Since the discovery the phenomenon of organic electroluminescence by Pope et al in 1963, more than two decades the research was mainly on the academic exploration. In 1987, Tang and Vanslyke demonstrated the potential of its practical application realized by a heterojunction architecture of organic light-emitting diode (OLED) with a high quantum efficiency and lower drive voltage. Since then, booming research effort by many groups has pushed the OLED material into the flat panned display era. Recent years, energy saving is becoming a global issue and attracted tremendous attention of research organizations for its commercial potential. Besides LED that has been commercialized and used in many areas, OLED certainly has the advantages and can play a strong role in white lighting application market.

With more than 10 years experience, MCL has developed an orange-yellow phosphorescent emitter material with very high efficiency and high brightness. As disclosed in two patents, TW patent(I242999) and US patent(7445857), the PO-01 is an organic Iridium complex compound material, (Iridium(III)bis(4-phenylthieno[3,2-c]pyridinato-N,C2')acetylacetonate) with a formula of C₃₁H₂₃IrN₂O₂S₂. This high efficiency yellow phosphorescent was designed as a dopant material for a hole-transport host, e.g. CBP (4,4’-bis(N-carbazolyl)-1,1’-biphenyl).

The PO-01 has been studied in a device with following configuration by using conventional hole transport, electron transport, host and blocking materials: NPB(40nm)/PO-01(8%):CBP(30nm)/BCP(10nm)/Alq₃(20nm)/LiF(0.5nm)/Al(100nm). The device performance was summarized in Inset 2, which is comparable to a world leading commercial yellow dopant of a 62.0 cd/A current efficiency.

In addition to superior current efficiency and power efficacy of 64.8 Cd/A and 55.8 lm/W, respectively, PO-01 is also endowed with a high thermal stability of Td = 395 °C. The data shown in following figures demonstrate PO-01 as an excellent emitter material characterized with high brightness and current efficiency, high color stability, and external quantum efficiency from 12.6% - 16.7%. Based on this material, because of its lower driving voltage, a device with a low power consumption feature can be easily engineered.
Among other OLED materials under development, a device scheme with LiF/Al/ETL/HBL/Materix:PO-01/EBL/HTL/ITO layout, even better performance data was observed with CE=76.7 cd/A, PE=84.4 lm/W, EQE=19.3%. MCL is keen to collaborate with organizations developing device applications based on our PO-01 emitter material. If you’re interested in our product, please send us your contact information and we will be happy to discuss with you about our offers.

**Contact information**

MCL Technology Showcase  
Chun-Sien Lin, PhD, Senior Researcher  
Materials and Chemical Research Labs, ITRI  
Tel: 886-3-5913597 Fax:886-3-5835087  
Email: mcl_tech@itri.org.tw  
Address: Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31015  
WebSite: http://www.materialsnet.com.tw/eng/OLED.html
We offer products of OEX-C200 and CNF-C500 for transparent conductive film, conductive filler and reinforcement filler applications.

The product OEX-C200 features network structured CNT used for transparent conductive film.

The product CNF-C500 features a low-tangled carbon nanofiber used for conductive filler (EMI, ESD) and reinforcement fillers (CFRP).

The discovery of carbon nanotube may date back to a patent regarding the carbon filament of incandescent lamp granted in 1889. However, only when in 1991, an NEC's scientist Dr. Iijima reported on Nature of his TEM observation, the mystery of a multi-walled carbon nanotube structure was unveiled. Since then, flourishing research activities have been carried out in many major research institutes in the world. Some postulate of its novel applications such as NASA's space elevator from the Earth to the moon have been discussed publicly. Numerous potential applications have been reported in the fields such as FPC, IC packaging, optoelectronics, energy storage, composites, among others.

The focuses of MCL technology expertise for the applications are in three major categories, which are:
- opto-electronics
- reinforcement
- EMI/ESD film/coatings

In Material and Chemical Research Lab (MCL) of ITRI, a research team has been working on this subject over 8 years, and accumulated valuable experiences of key technologies covering manufacturing of carbon nanotube, morphology tailoring, dispersion, coating/patterning processes, and among others. With MCL's unique CNT's properties, we are able to develop the applications with the forms of film, fiber, conductive liquid, and devices. As illustrated in Figure 1, among our innovative product technologies, two success cases including the licensing and technology transfer for CNT/CNF continuous manufacturing process, modification/dispersion, and CNT conductive film are underway.

With MCL platform technologies, two unique CNT products were developed with successful industrial applications, one is network structured OEX-C200 and the other one is low tangled CNF-C5000. The flexible manufacturing routes developed in MCL enable the morphology controlled CNTs for different applications. In addition to variety of morphologies, we can produce regular products with uniform size range, e.g. 40-100nm low-tangled CNF-C5000 and 1-3nm networked OEX-C200 with high conductivity.

**Modification & Dispersion**

![Image](Image)

*Figure 1. MCL's proprietary processes for modification and dispersion provide custom made master batch for different applications.*
The low-tangled CNF-C5000 is easily dispersed and modified by different functional groups to match the compatibility essential to our clients’ special matrixes. MCL’s CNF-C5000 can be used in reinforced composite and EMI film, etc., which features a low-tangled morphology, easy dispersion, tunable tube diameter, easy surface modification, higher connectivity when dispersed for EMI shielding products. Figure 2 illustrates our unique capability of modifying and dispersing CNTs in different matrices for clients' special requirement.

The network-structured CNT combined with our unique proprietary technologies of structure design can achieve high transparent and high conductivity demands. The MCL’s CNT/PET features an excellent flexurability, as shown in Figure 3, roll-to-roll process readiness and overall lower processing cost. With competitive lower cost and comparable properties, CNT/PET conductive film is a potential candidate to replace ITO/PET film in some opto-electronic applications. The comparison of OEX-C200 with world leading commercial products as shown in Figure 4, indicated that our products have excellent properties, particularly with a lower sheet resistance.

<table>
<thead>
<tr>
<th>Company</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>ITRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Arc Discharge</td>
<td>High Pressure CVD</td>
<td>CVD</td>
<td>CVD</td>
<td>Proprietary</td>
</tr>
<tr>
<td>Diameter</td>
<td>1.3-1.5nm</td>
<td>0.8-1.2nm</td>
<td>1.5-1.7nm</td>
<td>0.8-1.2nm</td>
<td>2-2.5nm</td>
</tr>
<tr>
<td>G/D</td>
<td>～40</td>
<td>13</td>
<td>2.81</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Carbon Purity(TGA)</td>
<td>60-70wt%</td>
<td>85wt%</td>
<td>&gt;70wt%</td>
<td>&gt;85wt%</td>
<td>&gt;90wt%</td>
</tr>
<tr>
<td>Appearance(SEM)</td>
<td>High purity&lt;sup&gt;1&lt;/sup&gt;</td>
<td>High purity&lt;sup&gt;1&lt;/sup&gt;</td>
<td>High purity&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Low purity&lt;sup&gt;2&lt;/sup&gt;</td>
<td>High purity&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> embedded metal catalyst impurity
<sup>2</sup> many spherical carbons

Figure 2. After bending 180°, MCL’s CNT film retain a low sheet resistance, e.g. < 1000Ω/□

The comparison of ITRI OE-CNT with other commercial products

Figure 4. The table shows the comparison of MCL’s CNT with leading companies. A significantly high conductivity compared with commercial products, as shown in the right-hand plot, is the advantage of MCL’s OEX-C200 in addition to controlled morphology and sizes.
The following table summarizes the common properties of two regular CNT products. We also can offer the derivatives based on these CNT fiber/powder materials for some novel applications.

<table>
<thead>
<tr>
<th></th>
<th>OEX-C200</th>
<th>CNF-C5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purity (wt%)</td>
<td>&gt;80%</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Diameter (nm)</td>
<td>1.5-2.5nm</td>
<td>40-60 nm</td>
</tr>
<tr>
<td>Surface area*</td>
<td>In determination</td>
<td>70-100m2/g</td>
</tr>
<tr>
<td>Length range*</td>
<td>1-10μm</td>
<td>1-5μm</td>
</tr>
<tr>
<td>Wall number*</td>
<td>1-3</td>
<td>NA</td>
</tr>
<tr>
<td>G/D Ratio</td>
<td>&gt;20</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Product type**

|                      | cake, powder, solution | Powder, cake, waterdispersion (0.2wt%) | Powder, CNF Cotton |

**Master solution**

| Continuous phase: Epoxy, Polyamide, PC, PP, etc. | NA | Epoxy |
| Solid content (wt%) | 5% |  |  |

* for reference only, not guaranteed.

**Contact information**

MCL Technology Showcase  
Chun-Sien Lin, PhD, Senior Researcher  
Materials and Chemical Research Labs, ITRI  
Tel: 886-3-5913597 Fax:886-3-5935087  
Email: mcl tech@itri.org.tw  
Address : Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31015  
WebSite: http://www.materialsnet.com.tw/eng/CNT.html
High performance TCO film developed by MCL’s research team now is available for leading edge users. The products will be delivered in the form of FTO film coated glass to your specific demands.

FTO is generally superior in combination of cost and performance, and avoids problems with indium diffusion into the N-type TiO₂ or ZnO nano-structured film.

**Potential Applications**

(a) Flat panel displays, (b) Touch panel, (c) Dye-sensitized solar cells, (d) Smart windows, (e) Flexible electronics, (f) Thin film solar cell.

**Able to offer**

MCL researcher is able to offer better material properties both with low "sheet resistance" and high "transmittance". With these unique properties, FTO can also be used in a wide range of thin film devices, including opto-electronics, photovoltaic, energy saving windows and so on. MCL’s high performance film was also verified by applying to the dye-sensitized solar cell module. As shown below, the high transmittance and low sheet resistance of FTO glass enable the high photocurrent and high fill factor (FF) of a DSSC module. MCL is also developing application for module temperature control and touch panel.

The graph shows a better performance of DSSC coated with MCL-FTO-VT film.
In addition to standard MCL-FTO sample specs, as shown in the table, we can offer a visible transmission up to 80-85% designated as MCL-FTO-VT for more advanced users, MCL can also provide even lower sheet resistance, e.g. < 6Ω/□, or higher visible transmission, e.g. > 85%, designated as Apollo series to meet your unique application needs. Please send your order request to MCL Technology Showcase contact address, we will reply you as soon as we can.

<table>
<thead>
<tr>
<th>Standard MCL-FTO Sample Specs (MCL-FTO)</th>
<th></th>
</tr>
</thead>
</table>
| **Size** | 5x5 cm²  
10x10cm² |
| **Sheet resistance** | < 12 Ω/□ |
| **Substrate thickness** | 1.1 mm |
| **Visible transmission** | > 75% |

**Contact information**

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Chun-Sien Lin, PhD, Senior Researcher  
Materials and Chemical Research Labs, ITRI  
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Email: mcl_tech@itri.org.tw  
Address : Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd.,  
Chutung, Hsinchu, Taiwan 31015  
WebSite: http://www.materialsnet.com.tw/eng/FTO.html
MCL's topnotch precision coating facilities is ready to convert your coating material into a valuable product applied in PCB, Electronic Packaging, Flat Panel Display, Flexible Electronics industries, and soon. Over 30 success cases with variable industrial partners enable us to offer an agile, flexible, open innovative platform to your custom needs. Upon request we also provide you services for new product development, new materials evaluation and process design. Through our networking capabilities, you can also connect to the leading industrial customers in the world.

As illustrated in the block diagram, depending on the incoming coating feedstock, this platform is capable of producing the product films on a flexible substrate with features: wet thickness from 3~300μm, thickness uniformity greater than 95%, and a coating width from 100~300mm. If on a rigid substrate, it is capable of making product film with a wet thickness from 10~300μm, thickness uniformity grater than 95% with a maximum sheet size up to 370 x 470 mm.

With more than 15 years hands-on experience, the team consisting of four doctors and two masters has accumulated unique competence which includes:
Coating :: A Precision Coating Platform

- Die design
- Flow field analysis
- Coating material and process interface studies
- Drying process simulation/analysis
- Simultaneously Dual layer coating
- Defect analysis for coating and drying processes

They have completed more than 30 difficult cases to help companies quickly engaged into leading market business. The success not only results from hands-on experience, but also funded upon their valuable knowledge and know-how of coating and drying technology, fluid mechanics, coating bead simulation, quality control and measurement, coating and drying defects analysis, and so on and so forth.

The Platform Facilities

Roll-to-Roll coater
- Coating for flexible substrate such as polyester film, polyimide film, TAC film and so on.
- Clean Room=Class 10,000
- roller width: 450mm
- Coating methods: Slot die coating, Comma coating, Kiss Gravure coating
- Drying methods: Thermal drying, IR, UV
- On-line thermal lamination Corona treatment; Rubbing device
- Viscosity of coatings: 1~5,000 cps

coating features:
- Wet thickness range: 3~300μm
- Thickness uniformity: ≥ 95%
- Coating width: 100~300mm

Patch coater
- Coating for rigid substrate such as glass, PMMA and so on.
- Coating method: Slot Die Coating
- Viscosity of coatings: 1~5,000 cps

coating features:
- Wet thickness: 10~300 μm
- Thickness Uniformity: ≥ 95%
- Max. sheet size: 370 x 470 mm

Characterization Capabilities
- Coating Thickness Gauge
- Rheometer
- Surface tensiometer
- SEM
- Haze meter
- Pencil hardness tester
- Colorimeter
- others
Pilot Production Facilities

Roll-to-Roll coater

Patch coater

Success cases

MCL research team has been working in coating process for over 15 years. In these years, the team has studied and refined the key processes in precision thin film coating and related technologies such as the critical drying process. The accumulated experience has helped to develop the simulation capability for fluid dynamics and drying procedures. The past success experiences are listed in the following, most of them are near pilot scale with equipment for the 2nd generation substrate:

- Slot Coating for PSA tape
- Lithium Battery
- DS-TAB
- Flexible Printed Circuit
- Ink-jet Paper and Overhead
- Thermal ribbon & receiver
- Ceramic Capacitor
- Medical Cover Tape
- Dry Film Photo Resistance
- Protective PSA Tape
- Color Filter Coating on Glass
- LOC Tape
- Hardcoat/Anti-glare/Anti-reflection Coating
- Liquid Film Optical Film
- Flexible Display Substrate
- Moisture and gas tight barrier coating
- CNT Conductive Film
- Polymer Conductive Film
- Fuel Cell Coating on Glass
- Chip Size Package Substrate
- RCC Substrate
- Dry Film Color Filter
- ACF/NCF
- etc.

Success Stories

Case 1: Transformed the products of a traditional specialty chemical company to penetrate the optoelectronics market.

Problems encountered:
The earlier spin coating technology had the problems of high rate of broken glass substrate
Coating: A Precision Coating Platform

during the transportation and spinning process. The material usage rate of spin coating technology is considerably too low, therefore, an urgent need was to develop a coating process with a high material usage rate as well as high production speed. The coating materials used were red, green and blue photoresist materials for color filter film. The team made use of MCL’s simulation software to fine-tune the properties of photoresist materials, and then successfully verified by MCL’s patch coater. These parameters were in turn used in slot die coating process to obtain high uniformity of the thickness and resulted in stable coating products. As a result of the project outcome, a ramp-up of the throughput leaded the company to penetrate the optical display industry.

The summary of the coating properties:

- Wet thickness: 15-25μm
- Coating coverage: 310 x 400mm
- Thickness uniformity: ≥92%
- Coating speed: ≥120mm/s

**Case 2: Coating Process Evaluation of Commercial Hardcoat Materials on TAC Substrate.**

MCL was contracted by a well-known international company to evaluate the possibility of using commercial hardcoat materials, including DSM, other Japanese, Taiwanese companies’ and MCL’s, on TAC substrate provided by this company. The TAC substrate material was originally used for traditional photography negative films, and was intended as a protective substrate for polarized films. The project goals covered a wide range of tasks which included the screening and selection of suitable commercial coating material, establishing necessary testing equipments, commissioning coating processes and curing, etc. The conditions used in the coating process and curing were optimized and successfully applied to obtain a high quality hardcoat on TAC Substrate provided by the company. The following lists the specs achieved by the project:

- Thickness: 3-5 μm
- Haze: <1%
- Total Light Transmittance (at 550 nm): >90%
- Pencil Hardness: 3H
- Bonding Strength on Coating Layer: 100/100
- Curl: <3cm

In terms of this project, the company could quickly penetrate the market through MCL’s connecting channels with downstream optoelectronics users in Taiwan. Since there are many world leading industries located in Taiwan, MCL’s partners can closely work with research team and verified by end-users through established networks. This advantage will save MCL’s partner tremendous effort of introducing their new products to make a debut in the market by collaboration projects.

**Contact Information**

MCL Technology Showcase
Chun-Sien Lin, PhD, Senior Researcher
Materials and Chemical Research Labs, ITRI
Tel: 886-3-5913597 Fax: 886-3-5835087
Email: mcl_tech@itri.org.tw
Address: Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31015

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High Conductivity MMC Substrate

~ High Performance Thermal Management Materials ~

Developed by MCL's research group on thermal management material, the Al-based MMCs is available for high demand users. We can provide you graphite series Al-based composite substrate or heat spreader to meet your specific needs on thermal management.

Able to offer

As shown in the following photos, the substrates were custom designed for Taiwan's local LED manufacturers to meet their unique requirements. The MCL research team with interdisciplinary expertise is able to offer those substrates with special circuit for different high power LED applications.

(a) MCL-G350 composite material  (b) MMC Composite substrate for LED

The composite materials are endowed with tunable high thermal conductivity, light weight and low thermal expansion coefficient. Our unique production processes also enable a high cost/performance ratio to meet your special requirements. There are potential applications for thermal base, substrate and heat spreader in many areas, such as CPU/GPU cooler, high power LED, power modules (IGBT), and even used in electric vehicle and hybrid car.

The composite material is light weight with a density of about one thirds of Cu and steel, one fifths of CuMo alloy, and one sixths of CuW. Its thermal conductivity, with a much lower CTE compatible with semiconductor, is higher than Cu and Al's. In addition to above advantages, the thermal dissipation capability as shown in the following graph proves it a perfect material for high demand applications.
With more than 10 years experience, the team also can tailor the thermal conductivity and CTE of MCL's graphite series Al-based MMC between 300–550 W/mK (Kxy =), and 3~10 ppm/K, respectively. The substrate with comparable Kxy and Kz is one of our current research goals for a commercial production. The following table is the comparison of MCL's unique composite substrate material with commonly used materials.

<table>
<thead>
<tr>
<th>Sample Designation</th>
<th>Density (g/cm³)</th>
<th>Conductivity (W/m*K)</th>
<th>CTE (ppm/K) RT~100°C</th>
<th>Flexural Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite series Al-based MMC</td>
<td>2.3~2.5</td>
<td>100~150(┴)</td>
<td>-</td>
<td>70~80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500~350(═)</td>
<td>3~10</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>8.9</td>
<td>380</td>
<td>16.5</td>
<td>250</td>
</tr>
<tr>
<td>Al</td>
<td>2.7</td>
<td>200</td>
<td>24</td>
<td>210</td>
</tr>
</tbody>
</table>

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Email: mcl_tech@itri.org.tw  
Address: Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31015  
Website: http://www.materialsnet.com.tw/eng/MCL-TechnologyShowcase.html
A powerful nano-photocatalyst which can perform even under an LED light, has been developed by MCL's research team. The composite structure consists of a metallic core and TiO₂ shell is proved to be an excellent photocatalyst both indoor and outdoor applications. This new photocatalyst can be used in the applications of pet deodorization, formaldehyde absorbent/decomposer, toilet deodorization, and others such as self-cleaning and germproof under certain circumstances. In the graph, we can see it's effective in whole visible light spectrum from 400 to 800nm.

Success cases with our photocatalyst for different purposes were applied in a couple of construction projects, which are Congressional leader office, Hsin-chu SS construction project, Kaoshiung green building project, a pet accessory manufacturing building, CPC building in Taipei and Chunwha Telecom headquarter in Taipei. Accelerated aging test have been performed for the anti-acidic, anti-basic and salt fog tests, which abide by the standard codes of CNS10757-K6801 and ASTM B117. The testing results shown in the following graphs, suggest that our photo-catalyst is suitable for a new furnished building by quickly reducing the formaldehyde content in the air.

The traditional photo-catalyst can work only under sunshine or a UV lighting condition as illustrated in the graph below. MCL's patented concept creates a new horizon of photo-catalyst with metal-anatase composite nano-particle, which is even effective in cloudy day and under visible light. This also expands its potential as an anti-germ spray.
Comparing to other commercial photo-catalyst products, the major features of our high performance photo-catalyst are summarized as follows:

- Multifunctional
  - Antimicrobial
  - Eliminate formaldehyde, NOx, deodorize indoor air
  - Easy Cleaning
- Activated by both UV and visible lights, ideal for indoor applications
- Antimicrobial function active even in darkness, providing 24 hours protection
- Ease of application – Spray applied from aqueous solution, substrate temperature up to 4000C
- Superior film forming property with excellent clarity and adhesion to substrate
- Long service life, >3 years for room temperature applied film (>3H hardness). Permanently bonded to ceramic substrates when applied at higher temperature.

Connecting to Our Services

If you're interested in enquiry our services, please fill out to send us an e-mail with your name, organization, detailed inquiry items, we will reply you with further information.

Key Technologies, Facility and Services

Nanotechnology; photocatalyst; core-shell structure; defromaldehyde; TiO₂

Contact information

MCL Technology Showcase
Chun-Sien Lin, PhD, Senior Researcher
Materials and Chemical Research Labs, ITRI
Tel: 886-3-5913597 Fax: 886-3-5835087
Email: mcl_tech@itri.org.tw
Address : Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31015
Website : http://www.materialsnet.com.tw/eng/MCL-TechnologyShowcase.html
MCL's anti-fouling coating is proved to be an excellent solution to the maintenance of building and vehicle's exterior, particularly the anti-fouling effect on glass. Minerals in water such as calcium/magnesium carbonates can easily deposit onto glass surface creating hard to clean spots. Traditionally, diluted HF and some other chemicals were used to clean the stubborn stains, however, resulting in problems of environment pollution and weakening physical strength of the glass.

Since 2007, we have been cooperating with local companies to apply this coating to railway trains' window and windshield glasses. In addition to easy cleaning without using difficult tooling, a tremendous saving of maintenance hour reduce the idle time of trains, and hence increases the effectiveness of service operation.

The coating durability has been tested under Xenon arc light exposure and by wet abrasion scrub, abiding by the standard codes of ASTM G155 and ASTM D2486 respectively. In the graph(a) the contact angle didn't change much after 20,000 scrubs. In the graph(b), our coating was compared with other commercial products, and shown the ability to main high contact angle after 1200 hours exposure.
In addition to the application of MCL's product on vehicles' window glass, our easy-cleaning coating can also be applied even to some household objects and appliances, such as toilet, coffee cup, kitchen wall tile and others. One of the examples is shown in bottom photos, where the left one is coated by our product. There are more examples of potential applications under our investigation, if you're interested in acquiring the samples, please fill out the separate enquiry form.

The photo shows the comparison of with and without the application of MCL's easy-clean coating on windshield glass.

The coffee cup is stain-free after service.

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**Connecting to Our Services**

If you're interested in enquiry our services, please fill out to send us an e-mail with your name, organization, detailed inquiry items, we will reply you with further information.

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**Key Technologies, Facility and Services**

Easy clean, Anti-fouling, Super-hydrophobic coating, Paint top coat, Vehicle windshield, Train windshield

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**Contact information**

MCL Technology Showcase  
Chun-Sien Lin, PhD, Senior Researcher  
Materials and Chemical Research Labs, ITRI  
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Address: Rm. 205-2, Bldg. 77, 195, Sec. 4, Chung Hsing Rd., Chutung, Hsinchu, Taiwan 31015  
Website: http://www.materialsnet.com.tw/eng/Easy-Clean-Coating.html