Electronics Business

Next-Generation High-Speed Communication

AGC Inc.

June 3, 2019

Your Dreams, Our Challenge

Contents

1. Electronics business positioning

Electronics Field Positioning at AGC

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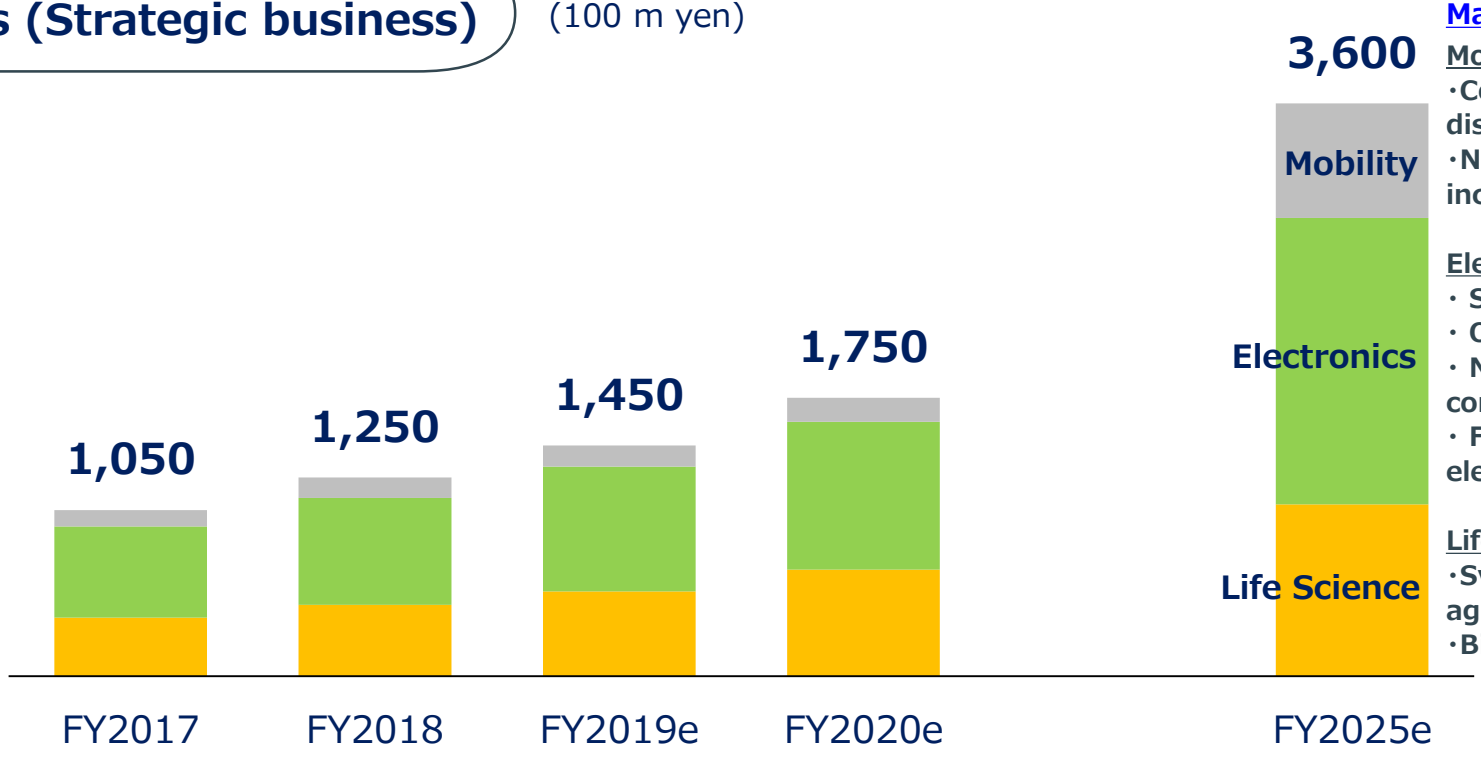
- Business activities that earn roughly half of our 360 billion yen in sales

Sales (Strategic business) (100 m yen)



Major products & business

Mobility
- Cover glass for car-mounted displays
- New materials for mobility, including 5G communications.

Electronics
- Semiconductor-related products
- Optoelectronics materials
- Next-generation high-speed communication related products
- Fluorinated products for electronics

Life Science
- Synthetic pharmaceutical and agrochemical
- Bio CDMO

2. Imminent arrival of next-generation high-speed communication

Market Trends and Communications that Use High-frequency Bands

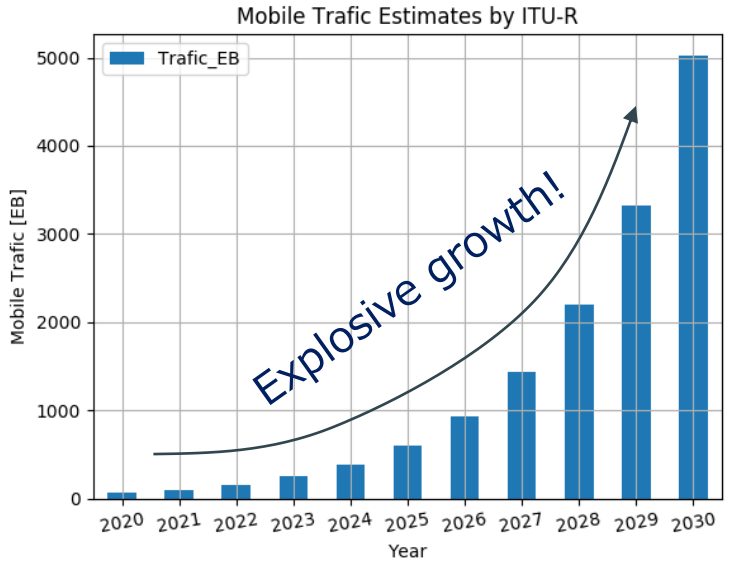


Fig. Estimation of mobile traffic in 2020-2030

- Increase in connected devices due to the expansion of IoT and M2M
- Increase in 4K/8K, ARVR and other high-volume data content communication
  - Mobile traffic volume is undergoing explosive growth, and it cannot be handled by simply extending existing technologies

(expected to grow by 1300 times in the 15 years from 2015)

Shift towards the next generation (5G) of high-speed communication that uses high frequency (millimeter-wave) bands

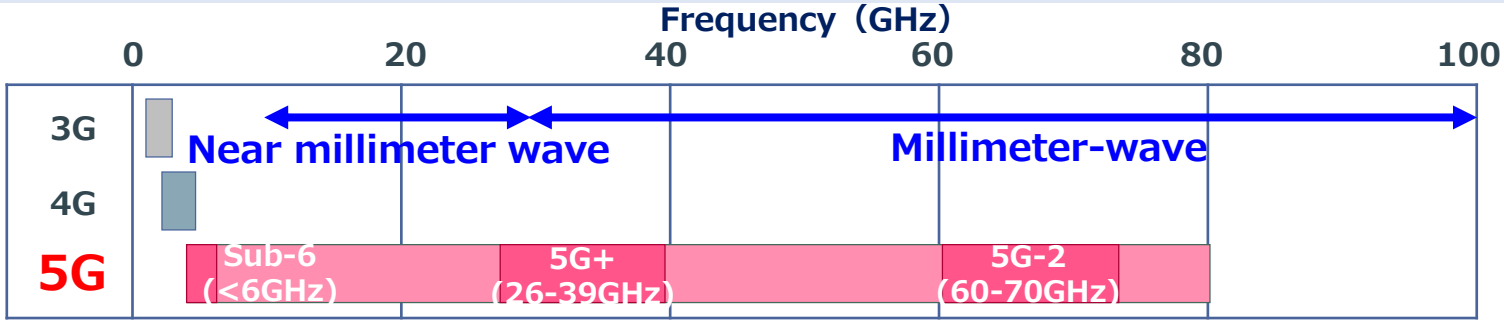


Fig. Frequency band for mobile communication

Why are High Frequencies Used?

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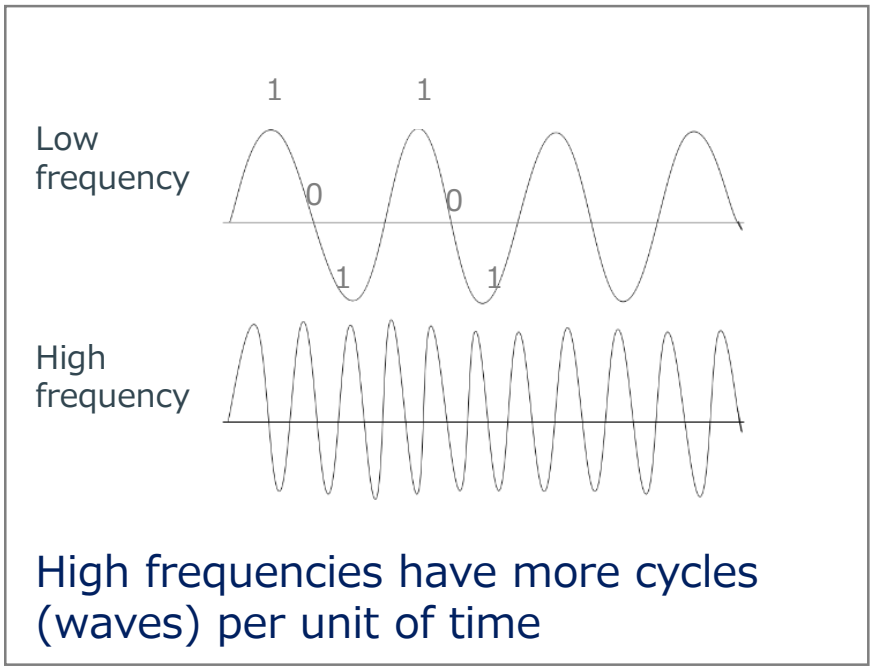
- High frequencies allow more information to be transmitted per unit time, which enables ultra-high speeds and high-volume data transfers



High frequencies have more cycles (waves) per unit of time

5G Benefits

- Ultra high-speed/high-volume data
- Ultra high-capacity connection
- Ultra low latency

Challenges with High Frequencies (1)

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Challenges with High Frequencies

- Large transmission loss
- Hard to diffract
  (=difficult for radio waves to permeate an area)
- Difficult to pass through materials

  ⇨ Distance that radio waves can travel is reduced as a result
  (= Loss of signal power)

Expected Future Trends

- Larger number of base stations
  (=increase in number of materials adopted)
- New materials and products that will make it easier to transmit and propagate high frequencies
- High-performance antennas
  (Ultra multi-element MIMO antenna)

Materials required for high-frequency transmission are drastically different from existing materials, which will lead to a growing market for the newly adopted materials!

Challenges with High Frequencies (2)

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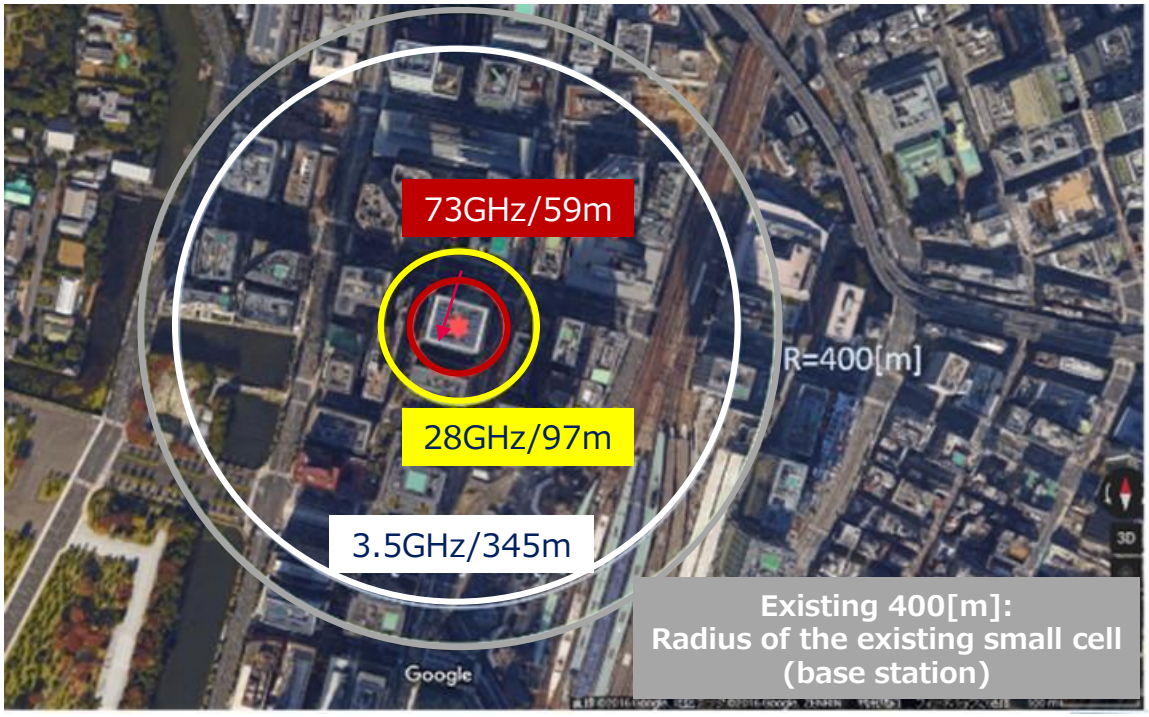
- The higher the frequency, the shorter distance radio waves can reach

Distance range comparison (note)



	Frequency	Distance range (Note)
Sub-6	3.5GHz (Microwave)	345m
5G+	28GHz (Millimeter-wave)	97m
5G-2	73GHz (Millimeter-wave)	59m

(Note) 130 dB decay distance

Sources: Microwave (3.5 GHz): ITU-R M.2135-1 "Guideline for evaluation of radio interface technologies for IMT-Advanced"
Millimeter wave (28GHz, 73GHz): T. S. Rappaport et al., “Millimeter wave channel modeling and cellular capacity evaluation”
New York Univ. IEEE Journal on selected areas in communications vol. 32 No. 6 2014

3. AGC's business opportunities in next-generation high-speed communication

AGC's Business Opportunities: Synergy with Our Core Technologies

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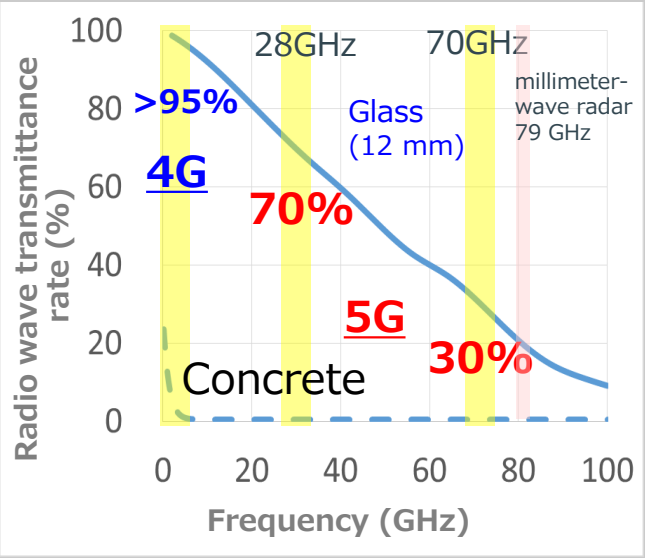
① Glass is not transparent	② Making circuit boards low-loss is important	③ Element miniaturization/higher complexity/more precise mounting

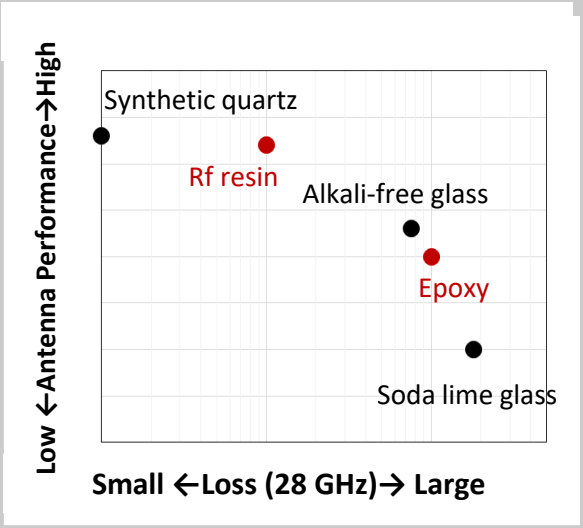
[Radio wave transmittance rates]



- ✓ Glass does not pass radio waves easily, limiting communication through glass openings

⇒ **Glass manufacturers have an important role to play**

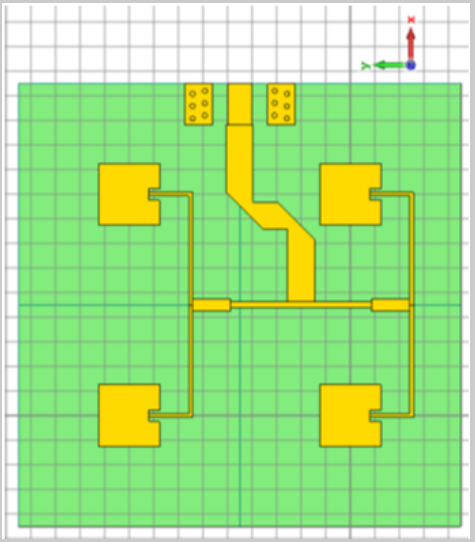
[Antenna gain in 28 GHz band]



- ✓ Substrate's dielectric loss has a large impact on the performance of antennas and circuits

⇒ **This is where low-loss materials (quartz, fluoride) come into play!**

[Antenna elements]



- ✓ Requires higher precision patterning, microfabrication and mounting design

⇒ **AGC's materials and know-how can be utilized here**

① Shift towards glass antennas	② High-frequency low-loss substrate (CCL)	③ High-frequency communication devices (Antenna filters)

Anticipated Business Opportunities for AGC : AGC's Low-loss Materials

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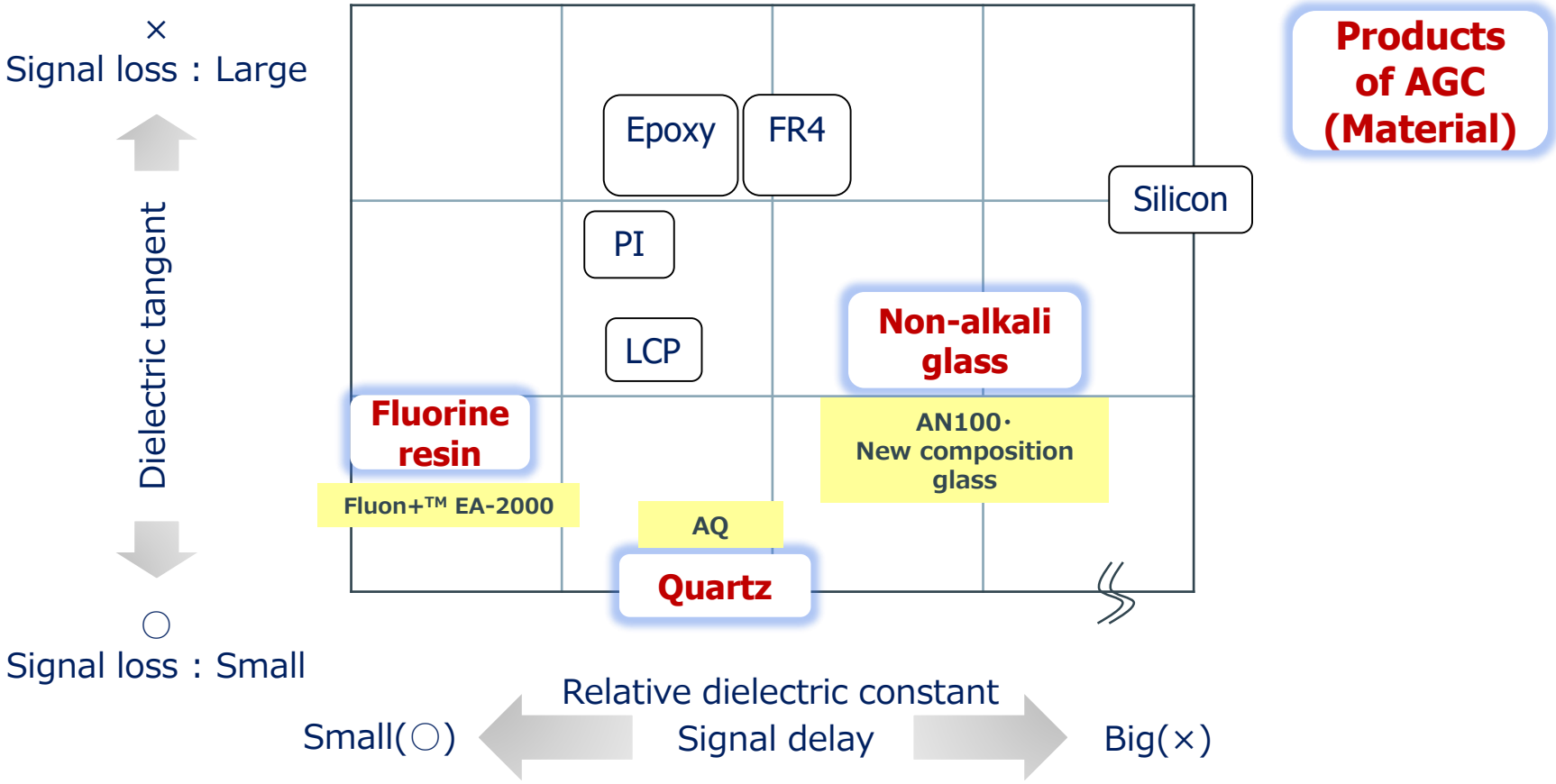
- AGC can provide low-loss materials that are effective in solving communication material problems in the shift towards higher radio frequencies

Performance comparison of communication material



4. Entering the copper clad laminate (CCL) market

What is Copper-clad Laminate (CCL)? (1) Structure

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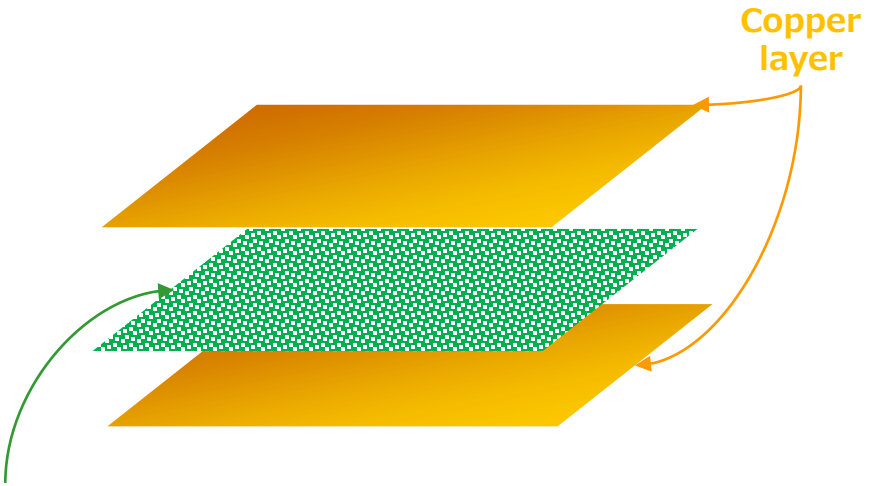
- CCL is a printed circuit board material composed of copper layers and an insulating resin

Rigid CCL cross section

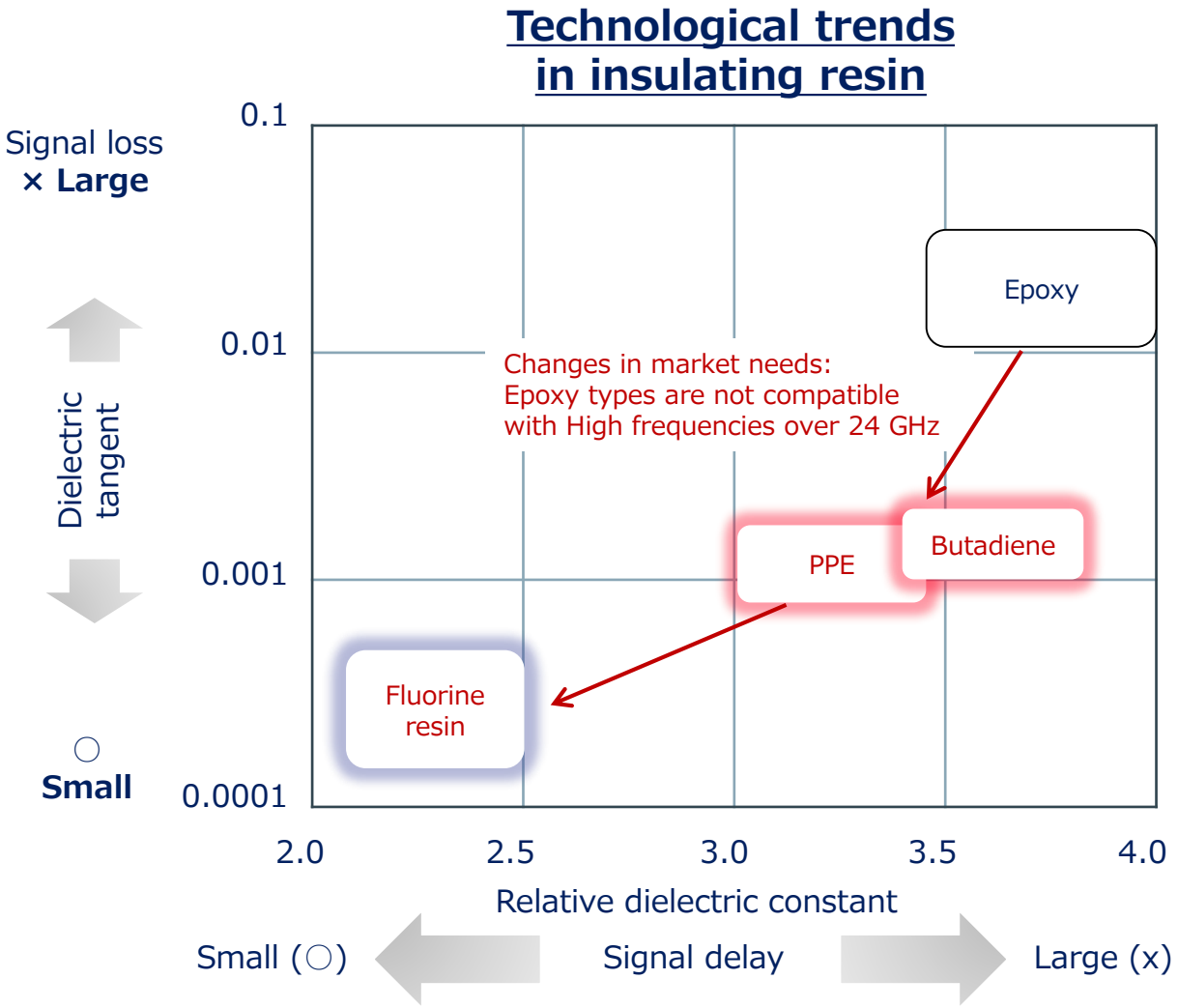


- If including glass fiber:
  - Resin (fluorine, PPE, etc.) is impregnated into the glass fiber

- If not including glass fiber:
  - Uses a composite material of resin + ceramics

What is Copper-clad Laminate (CCL)?
(2) Technology trends

- Since it is difficult to use epoxy resin compositions with next-generation high-speed communication such as 5G, PPE/fluorinated resin is required



Example of the supply chain for Rigid CCL Business

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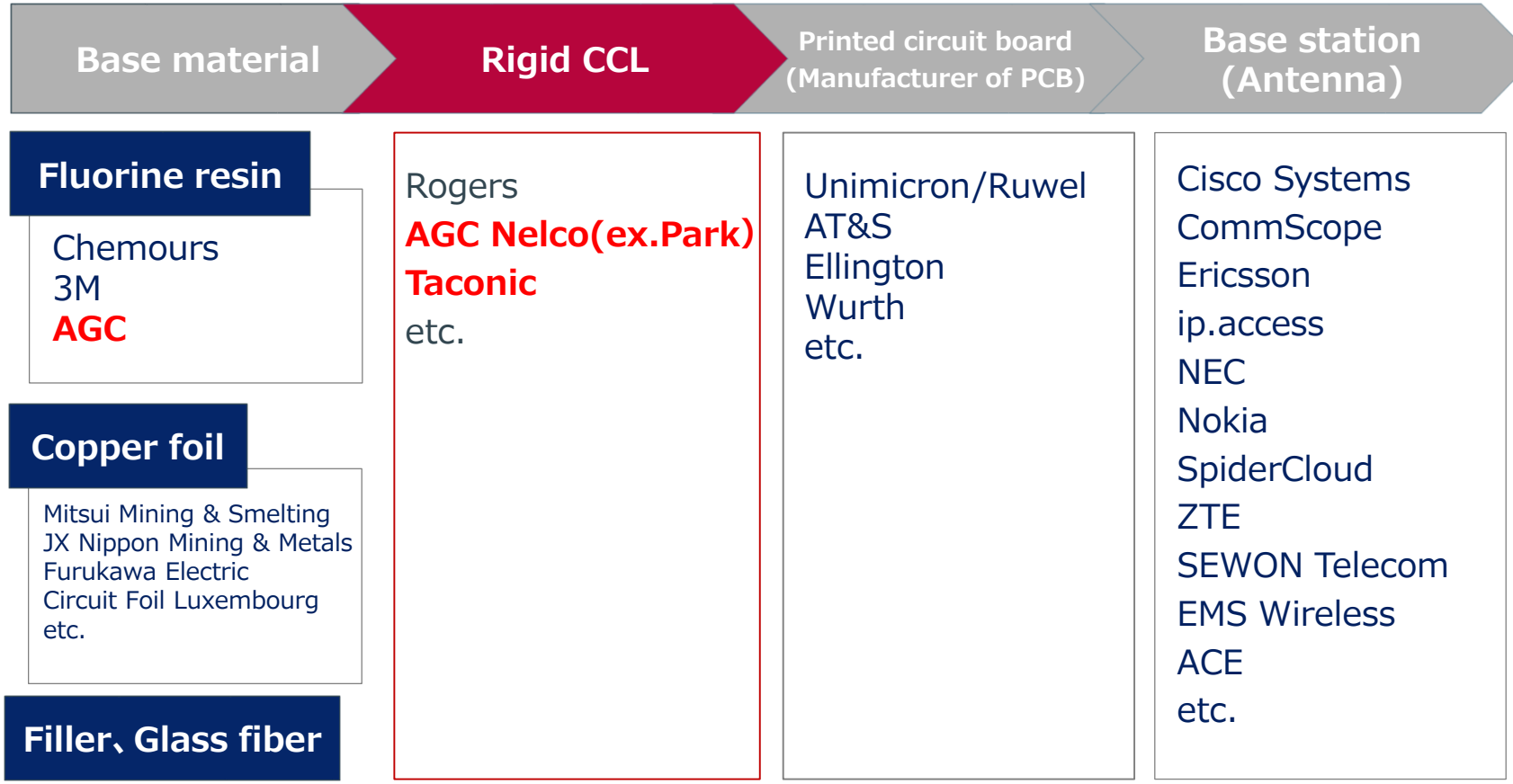
- CCL is generally classified into hard type “Rigid CCL" or soft type "Flexible CCL".
- Market growth is forecast at about CAGR 15% in next-generation high-speed telecommunications applications which include consumer communications (base stations, servers), automotive (millimeter-wave radar), aerospace (satellite communication), etc.



Business Scale and AGC's Positioning in the Rigid CCL Market

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- The super high-end rigid CCL market is expected to grow to about 200–280 billion yen (CAGR 13–17%) by 2025
- Of this, the CCL market to be adopted for '5G antennas' and 'millimeter-wave vehicle antennas' (24 GHz and up) is expected to grow dramatically from 7.5 billion yen (2016) to 140 billion yen (2025) with a CAGR 38%

	Player	Market scale in 2025 (Estimate)
Super high end (Use : Millimeter wave、Base station for 5G、Satellite etc.)	ROGERS CORPORATION, TACONIC, PARK ELECTROCHEMICAL CORP., isola	200～ 280 billion yen Of this, the CCL market to be adopted for '5G antennas' and 'millimeter-wave vehicle antennas' (24 GHz and up) is 140 billion yen (2025)
High end (Use : Server、Router etc.)	PARK ELECTROCHEMICAL CORP., isola, Panasonic, tuc, DOOSAN, Hitachi Chemical Working On Wonders, EMC 台光電子材料股份有限公司 Elite Material Co., Ltd.	
Middle&low end	isola, Panasonic, tuc, ITEQ INNOVATION · TEAMWORK · EXCELLENCE · QUALITY, EMC 台光電子材料股份有限公司 Elite Material Co., Ltd., 南亞塑膠工業股份有限公司 NAN YA PLASTICS CORPORATION, 生益科技 SYTECH	1,100～ 1,200 billion yen

Source: Global PTFE CCL Market Research Report 2018 (MARKET.BIZesearch); 2017 market forecast material on millimeter-wave radar/next-generation (5G) communications and high-speed and high-frequency PCB material (JMS); AGC estimates

Affinities with AGC Technologies

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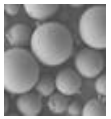
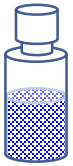
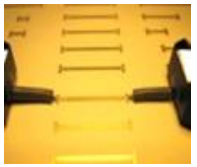
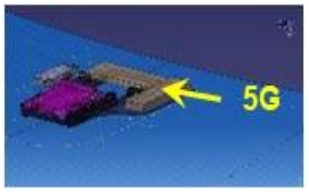
- In terms of (1) raw materials (organic/inorganic substances), (2) manufacturing processes, and (3) applications, AGC has the technology and human resources needed to produce super high-end CCL (copper clad laminate), which is required to achieve next-generation high-speed communication.

	①Base material	composite	②CCL Manufacturing	②CCL Characterization	③ Example of AGC's applications
CCL materials & processes	Inorganic filler  Adhesive fluorinated resin (Fluon+TM EA-2000) 	Composite technology 	CCL  **Acquired Park Electrochemical and Taconic** R2R technology 		Base station antenna   Glass antenna for buildings  On-glass antennas for automotive
AGC's CCL technology	**Adhesive fluorine resin** **Inorganic filler** ・Eg) Ceramics, glass etc.	**Composites** • Melt-kneaded sheet • Solvent dispersion • Control structure	**CCL migration** ・R2R ・Vacuum heat press **Interface control technology** ・Analysis of binding mechanisms	**CCL properties evaluation** ・CTE ・Dielectric properties ・Peel strength ・Thermal conductivity ・Transmission loss	

AGC's Advantages in the Super High-End Market

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■ Our product portfolio combines fluorinated resins and PPE-based super high-end CCL

	Fluorinated resin based CCL	PPE resin based CCL	Features
PARK ELECTROCHEMICAL CORP. an Aerospace Company (Currently: AGC Nelco)	Held ○	Held ○	• Develops PPE resin based super high-end CCL for supporting 5G focused high-speed high-frequency communication, and is currently entering the market • Mainly aimed at high-speed servers etc.
TACONIC	Held ○	No	• No.2 in the fluorinated resin super high-end CCL market • Mainly aimed at automobile millimeter-wave radar, communications base stations, etc.
ROGERS CORPORATION	Held ○	No	• Industry leader in the fluorinated resin super high-end CCL segment • Mainly aimed at automobile millimeter-wave radar, communications base stations, etc.
Panasonic	No	Held ○	• Industry leader in the PPE resin super high-end CCL segment • Mainly aimed at high-speed servers etc.

5.Outlook for 2025

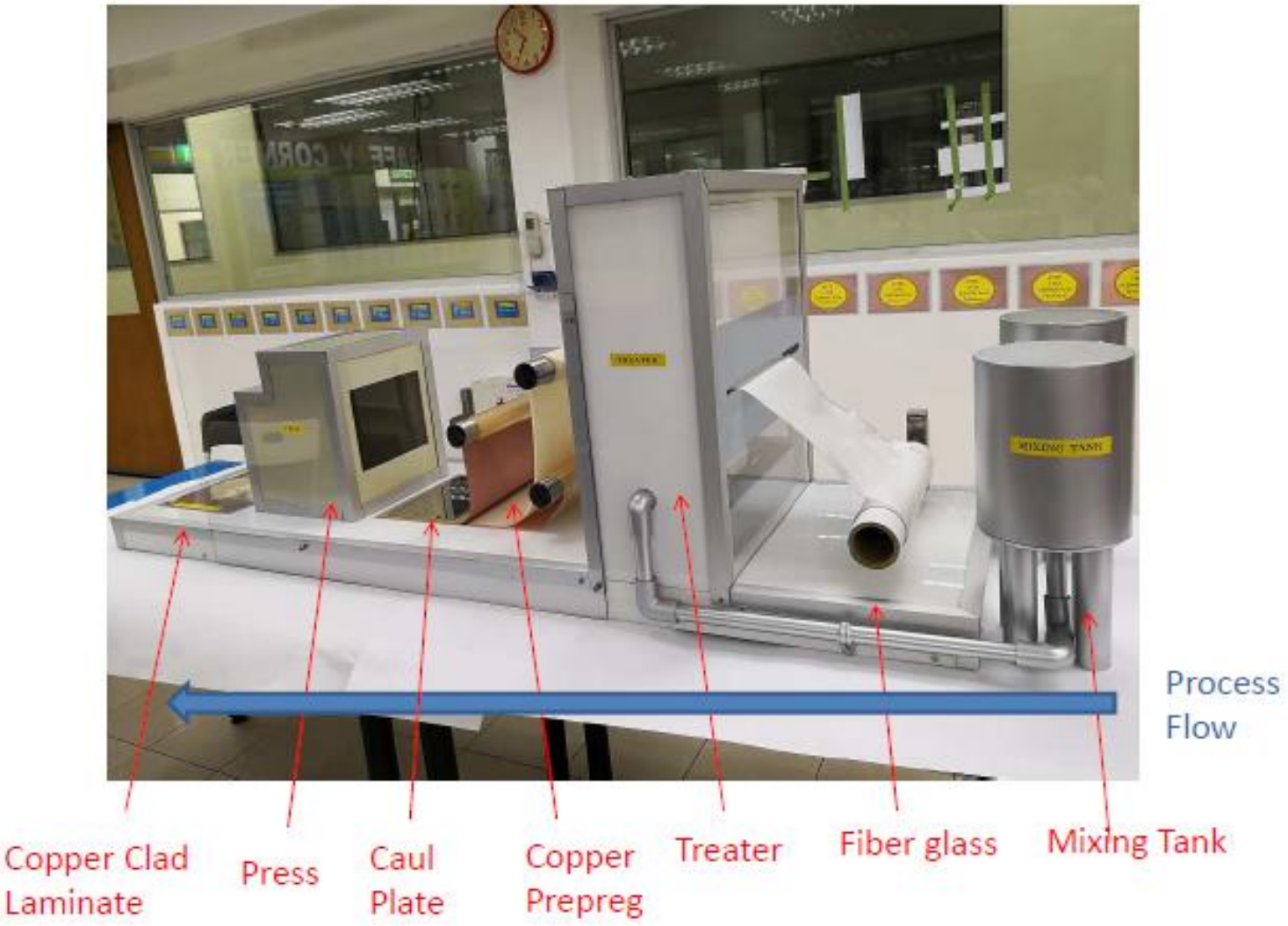
Outlook for 2025

- We are aiming to **generate around 60 billion yen in sales** from new business by 2025 in next-generation high-speed communications
- **Approx. 40 billion yen** has gone into acquiring two CCL companies and CCL related material (new) business that uses Fluon+™ EA-2000, etc.
- **About 20 billion yen** in other new products is also anticipated

AGC's Outlook for Next-generation High-speed Communications Related Sales

APPENDIX

Rigid CCL manufacturing process



AGC's Materials and Components for Next-generation High-speed Communication

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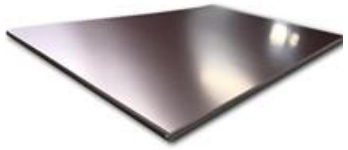
	Super high-end rigid CCL	Fluon+™ EA-2000	Ultra-low transmission loss flexible antennas for millimeter wave
Product			
Features	・CCL (copper clad laminate) is a material for printed circuit boards that is composed of copper foil and insulating resin ・With the expansion of 5G and autonomous operation, super high-end rigid CCL is expected to have a market growth of about 15% annually from 2016 to 2025 in next-generation high-speed telecommunications applications at 28 GHz and up.	・AGC's fluoropolymer Fluon+™ ("Fluon Plus") EA-2000 is a product that provides the same superior heat resistance, water resistance, and electrical properties of fluorinated resin while adding the plus of adhesive properties. ・Fluoropolymers other than Fluon+™ EA-2000 have problems with adhesion to other materials and dispersibility. EA-2000's advantages over other materials becomes more pronounced as the frequency band increases. ・Capacity is being raised with operations scheduled to start from September 2019	・By combining Fluon+™ EA-2000 with flexible antenna design technology, AGC has realized a product that achieves ultra-low transmission loss suitable for millimeter-wave band together with the advantages of lightweight construction and flexibility. ・Comprises a composite containing AGC's fluoropolymer on a copper layer ・AGC's advantage is its combination proprietary fluoropolymer Fluon+™ EA-2000 and various antenna design technologies that have been refined over the years
Applications	・Mainly consumer communications (base stations, servers), automotive (millimeter-wave radar), aerospace (satellite communication), etc.	・Assumed to be PCBs for mobile, base stations, servers, and vehicles ・Can also be used as a composite material with coatings, lining materials and engineering plastics.	・Various industrial devices for IoT, mobility for vehicles etc., buildings in urban areas, robots etc.
Reference info	July 26, 2018 release AGC Acquires the Electronics Business of US-based Park Electrochemical https://www.agc.com/news/detail/1197406_2148.html February 19, 2019 release AGC to acquire global operations of the Advanced Dielectric Division of US-based Taconic http://www.agc.com/news/detail/1198853_2148.html	August 30, 2018 release AGC to Make Drastic Expansion to Production Capacity for Fluon+ EA-2000 Fluorinated resin, a Material Used in 5G High-Speed High-Frequency Printed Circuit Boards http://www.agc.com/news/detail/1197653_2148.html	20 May 2019 Release AGC Develops Flexible Antenna Design Technology for Millimeter Wave with Ultra-low Transmission Loss http://www.agc.com/news/detail/1199212_2148.html

Applications of AGC's Next-generation High-speed Communication Technology (1)

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	Glass antenna for turning windows into base stations	5G compatible vehicle-glass-mounted antenna	Glass-integrated 5G antenna
Product			
Features	・World's very first glass antenna that can transmit and receive radio, and turns windows into base stations by installing onto building window glass ・Takes advantage of the transparent properties of glass to avoid spoiling the outside view or interior design ・Limits reflection and attenuation of radio waves as they pass through the window ・Installation is on the inside of buildings, eliminating the need for scaffolding or foundation work ・The timeline for adapting the glass antennas for 5G communication is aiming for a 2020 launch	・Capable of 5G high-speed communication of up to 8 Gbps traveling at about 100 km/h, and up to 11 Gbps traveling at about 30 km/h ・Avoids spoiling the vehicle's design by being hard to see from outside the vehicle ・Development is underway in sync with the vehicle installation and telecom operator network development schedules of each country, with widespread adoption estimated between 2020 and 2025	・Glass antenna exclusively for 28 GHz band 5G communication ・Compact and thin transparent glass antenna ・Capable of 5G communication in-vehicle of up to 3.8 Gbps downloads at 400 MHz bandwidth when traveling at about 30 km/h, and averaging 1.3 Gbps within a 100-meter radius of the base station. This demonstrates that in addition to current communication required by vehicles, it is also possible to send/receive sensor info that is problematic under the LTE communication standard ・Commercialization is expected sometime between 2020 and 2025
Applications	・For buildings	・For vehicles	・Mainly for vehicles
Reference info	November 7, 2018 AGC Collaborates with NTT DOCOMO to Create World's First Product to Add Cellular Base Station Functions to Windows http://www.agc.com/news/detail/1198104_2148.html	July 25, 2018 Success with 5G Communications Using "Vehicle Glass Mounted Antenna" for 5G Connected Car http://www.agc.com/news/detail/1197412_2148.html	May 29, 2019 DOCOMO, AGC and Ericsson Achieve World's First 5G Communication Using Glass Antenna for 28 GHz http://www.agc.com/news/detail/1199303_2148.html

Applications of AGC's Next-generation High-speed Communication Technology (2)

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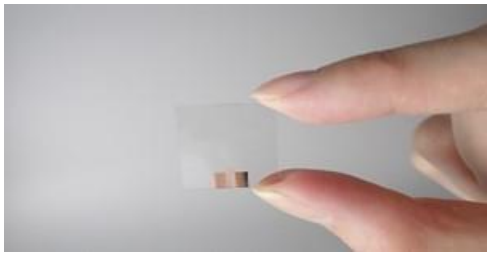
Synthetic fused silica glass for 5G

Product



Features

- Structure comprises a metal antenna pattern mounted on a synthetic fused silica glass with low transmission loss
- With lower dielectric loss than ordinary glass, synthetic fused silica glass is capable of ultra-low transmission loss
- Even when installed in the line-of-sight, these new antennas obstruct the view as minimally as possible to avoid spoiling the view

Applications

- Anticipated for use as a vehicle antenna, indoor/outdoor antenna (for base station) etc.

Reference info

November 29, 2018
AGC Develops a Synthetic Fused Silica Glass Antenna for 5G
http://www.agc.com/news/detail/1198306_2148.html

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