | ϕ 1.6mm |
| Corrosion Resist. (Salt spray test***) | 1000h | 500h | 3000h | 6000h | 240h | 250h |
| Torque Coeff. (A | 0.12 | 0.16 | 0.08 | 0.12 | 0.15 | 0.2 |

* TAKECOAT-1000[®], Takenaka-Seisakusho Co., Ltd.

** Number of rounds at the first appearance of the steel matrix.

***Hours at the first appearance of rust.

Information

- 1: NANOTECT® has won the grants-in-aid of The Enhancement of Manufacturing Technology for Small and Medium Enterprises (NEDO, Subsidy No: Kinki-0608001: 2006-2008)
- 2: The Resona Foundation For Small And Medium Enterprise Promotion
中小企業優秀新技術・新製品賞 受賞
- 3: and the award of (2009).
ものづくり中小企業製品開発等支援補助金
National federation of small Business Associations
- 4: Related patents:
 - ①Patent No. 4340489
 - ②Takenaka Seisakusho Co. Ltd, *JP* P2005-28802A & P2005-7622A
 - ③Takenaka Seisakusho Co. Ltd, GSI Creos Corp, Inagaki H. *JP* P2007-291280A;
PCT: JP2007/059418.



TAKENAKA SEISAKUSHO CO., LTD.

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Unparalleled Maker of High-Quality Bolts and Nuts and Their Coatings

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JIS designated plant

ISO Quality Assurance authorized plant (JQA-0872)

Insulation resistance(Ω)

| Sample | Nanotect-A | Nanotect-C | Not Include CNT Film | General Polymer Film |
|-----------------------------------|-------------------|----------------------|----------------------|----------------------|
| Insulation resistance(Ω) | 1.1×10^9 | 3.5×10^{12} | 4.3×10^5 | 2.3×10^{14} |
| Salt Spray test(hr) | 1000 | 3000 | 2 | 6000 |
| Film thickness (μ m) | 34.2 | 33.9 | 38.0 | 37.5 |

