REPORT ON FUNCTIONAL CERAMICS DEVELOPMENTS IN JAPAN PREPARED FOR THE CANADIAN EMBASSY IN TOKYO

MAY 1987

RAPPORT SUR LES DÉVELOPPEMENTS EN NÉO-CÉRAMIQUES FONCTIONNELLES AU JAPON PRÉPARÉ POUR L'AMBASSADE DU CANADA À TOKYO

MAI 1987

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Introduction

The purpose of this research is to create data in order to grasp the market trend and the future prospect of each functional materials (substance) in the fine ceramics sector.

At the same time, it intends to show the feasibility of making inroads to the sector, by elucidating users' trend relative to various functional materials (electronic materials) as well as by evaluating super fine particles.

In anticipation of the difficulties you might encounter with and to realize quick and effective product development for smoother participation in the market, advisable measures would be:

1) Develop new-core products derived from the interfacial area between petrochemicals and specialty chemicals.

2) Put emphasis on peripheral substances, not on fine ceramics itself.

The reasons are:

1) No invention or discovery made in the fine ceramics field for the last ten to twenty years.

2) Though attracting attention, fine ceramics applications have been limited to electronic components, as supplemental parts.

   Fine ceramics automobile engine and artificial bone still require another step before practical use as established products.

3) Since cost performance is the most severe requirement with the electrical equipment, an epochal development or an amazing low price is considered as being the must for a new entry into the market.

(I) Function-Material-Application-Issue (No.1)

ELECTRO·MAGNETIC

Function	Materials	Expected Features	Application	Competing Materials	Technical Issues	Others
Insulation	Al_2O_3, SiC, BeO, AlN, $MgO\cdot SiO_2$, $2MgO\cdot SiO_2$	•Good thermal conductivity and corrosion resistance •Excellent mechanical strength •Contributing to make electric or electronic appliances small and to give them higher reliability	IC board/package, SCR vessel, spark plug, high frequency insulation material, substrate for printer head	Plastic, enamel, glass	•Large scale, thin board •Small thin package •Removal of radiactive substances •Lower dielectricity •Higher thermal conductivity •Fitness with conductive material (Cu, Ag, Pt, etc.)	•Effect of BeO powder on human body •Attachment to device saving gold
Dielectric	$BaTiO_3$ $MgO\cdot La_2O_3\cdot$ $SrTiO_3$, Pb Perovskite	•Excellent thermal resistance and high frequency performance •Contributing to make capacitors small and high capacity and to give them higher reliability •Meeting demand for small high performance micro-wave filter	Capacitor, dielectric resonator	Organic film, aluminum	•Small size, light weight •High reliability (high density sintered body fabrication) (precise synthesis of complete crystal) •Lower sintering temp.	
Piezo-electric	PZT, PLZT, ZrO_2, crystal, $LiNbO_3$	•New applications for electromechanical products by the use of special functions •Developing new equipment using these products •Making small size and giving high performance	Piezoelectric ignition device, piezoelectric ceramic transducer, ceramic filter		•High performance •New functions and applications to be developed by making thin film and single crystal •New applications by combination with other materials	
Magnetic	Hard ferrite, soft ferrite, magnetic garnet, $-Fe_2O_3$, CrO_2	•Making electronic devices small and giving them high performance	Core, transformer core, storage device, magnetic head, magnetic tape, speaker, micro-motor	Sendust metal, amorphous metal, magnetic metal powder	•High performance of the material •Composite	
Semi-conductive	$BaTiO_3$, $SrTiO_3$, ZrO, TiO_2, SnO_2, $MgCr_2O_4$-TiO_2, SiC	•New electronic products with new functions •Environmental control	Thermistor, Varistor semiconductor capacitor, gas sensor	Zener diode, plastics, nylon, swelling resin	•Manufacturing of material controllable of lattice failure •Making thin film, superfine grain and building layer •Multi-function •Composite	
Ion conductive	ZrO_2, $-Al_2O_3$	•Energy conservation by combustion control or power storage	Oxygen sensor, solid electrolyte cell		•Improving for expansion of temperature range •Making small •New material	
Electron Emmisive	LaB_4	•High current density for electron beam source and tube •High reliability	Anode for electron gun of electron microscope, Braun tube	Diode	•Higher current density •Longer life •Smaller beam diameter	

Function - Material - Application - Issue (No.2)

	Function	Materials	Expected Features	Application	Competing Materials	Technical Issues	Others
	Fluorescent (Luminous)	ZnS: Ag, Cl Y_2O_2S: Eu ZnO:Zn Pare earth: Eu Al_2O_3: Cr	∘High performance Braun tube for color TV and fluorescent lamp ∘New technology and products using electro-luminescence	Braun tube for color TV, fluorescent lamp, Braun tube for display, solid rador oscillator	Liquid crystal	∘Expansion of applications by using synthesis of superfine powders, vaporization and CVD ∘Developing high value added products	
OPTICAL	Translucent	Al_2O_3, MgO, PLZT	∘Energy conservation by application to high voltage emitter ∘New tecnology and products to be developed by using electro-optic function	Emitter for high voltage sodium lamp, crucible, window for detecting high temp. IR ray		∘High quality material by controlling micro structure	∘Ensuring high purity, active alumina material
	Translucent-Polarizing	PLZT	∘Development of opto-electronic technology and products by the use of new functional materials	Optical memory, optical shutter, display, transparent piezoelectric speaker	Liquid crystal	∘Raw powders having even composition distribution ∘Sintering process having less remaining pores instead of hot press	∘Exploring demand and application
	Photo-sensitive	Glass containing silvr hallid, CaF_2, sodalite	∘New technology and products to be developed by the use of photochromic material	Optical memory, display device, screen memory device		∘Big fading velocity ∘Small temperature dependency ∘Application technology	
	Photo-reflective	Thin Metal Oxide film	∘Contributes toward energy saving & improves living environment	Thermic ray reflector glass		∘Development & realization of new reflective film	∘Measures against Public nuisance
	Photo-conductive	SiO_2 fiber, multi-component glass fiber	∘Applicable to transmitting media due to low transmission loss	Opto-communication fiber	Plastic fiber	∘Technology for application system	∘Ge source ∘Research network for fiber optics

Function - Material - Application - Issue (No.3)

	Function	Materials	Expected Features	Application	Competing Materials	Technical Issues	Others
BIOLOGICAL·CHEMICAL	Corrosion Resistant	Al_2O_3, Si_3N_4, SiC	°Long life of various components using acid/alkali/molten metal resistance	Chemical equipment, heat exchanger, high grade refractory		°Improving design and bonding technology °Non-destructive evaluation °Accumulation of applications	
	Adsorptive	Al_2O_3, $SiO_2 \cdot Al_2O_3$, cordielite	°Improvement of purification and manufacturing process for chemicals and intermediates °Higher quality of products °Improvement of living conditions	Catalyst carrier, oxygen fixation carrier, absorbant, sensor	Polymers		
	Catalytic	Zeolite, transition metal oxide	°Improvement of purification and manufacturing process for chemicals and intermediates °Higher qulity of products °Improvement of living conditions	Catalyst for catalytic decomposition, purification catalyst for off-gas			
	Biocompati-ble	Al_2O_3, C, hydroxy apatit	°Up-grading medical science °Meeting demand for maturity/ welfare society	Artificial teeth root, artificial joint, artificial bone	Stainless steel, Polymers	°Shortening duration of processing °Automation of design and processing	°Application of health insurance

Function - Material - Application - Issue (No.4)

	Function	Materials	Expected Features	Application	Competing Materials	Technical Issues	Others
MECHANICAL	Hard/Wear Resistance	Al_2O_3, SiC, c-BN	∘Longer life of structural parts for various machines ∘Improving accuracy of products	Cutting tool, abrasive, mechanical seal	Superhard alloy	∘High efficiency grinding to be developed	
	High Strength	Si_3, SiC, Sialon	∘Improving heat efficiency by high temp. engine ∘Resource conservation ∘Longer life of various mechanical parts	Engine component, power turbine component, combustion nozzle	Heat resistant steel, superalloy	∘Unification of evaluation ∘Nondestructive evaluation ∘Design technology ∘Accumulation of data	
	Lubricative	h-BN, MoS_2	∘High temp. lubrication without using lubricant ∘Improving operation efficiency ∘Longer life of machine	Solid lubricant, mould release	Carbon	∘Improving sintering technology ∘Composite with other material	
THERMAL	Low Termal Expansion	Al_2O_3	∘High accuracy of machine ∘Longer life	Parts for precision machines (block gauge, precise surface plate, V-block)		∘Improvement of precise processing	
	Theraml Resistant	Al_2O_3, MgO	∘Longer life to material ∘Improving heat efficiency	Sintering vessel, furnace tube, protection tube			
	Insulation	fiber, potassium titanate fiber				∘Improved works	
	Thermal Conductive	BeO, AlN	∘High performance parts	IC substrate/package			Effect of BeO powder on human body
	Thermal Shock Resistant	Cordielite, Lithium aluminosilicate	∘Longer life of parts	Honeycomb for catalyst carrier, plate for sintering, bunner, block		∘Commercialization of heat exchanger	
NUCLEAR		UO_2, C, B_4C, Eu_2O_3	∘New energy development with ceramics	Nuclear fuel retardant fuel lagging, shielding material, control rod material		∘Manufacturing technology for large structures to be developed ∘Ensuring high reliability	

(II) Applications of Major Substances by Shapes (No.1)

Shape / Substance	Single Crystal	Sintered or Amorphous	Powder	Porous or Through-Hole	Thin Film	Fiber	Composite or Bonded
Aluminum Oxide Al_2O_3	∘Jewelry (ruby, sapphire) ∘Record needle ∘Bearing	∘IC board ∘Luminecent material (tube for Na lamp) ∘Cutting tool ∘Heat/corrosion resistant vessel ∘Refractory	∘Abrasive ∘Grinding material	∘Adsorvant ∘Catalyst carrier ∘Honeycomb carrier	∘Ceramic coating ∘Insulated substrate for IC	∘Thermal resistant insultion material ∘Reinforcing material for cermet	∘Cermet (metal matrix)
Zinc Oxide ZnO	-	∘Resistor	∘White pigment ∘Electro-conductive paint	∘Gas sensor	∘Surface elasticity wave delay device	-	∘Improver for sensitivity and selectivity of gas sensor (carried with Pt, Pd) ∘Varistor (composite with Bi_2O_3
Titanium Oxide TiO_2	∘Jewelry (rutile) ∘Bearing	∘Corrosion resistant vessel ∘Resistor	∘White pigment	∘Catalyst carrier ∘Gas sensor	∘Coating for heat ray reflecting glass	∘Thermal resistant insulation material	-
Tin Oxide SnO_2	-	∘Resistor	∘Electro-conductive glaze	∘Gas sensor	∘Coating for heat ray reflecting glass	-	∘Contact material (composite with Ag)
Barium Titanate $BaTiO_3$ and Titanate Zirconate	-	∘Capacitor ∘Piezoelectric material ∘Pyroelectric material	-	∘Secondary electron multiplier	∘Capacitor ∘Surface elasticity wave delay device	-	∘PTC thermistor (grain boundary is insulating) ∘Two-step PTC thermistor (Bi_2O_3 layer is formed on PTC thermistor surface) ∘Flexible piezo-electric material (composite with PVF)

(II) Applications of Major Substances by Shapes (No.2)

Shape / Substance	Single Crystal	Sintered or Amorphous	Powder	Porous or Through-Hole	Thin Film	Fiber	Composite or Bonded
Cadmium Sulphide CdS	∘Compound semiconductor	∘Fine powder sintered material (Cd^{2+} ion sensor)	∘Pigment ∘Fluorescencer	–	–	–	∘Solar cell (bonded with Cu_2S)
Silicon Nitride Si_3N_4	–	∘Thermal resistant fortifier ∘Thermal resistant vessel ∘Refractory	–	–	∘Ceramic coating ∘Insulation film for IC	–	–
Silicon Carbide SiC	–	∘Thermal resistant fortifier ∘Thermal resistant vessel ∘Refractory	∘Abrasive ∘Grinding material	–	–	∘Thermal resistant insulation material ∘Reinforcing material for cermet	∘Whetstone ∘Cermet
Carbon (diamond, graphite, amorphous) C	∘Jewelry (diamond)	∘Cutting tool (diamond) ∘Thermal resistant vessel (graphite) ∘Electric wave absorber	∘Abrasive (diamond) ∘Grinding material (diamond) ∘Lubricant (graphite)	∘Adsorbant (amorphous)	–	∘Carbon fiber (amorphous)	∘Cutting tool ∘Composite with metal on resin
Silicon Oxide SiO_2	∘Crystal oscillator	∘Mask substrate for IC ∘Quartz crucible	–	∘Adsorbant ∘Catalyst carrier ∘Secondary electron multiplier	–	∘Reinforcer for glass fiber ∘Optic communication fiber (super high strength)	∘Glass fiber ∘FRP
Ferrite (ion oxide)	∘Magnetic head	∘Magnetic head ∘Magnet core (soft) ∘Magnet (hard)	∘Powder for magnetic tape (needle powder) ∘Electric wave absorber	∘Catalyst	∘Magnetic tape	–	∘Magnetic tape
Boron Nitride BN	∘Cutter/grinder for precise processing	∘Cutting tool ∘Wire draw dice tool	∘Sheathed thermo-couple insulation ∘Crucible	–	∘Lubricant ∘Electric insulation ∘Varistor ∘EL device	∘Composite material	–

Major Application of Al_2O_3

1) Dielectric - electrolysis condensor, solid electrolysis condensor, powder sintering condensor, copy transfer drum

2) Insulating - alumite cable, alumite print substrate, hybrid IC board, selective cathode oxidation (LSI), multi-layer electrode CCD

3) Electron-conductive - tunnel element, negative resistance element, metal based film transistor

4) Magnetic - magnetic alumite, alumite based magnetic disc

5) Optical
   - Luminecence - electroluminecence (EL) device, photoluminecence (PL) display panel
   - Color
     - electrolysis coloring - solar heat absorbing plate, electronic radiator
     - electrochromism (EC) device
     - photosensitive alumite plate

6) Mechanical - hard alumite, lubricant alumite, speaker vibrator

7) Moisture absorptive - alumite moisture sensor, moisture control alumite

8) Printable - PS off-set printing plate

9) Chemical - catalyst alumite, ion selective membrane

10) Other - processing size adjusting function

Major Applications of Pb (Zr, Ti) O_2

filters (ladder filter, trap filter, lead filter, surface wave filter, ceramic filter, discriminater), ultrasonic wave transducer (microphone, speaker, piezoelectric buzzer, probe, various transducers), elements (pick-up element, ignition element, mechanical filter, sensing element for delay line, Baimorph element), resistance heater, thermistor, varistor, gas sensor, condensor, IR detector, optical valve, optical shutter, optical memory, image storage display, deflecting system, light and dulation element, dielectrics for microwave (wired waveguide, covibrator, etc.)

(III) List of Participant Manufacturers & Their Product Lines

Name of Manufacturer	Ceramic substrate	Ceramic package	Mask plate	Ceramic filter	Piezo-electric buzzer	Resistor	Varistor	Capacitor	Sensor: Temp.	Sensor: Humidity	Sensor: Gas	Sensor: Oxygen
Asahi Glass	O											
Asahi Gaishi Kogyo	O											
Adamando Kogyo										O		
Ishizuka Denshi							O		O			
Ibaragi Seiskusyo	O											
Iwaki Musen Kenkyusho						O						
Ohoizumi Seisakusho							O		O			
Kamaya Denki						O						
Kyocera	O	O		O	O			O				
K C K								O				
Koa Denko						O						
Komei Rikagaku Kogyo											O	
Sanko-sha											O	
Shinagawa Refractories												O
Shibaura Denshi Seisakusho							O		O		O	
Sharp										O		
Shinetsu Chemical			O									
Shinko Seisakusho											O	
Shinko Denki Kogyo		O										
Shin Cosmos Denki											O	
Sumitomo Electric Ind.					O							
Sumitomo Special Metals					O							
Taiyo Yuden	O				O			O				
Taiyosha Denki						O						
Daido Kako		O										
Takara Kogyo									O			
Takasago Kogyo								O				
Tama Denki Kogyo						O						
Chichibu Cement										O		
Teikoku Tsushin Kogyo						O						
T D K	O			O	O			O	O	O		
Tokai Konetu Kogyo							O					
Thoka Seiki											O	
Tokyo Cathode Kenkyusho										O		
Tokyo Sanyo Electric							O					
Tokyo Dempa										O		
Toko, Inc.				O								
Toshiba Corp.								O				
Toshiba Ceramics	O		O									
Tohoku Kinzoku Kogyo								O				
Toray Industries												O
Narumi Ceramics	O	O										
Nikko	O											
AMP Japan				O								

Name of Manufacturer	Ceramic substrate	Ceramic package	Mask plate	Ceramic filter	Piezo-electric buzzer	Resistor	Varistor	Capacitor	Sensor			
									Temp.	Humidity	Gas	Oxygen
Nihon AVX								○				
NGK Insulators	○	○										○
Nihon Kagaku Togyo												○
Nippon Carbide Ind.	○											
Nichicon Capacitor	○							○				
Nihon Sekiei Glass			○									
Nihon Ceramic					○							
Nippon Tungsten	○											
Nitsuko								○				
Japan Resistor Mfg.						○						
NEC Corp.								○	○			
JEOL												○
Nippondenso									○			○
NGK Spark Plug	○	○		○	○							○
Niwasho Denki Seitosho	○											
Noritake Co., Ltd.	○											
Nippon Kasei Chemical	○	○										
Hitachi Metals	○											
Hitachi Ltd.	○								○			
Fukui Matsushita Denki						○						
Fukushima Futaba Denki						○						
Fuji Giken											○	
Fujitsu	○						○					
Fuji Electric							○		○	○	○	○
Fuji Electrochemical				○	○							
Primo					○							
Hokuriku Ceramic	○											
Hokuriku Electric Industry						○						
Matsushita Electric Works											○	
Matsushita Electronic Components				○	○	○	○	○	○	○		
Marukon Denshi							○			○		
Maruwa Ceramic	○											
Mitsubishi Mining & Cement							○	○	○			
Mitsumi Electric				○								
Miyata Industry											○	
Murata Mfg.				○	○	○		○	○	○		
Meiwa Kogyo	○											
Yazaki Keiki											○	
Yamago Togyo	○							○				
Unison							○		○			
Riken Keiki Fine Instrument											○	
Rhohm						○						
Y S Jikikan Seisakusyo	○											

List of Major Manufacturers (No.1)

Manufacturer	Address & Phone Number	Capital (million yen)	Number of Employee
Asahi Gaishi Kogyo	3-24, Kamijyo-machi, Kasugai-shi Aichi-ken Tel: 0568-81-2166	90	220
Asahi Glass	2-1-2, Marunouchi, Chiyoda-ku, Tokyo Tel: 03-218-5555	51,730	9,152
Adamando Kogyo	1-16-7 Shinden, Adachi-ku, Tokyo Tel: 03-919-1171	31	304
Ishizuka Denshi	3-16-7, Higashi Koiwa, Edogawa-ku, Tokyo Tel: 03-658-5111	48	216
IwakiMusen Kenkyusho	485, Futago, Kozu-ku, Kawasaki-shi Tel: 044-833-4311	15	210
Ohizumi Seisakusho	1-11-4, Shin-Sayama, Sayama-shi Tel: 0429-52-5151	120	187
Kamaya Denki	3315,Kami-Wada, Yamato-shi Tel: 0462-69-2077	300	307
Kyocera	5-22,Kita Inoue-cho, Higashino, Yamanashi-ku Kyoto Tel: 075-592-3851	34,022	12,896
K C K	5-16-1, Takinogawa, Kita-ku, Tokyo Tel: 03-916-3521	100	510
Koa Denko	3672, Ohaza-Ina, Ina-shi, Nagano-ken Tel: 0265-78-2121	4,590	1,287
Kohmei Rikagaku Kogyo	660-1, Miyauchi, Nakahara-ku Kawasaki-shi Tel: 044-751-2121	100	188
Sanko Sha	2-6-8, Shiba Daimon, Minato-ku, Tokyo Tel: 03-433-2677	4	13
Shinagawa Refractories	2-2-1, Ote-machi, Chiyoda-ku, Tokyo Tel: 03-211-3721	3,300	2,362
Shibaura Denshi Seisakusho	520, Machiya, Urawa-shi Tel: 0488-52-6661	250	171
Sharp	22-22, Nagaikecho, Abeno-ku, Osaka Tel: 06-621-1221	50,395	22,314
Shin-etsu Chemical	2-6-1, Ote-machi, Chiyoda-ku, Tokyo Tel: 03-246-5111	15,214	2,792
Shinkho Denki Kogyo	711, Kurita Shariden, Nagano-shi Tel: 0262-26-1145	1,188	2,300
Sumitomo Electric Ind.	5-15, Kitahama, Higashi-ku, Osaka Tel: 06-220-4141	39,194	12,430

List of Major Manufacturers (No.2)

Manufacturer	Address & Phone Number	Capital (million yen)	Number of Employee
Sumitomo Special Metals	5-22, Kitahama, Higashi-ku, Osaka Tel: 06-220-8821	10,706	1,414
Taiyo Yuden	1-2-12, Ueno, Taito-ku, Tokyo Tel: 03-832-0101	8,319	1,454
Taiyosha Denki	1956, Otaka-machi, Kani-gun, Gifu Tel: 05746-7-2121	150	580
Takara Kogyo	2-14-26, Shin-Yokohama, Kohoku-ku Yokohama Tel: 045-931-3321	500	130
Takasago Kogyo	2321-2, Dachi-machi, Toki-shi, Gifu Tel: 05725-9-8254	169	369
Tama Denki Kogyo	2-15-12, Nakane, Meguro-ku, Tokyo Tel: 03-723-1211	1,133	480
Chichibu Cement	1-4-6, Marunouchi, Chiyoda-ku, Tokyo Tel: 03-281-1361	2,352	1,740
Teikoku Tsushin Kogyo	332, Kariyado, Nakahara-ku Kawasaki-shi Tel: 044-422-3171	2,744	729
TDK	1-13-1, Nihonbashi, Chuo-ku, Tokyo Tel: 03-278-5111	6,018	7,698
Tokai Konetsu Kogyo	6-14-1, Nishi-Shinjuku, Shinjyuku-ku Tokyo Tel: 03-349-7481	1,400	245
Tokyo Cathode Kenkyusho	1-10-14, Itabashi, Itabashi-ku, Tokyo Tel: 03-962-8311	58	126
Tokyo Sanyo Electric	180, Ohaza-Sakata, Ohizumi-cho Yura-gun Gunma Tel: 0276-63-2111	34,038	14,363
Tokyo Dempa	5-6-11, Chuo, Ohta-ku, Tokyo Tel: 03-751-6171	100	110
Toko, Ltd.	2-1-17, Higashi-Yukigaya, Ohta-ku Tokyo Tel: 03-272-1161	6,302	969
Toshiba Corp.	1-1-1, Shibaura, Minato-ku, Tokyo Tel: 03-457-4511	140,635	69,771
Toshiba Ceramics	1-16-2, Nishi-Shinjuku, Shinjuku-ku Tokyo Tel: 03-348-7411	13,768	2,346
Tohoku Metal Ind.	2-5-8, Kita-Aoyama, Minato-ku, Tokyo Tel: 03-402-6161	4,767	1,646
Toray Industries	2-2, Muromachi, Nihonbashi, Chuo-ku Tokyo Tel: 03-245-5111	60,727	11,835

List of Major Manufacturers (No.3)

Manufacturer	Address & Phone Number	Capital (million yen)	Number of Employee
Narumi Ceramics	3, Narumi Denjiyama, Midori-ku Nagoya Tel: 052-891-2111	540	1,500
Nikko	383, Aiki-cho, Matsutho-shi Ishikaw-ken Tel: 0762-76-2121	486	942
AMP Japan	7-15-14, Roppongi, Minato-ku, Tokyo Tel: 03-404-7171	5,850	1,045
NKG Insulators	2-56, Suda-cho, Mizuho-ku, Nagoya Tel: 052-872-7171	14,965	5,069
Nihon Kagaku Togyo	3-2-24, Torori Ono-machi, Sakai-shi Tel: 0722-38-3641	801	242
Nihon Carbide Kogyo	3-3-1, Marunouchi, Chiyoda-ku, Tokyo Tel: 03-240-8634	2,710	822
Nichicon Capacitor	Karasumaru Higashi Hairu, Oike-tori Nakakyo-ku, Kyoto Tel: 075-231-8461	5,137	1,438
Nihon Sekiei Glass	3-2-4, Kyobashi, Chuo-ku, Tokyo Tel: 03-273-9071	150	284
Nihon Ceramic	2-7, Hinode-machi, Sakado-shi Saitama-ken Tel: 0492-81-8111	10	9
Nippon Tungsten	2-20-31, Shimizu, Minami-ku Fukuoka-shi Tel: 092-511-1111	2,509	758
Nitsuko	260, Kitamikata, Kozu-ku Kawsak-shi Tel: 044-811-1111	8,476	973
Japan Resistor Mfg.	2315,Kitano,Jyohana-machi, Higashi Tonami-gun Toyama Tel: 0763-62-1180	504	250
N E C Corp.	5-33-1, Shiba, Minato-ku, Tokyo Tel: 03-454-1111	107,933	36,832
J E O L	1671-1, Kasugawa-cho, Isezaki-shi Tel: 0270-24-2441	2,400	1,400
Nippondenso	1-1, Showa-machi, Kariya-shi Tel: 0566-22-3311	34,938	31,838
NGK Spark Plug	14-18, Takatuji-cho, Mizuho-ku Nagoya Tel: 052-871-2111	11,918	3,958
Niwasho Denki Seitosho	1-2-1, Asahidai, Owari Asahi-shi Tel: 05615-3-3321	14	128
Noritake Co., Ltd.	3-1-36, Noritake Shin-machi,Nishi-ku Nagoya Tel:-052-561-7111	6,146	1,904

List of Major Manufacturers (No.4)

Manufacturer	Address & Phone Number	Capital (million yen)	Number of Employee
Hitachi Chemical	2-1-1, Nishi-Shinjuku, Shinjuku-ku Tokyo Tel: 03-346-3111	8,326	4,941
Hitachi Metals	2-1-2, Marunouchi, Chiyoda-ku, Tokyo Tel: 03-284-4511	16,556	9,353
Hitachi Ltd.	4-6, Surugadai, Kanda, Chiyoda-ku Tokyo Tel: 03-258-1111	140,361	79,140
Fukui Matsushita Denki	1-2503, Nishi-Kaihatsu, Fukui-shi Tel: 0766-54-1660	240	1,114
Fukushima Futaba Denki	6-36-5, Kamata, Ohota-ku, Tokyo Tel: 03-732-8291	30	171
Fujitsu	1-6-1, Marunouchi, Chiyoda-ku, Tokyo Tel: 03-326-3211	103,605	48,383
Fuji Electric	1-12-1, Yuraku-cho, Chiyoda-ku,Tokyo Tel: 03-211-7111	29,281	13,372
Fuji Electrochemical	5-36-11, Shinbashi, Minato-ku, Tokyo Tel: 03-434-1271	3,906	2,094
Primo	6-25-1, Mure, Mitaka-shi, Tokyo Tel: 0422-43-3121	300	401
Hokuriku Electric Ind.	3158, Shimo-Okubo Osawano-machi Shinkawa-gun Toyama Tel: 0764-67-1111	3,891	1,004
Matsushita Electric	1048, Kadoma, Kadoma-shi, Osaka Tel: 06-908-1131	25,076	13,397
Matsushita Denshi Buhin	1006, Kadoma, Kadoma-shi, Osaka Tel: 06-908-1101	12,550	10,147
Marukon Denshi	1-1, Saiwai-cho, Nagai-shi Yamagata-ken Tel: 02388-4-2131	600	975
Mitsubishi Mining & Cement	1-5-1, Marunouchi, Chiyoda-ku, Tokyo Tel: 03-211-7412	20,152	2,114
Mitsumi Electric	8-8-2, Sekiryo-cho, Chyofu-shi, Tokyo Tel: 03-489-5333	2,015	1,899
Miyata Industry	3678, Chigasaki, Chigasaki-shi Kanagawa-ken Tel: 0467-85-1211	1,320	761
Murata Mfg.	2-26-10, Tenjin, Nagaoka-kyo - shi Kyoto Tel: 075-951-9111	2,234	2,353
Meiwa Kogyo	977, Anada-cho, Seto-shi, Aichi-ken Tel: 0561-48-5011	21	240

List of Major Manufacturers (No.5)

Manufacturer	Address & Phone Number	Capital (million yen)	Number of Employee
Yazaki Keiki	1-4-28, Mita, Minato-ku, Tokyo Tel: 03-455-8811	100	1,771
Yamago Togyo	118, Saruzume, Mizunami-shi, Gifu-ken Tel: 0572-65-2211	50	250
Riken Keiki Fine Instrument	2-7-6, Azukizawa, Itabashi-ku, Tokyo Tel: 03-966-1111	1,445	266
Rhomu	21, Nishiin-mizosaki, Ukyo-ku, Kyoto Tel: 075-311-2121	18,087	2,072
Y S Jikikan Seisakusho	58, Izumi-cho, Seto-shi, Aichi-ken Tel: 0561-82-2629	48	265

Grouping of Manufacturers by Material

Material	Manufacturer
Al_2O_3	Taimei Kagaku, Sumitomo Aluminum Seiren Nikkei Kako
SiC	Pacific Metals, Denki Kagaku Kogyo, Showa Denko
$BaTiO_3$	Murata Mfg., TDK Electronics
ZrO	Toyo Soda Mfg., Daiichi Kigenso Kagaku Kogyo Hokko Chemical Industry, Shin Nihon Kinzoku Kagaku Toray, Dowa Chemical
ZnO_2	Sakai Chemical Industry, Hakusui Kagaku, Honjo Chemical Toho Zinc, Nippon Chemical Industrial, Mitsui Mining & Smelting, Shodo Kagaku, Tokyo Kasei
MgO_2	Tateho Kagaku (90%) Tomita Seiyaku, Akoh Kasei
TiO_2	Ishihara Sangyo Kaisha, Fuji Titanium Industry Teikoku Kako, Sakai Chemical Industry
Fe_2O_3	Toda Kogyo, Morishita Bengara, Tetugen, Ishihara Sangyo, Titan Kogyo, Nihon Bengara, Chemilite Kogyo, Sakai Chemical Industry, Tone Sangyo, Saikai Kogyo, Dowa Mining
h-BN	Denki Kagaku Kogyo, Showa Denko, Toshiba Ceramics (Import)
c-BN (Carat)	No electrical ceramics material
(Synthetic Diamond)C (Carat)	Sumitomo Electric Industries, Tomei Diamond Kogyo

List of Companies (No.1)

Company Name	Address & Phone Number
Taimei Kagaku Kogyo K.K.	36-85-2, Minowa-mura, Kami-Ina-gun, Nagano-ken Tel: 0256-72-4151
Sumitomo Aluminum Seiren K.K.	Sumitomo Bldg. 5-15, Kitahama, Higashi-ku, Osaka Tel: 06-220-3333
Nikkei Kako K.K.	Nikkei Bldg. 3-13-12, Mita, Minato-ku, Tokyo Tel: 03-456-8511
Showa Denko K.K.	1-13-9, Daimon, Shiba, Minato-ku, Tokyo Tel: 03-432-5111
Pacific Metals Co., Ltd.	Ohtemachi Bldg. 1-6-1, Ohte-machi, Chida-ku, Tokyo Tel: 03-201-6661
Murata Mfg. Co., Ltd.	2-26-10, Tenjin, Nagaokakyo-shi, Kyoto Tel: 075-921-9111
T D K	1-13-1, Nihonbashi, Chuo-ku, Tokyo Tel: 03-278-5111
Toyo Soda Mfg. Co., Ltd.	Toso Bldg. 1-7-7, Akasaka, Minato-ku Tel: 03-585-3311
Hokko Chemical Industry Co., Ltd.	Mitsui 2nd Annex 4-2, Nihonbashi Hongoku-cho, Chuo-ku, Tokyo Tel: 03-279-5151
Toray Industries, Inc.	Toray Bldg. 2-2, Nihonbashi Muromachi, Chuo-ku Tel: 03-245-5111
Daiichi Kigenso Kagaku Kogyo K.K.	Imai Bldg. 5-17, Koraibashi, Higashi-ku, Osaka Tel: 06-231-3835
Shin Nihon Kinzoku Kagaku K.K.	11-1, Umezu Nakakura-machi, Sakyo-ku, Kyoto Tel: 075-861-1191
Dowa Chemical K.K.	Hanyuda Bldg. 2-7-6, Nihonbashi Kayaba-cho, Chuo-ku, Tokyo Tel: 03-667-7821
Sakai Chemical Industry Co., Ltd.	5-1, Ebisujima, Sakai-shi, Osaka Tel: 0722-23-4111
Toho Zinc Co., Ltd.	Asahi Bldg. 3-12-2, Nihonbashi, Cho-ku, Tokyo Tel: 03-272-5611
Shodo Kagaku Kogyo K.K.	Kitahama Matsuoka Bldg. 3-43, Kitahama, Higashi-ku Tel: 06-231-0515
Hakusui Kagaku Kogyo K.K.	3-9-7, Toyosaki, Oyodo-ku, Osaka Tel: 06-373-0231
Nippon Chemical Industrial Co., Ltd.	9-15-1, Kameido, Koto-ku, Tokyo Tel: 03-636-8111

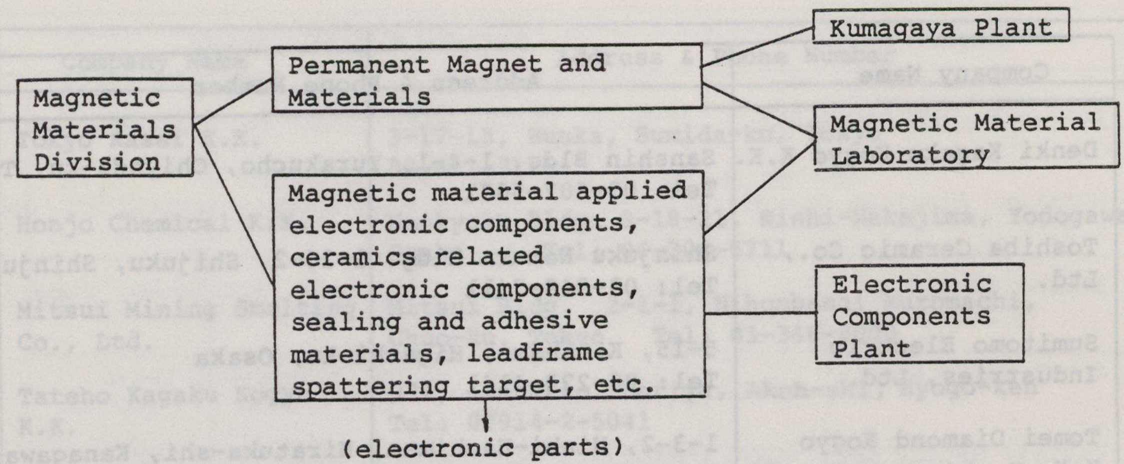
List of Companies (No.2)

Company Name	Address & Phone Number
Tokyo Kasei K.K.	3-17-15, Bunka, Sumida-ku, Tokyo 03-611-3146
Honjo Chemical K.K.	Nankyoku Bldg. 3-18-21, Nishi-Nakajima, Yodogawa-ku Osaka Tel: 06-304-5711
Mitsui Mining Smelting Co., Ltd.	Mitsui Bldg. 2-1-1, Nihonbashi Muromachi, Chuo-ku, Tokyo Tel: 03-346-8000
Tateho Kagaku Kogyo K.K.	974, Aza-Kato, Kariya, Akoh-shi, Hyogo-ken Tel: 07914-2-5041
Tomita Seiyaku K.K.	85-1, Aza-maruyama, Myojin, Seto-machi, Naruto-shi Tokushima-ken Tel: 08868-8-0511
Akoh Kasei K.K.	329, Hanetu, Akoh-shi, Hyogo-ken Tel: 07914-8-1111
Ishihara Sangyo Kaisha Ltd.	1-3-47, Edobori, Nishi-ku, Osaka Tel: 06-444-1451
Teikoku Kako Co., Ltd.	1-3-47, Funa-machi, Taisyo-ku, Osaka Tel: 06-552-1251
Fuji Titanium Industry Co., Ltd.	Osaka Bldg. 3-6-32, Nakanoshima, Kita-ku, Osaka Tel: 06-441-5856
Toda Kogyo K.K.	7-1, Yokokawa Shinmachi, Nishi-ku, Hiroshima-shi Tel: 082-231-2131
Titan Kogyo K.K.	1978-25, Oaza-Ogushi, Ube-shi, Yamaguchi-ken Tel: 0836-31-4155
Tone Sangyo K.K.	1612, Oaza-shimonakajyo, Gyoda-shi, Saitama-ken Tel: 0485-57-2111
Morishita Bengara Kogyo K.K.	2379, Shijyuku, Ueno-shi, Mie-ken Tel: 0595-21-2636
Nihon Bengara Kogyo K.K.	1099-3, Yada, Saeki-cho, Wake-gun, Okayama-ken Tel: 08698-8-1111
Saikai Kogyo K.k.	7521-1, Oaza-Onoda, Onoda-shi, Yamaguchi-ken Tel: 08698-4-1661
K.K. Tetsugen	1-4-4, Fujimi, Chiyoda-ku, Tokyo Tel: 03-262-4141
Chemilite Kogyo K.K.	Fukuda Bldg. 7-2-20, Ginza, Chuo-ku, Tokyo Tel: 03-573-3668
Dowa Mining Co., Ltd.	Daiichi Tekko Bldg. 1-8-2, Marunouchi, Chiyoda-ku, Tel: 03-201-1085

List of Companies (No.3)

Company Name	Address & Phone Number
Denki Kagaku Kogyo K.K.	Sanshin Bldg. 1-4-1, Yurakucho, Chiyoda-ku, Tokyo Tel: 03-507-5071
Toshiba Ceramic Co., Ltd.	Shinjuku Nomura Bldg. 1-26-2, Shijuku, Shinjuku-ku Tel: 03-348-7411
Sumitomo Electric Industries, Ltd.	5-15, Kitahama, Higashi-ku, Osaka Tel: 06-220-4141
Tomei Diamond Kogyo K.K.	1-3-2, Nishi-Hachiman, Hiratuka-shi, Kanagawa-ken Tel: 0463-31-7030

Example of Development Organization (the case of Hitachi Metals, Ltd.)



Structure of Research & Development Division

The structure of the Magnetic Material Laboratory of Hitachi Metals Ltd. is as follows.

- The present laboratory has eight research groups including the Basic Technologies Research Group.
- Research group 5 is responsible for the development of hard-ferrite.

(number of personnel in parentheses)

Hitachi Metals, Ltd. Material Laboratory (172)

- Planning Dept. (4)
- Operations Dept. (8)
- Research Group 1 (12) - engaged in software study
- Research Group 2 (15) - engaged in metal materials
- Research Group 3 (13) - responsibility unknown
- Research Group 4 (15) -
- Research Group 5 (17) - engaged in ferrite magnet
- Research Group 6 (15) - responsibility is not known
- Research Group 7 (18) - engaged in ceramics
- Basic Technologies Research Group (10)
- TD (Tool Development Center) (10)
- RA (15)
- Pilot Production Research Dept. (20)

Ten to twenty research workers organize a specific research group.

Planning Dept. - engaged in selection and planning of research items.

Operation Dept.- engaged in research budget control, coordination and communication among departments.

In addition to its proper research programs on magnetic materials development, the Magnetic Materials Laboratory recently puts more emphasis on practical applications of its research results.

Furthermore, the laboratory has become involved in the development of material processing technology for new ceramics, amorphous metals and sigle crystals, as well as in the development of electronic circuit technology in the field of softwares.

(IV) Consumption of Major Materials Used for Ceramics Production

(Units) Quantity: ton Amount: Million yen Unit Price: yen/kg

Material	Items	1984	1985	1986	1987	1990
Al_2O_3	Q'ty	31800	32600	40600	42500	60000
	Unit Price	250	220	200	200	180
	Amount	7950	7160	8120	8500	10800
SiC	Q'ty	50	70	110	120	200
	Unit Price	5200	5100	4900	4800	4500
	Amount	260	360	540	570	900
$BaTiO_3$	Q'ty	95	90	115	120	170
	Unit Price	4000	3400	3300	3200	3000
	Amount	380	310	380	380	510
ZrO	Q'ty	290	350	440	450	650
	Unit Price	3500	3200	3000	2800	2500
	Amount	1020	1130	1310	1260	1620
ZnO	Q'ty	1450	1600	1750	1800	2600
	Unit Price	450	420	400	400	380
	Amount	660	670	700	720	990
MgO	Q'ty	650	700	800	850	1200
	Unit Price	700	650	600	550	500
	Amount	460	460	480	470	600
TiO_2	Q'ty	2100	2200	2700	2800	4000
	Unit Price	450	400	400	400	400
	Amount	940	890	1090	1120	1600
Fe_2O_3	Q'ty	8450	8500	11400	12000	17000
	Unit Price	200	200	200	200	200
	Amount	1690	1700	2280	2400	3400
h−BN	Q'ty	19	26^{5}	30	32	45
	Unit Price	20000	20000	20000	19000	18000
	Amount	380	530	600	650	800
c−BN (Carat)	Q'ty	480	480	480	500	700
	Unit Price	600	580	560	540	500
	Amount	290	280	270	270	350
(Synthetic diamond) C (Carat)	Q'ty	※	2	5	10	100
	Unit Price	※	300	200	200	150
	Amount	※	※	1	2	15

Note for C-BN and C: Volume: 1,000 carat, Unit price: yen/carat

(IV) Consumption of Major Materials Used for Ceramics Production (revised)

(Units) Quantity: ton Amount: Million yen Unit Price: yen/kg

Material	Items	1984	1985	1986	1987	1990
Al_2O_3	Q'ty	40000	40800	50800	53000	75000
	Unit Price	250	220	200	200	180
	Amount	10000	9000	10200	10600	13500
SiC	Q'ty	60	90	140	150	250
	Unit Price	5200	5100	4900	4800	4500
	Amount	310	460	690	720	1130
$BaTiO_3$	Q'ty	120	110	140	150	210
	Unit Price	4000	3400	3300	3200	3000
	Amount	480	370	460	480	630
ZrO	Q'ty	360	440	550	560	800
	Unit Price	3500	3200	3000	2800	2500
	Amount	1260	1400	1650	1570	2000
ZnO	Q'ty	1800	2000	2200	2250	3250
	Unit Price	450	420	400	400	380
	Amount	810	840	880	900	1230
MgO	Q'ty	800	870	1000	1050	1500
	Unit Price	700	650	600	550	500
	Amount	560	560	600	580	750
TiO_2	Q'ty	2600	2750	3350	3500	5000
	Unit Price	450	400	400	400	400
	Amount	1170	1100	1340	1400	2000
Fe_2O_3	Q'ty	10500	10600	14200	15000	21000
	Unit Price	200	200	200	200	200
	Amount	2100	2120	2840	3000	4200
h−BN	Q'ty	24	33	37	40	55
	Unit Price	20000	20000	20000	19000	18000
	Amount	480	660	740	760	990
c−BN (Carat)	Q'ty	600	600	600	620	850
	Unit Price	600	580	560	540	500
	Amount	360	350	340	330	420
(Synthetic diamond)C (Carat)	Q'ty	※	2	5	10	100
	Unit Price	※	300	200	200	150
	Amount	※	※	1	2	15

Note for C-BN and C: Volume: 1,000 carat, Unit price: yen/carat

* It is quite difficult to determine the quantity of respective material used for fine ceramics production.

  Accordingly, in this study combined with out analysis, we adopted the figures from the report on the electric and electronic related substances in "Research on the Trend of Fine Ceramics Industry" published by the Fine Ceramics Association in March 1986, based on the results of questionnaire to the members of the Association in January 1986. Generally speaking, the resulting figures are smaller compared to the actual ones. As for the price trend of each substance, we obtained the data respectively from the personnel in charge of marketing of major manufacturers.

* On the whole, prices are dropping affected by yen's appreciation, price cut requirements from users, originating in semiconductor trade friction and decreased demand. (As for titanium oxide, price remains at the same level due to the increase in demand on the overseas market and little absolute deposits.) Manufacturers have no optimistic views for the future price trend, or they rather take precautions against volume when the demand is stimulated in future.

* It is almost impossible to get the precise unit price of each substance used for fine ceramics production; as it widely differs by purity, particle shape and particle distribution as well as by application. Therefore, the followings are the approximate average prices.

Price Trend of Each Substance

Al_2O_3 (Sumitomo Aluminum Refining and several others)

Kyocera produces a very high quality and fine particle Al_2O_3 for captive use only to maintain product quality high. Products by few other companies including Sumitomo Aluminum Refining have stepped up to Kyocera's level. The price ranges from 5,000 yen/kg at 0.9999 purity to 200 yen/kg of general product, with lowering price trend.

SiC (Showa Denko K.K.)

The price widely varies from 15,000 yen/kg products of super fine 0.5μm particles to 1,000 yen/kg low-purity products. We predict the price will show lower trend considerably.

$BaTiO_3$ (Mitsui Mining & Smelting Co., Ltd.,
TDK Electronics Co., Ltd.

It is difficult to present prices as they purchase TiO_2 and $BaCO_3$ from material supplyers. However, with lowering of raw material price and improvement of manufacturing technologies, we predict the price will considerably go down.

ZrO_2 (Toyo Soda Mfg. Co., Ltd.)

ZrO_2, major application of which is for refractories, for electronic industry (including sensors) hold 10% of the overall demand. As products for electronic industry require materials of 99.0 - 99.6% purity, the price range is very wide from 2,500 yen to 10,000 yen (PSZ)/kg. The company is perplexed with the strong requirements from electronic component manufacturers.

Estimated Demand for Zirconia by Type of END Product (t)

	1982	1983	1984	1985	1985/1984(%)
Refractories	3,200	3,300	4,300	4,600	107
Abrasives/grinders	550	500	520	650	125
Electronic components	350	460	510	500	98
Pigments for ceramic industry	450	450	600	600	100
Glass products	70	90	110	120	109
Sensors	150	150	130	150	115
Fine ceramics	-	50	80	80	100
Total	4,720	5,000	6,250	6,700	107

(Data from Dai-ichi Kogenso Kagaku Kogyo Ltd.)

ZnO (Toho Zinc Co., Ltd., Sakai Chemical Industry Co., Ltd.)

The price of zinc ingot fell sharply from 270,000 yen/ton in 1985 to 170,000 yen/ton in June 1986. Although we consider the price has hit the bottom, the market is still soft. However, we might make mistakes with the price movement, if we forecast the yearly mean based only on the current price level.

ZnO for electronic ceramics often differ with respect to their purity, impurities to be eliminated and particle distribution depending on users' specifications. Therefore, it is difficult to specify general prices. They range from 250 yen to 10,000 yen/kg with no significant price cut.

MgO (Kyowa Chemical Co., Ltd.)

Although the price of product with 0.9999 purity is kept at 9,000 - 10,000 yen/kg, the price of ordinary high quality product is generally at 2,000 yen/kg. However, even if a laboratory requires a high purity product, negotiations with Materials Supply Department often result in the acceptance of general-purpose product priced at 400 yen to 600 yen/kg. Therefore, practical demand for high purity material will not likely increase.

Accordingly, the prices are gradually lowering.

TiO_2 (Titan Kogyo K.K.)

The production of TiO_2 for electronic components in 1985 was stagnant with users' rigorous price requirements.

However, due to the tight overseas market situation of TiO_2 and scared absolute reserves, the price will maintain the same level.

* Titanium Oxide

Production of titanium oxide in 1985 was 219,000 tons showing 6% increment versus previous year, but the domestic demand increased only by 1% with 158,000 tons production due to sluggish demand from paint, rubber and condensor sectors. Remarkable reduction was seen in the demand of barium titanate for condensor (48% decrease). On the other hand, export was greatly increased by 18% to 59,000 tons because of abundant supply caused by slugish domestic demand. Although the total shipment amounted to 217,000 tons, the supply situation still remains tight.

1986 titanium oxide market is forecasted by the industry to increase by 2% for domestic market and decrease by 1% for export, based on the zero growth forecast for paint, rubber and synthetic fiber industries, 4% up for printing ink industry and an expected slight increase for paper industry.

Production and Supply of Titanium Oxide in 1985 (in metric tons)

	1983	1984	1985	85/84(%)
Production	198,010	206,342	218,851	+6
Domestic	145,253	157,356	158,156	+1
Export	52,702	50,140	59,270	+18
Total Supply	197,955	207,496	217,426	+5
Import	38,097	37,140	42,213	+14
Total Demand	236,052	244,636	259,639	+6
Inventory	9,899	8,745	10,170	+16
Shipment by Applications (t)				
Paint	76,702	84,361	83,651	-1
Ruber	3,783	4,386	3,778	-14
Synthetic Fiber	4,999	5,072	5,057	-1
Printing Ink	23,423	25,202	25,677	+2
Plastics	12,729	13,140	14,153	+8
Paper	11,466	11,369	10,867	-4
Condensor	1,460	2,580	1,332	-48
Others	10,691	11,246	13,641	+21
Total Domestic Demand	145,253	157,356	158,156	+1

(Source: Japan Titanium Oxide Industry Association)

Fe_2O_3 (Toda Kogyo Corp.)

Although the Fe_2O_3 market shows the sign of slight recovery compared to the latter half of 1985, the market is still in bearish tone due to oversupply. However, since in this market the price has been stabilized at low level, further sharp price down is not likely to happen.

Changes in Productions of Iron Oxide, Soft Ferrite & Hard Ferrite (1,000 t)

	1978	1979	1980	1981	1982	1983	1984
Ferrite							
Hard	35.7	41.7	51.4	52.6	48.7	58.8	70.1
Soft	19.7	21.4	24.9	23.6	19.5	26.7	37.6
Iron Oxide	85.9	89.5	91.9	91.5	81.6	94.1	126.8

(Iron Oxide expressed in Shipped amount.
Data from Electronic Materials Association &
Statistics of Japan Inorganic Chemical Industry Association)

Monthly Production Capacity and Material Source of Iron Oxide and Ferrite Pre-Baked Powder by Manufacturer (Unint: ton)

Company Name	Iron Oxide	Prebaked Hard Ferrite	Powder for Soft Ferrite	Resources	Factory Site	Remarks
Tetu Gen	2,400	-	-	Waste liquor from ferrous chloride production (each Iron Works of Nippon Steel)	Hirohata, Muroran, Tobata, Yahata, etc.	In 1984 monthly production reached 3,000 to.
Dowa Mining	-	1,400	-	Pyrites from Sakuhara Mine	Okayama Iron Works	Among 2 lines, one line which had been idle before could go into full operation through last year.
Nihon Bengara Kogyo	-	1,400	-	Pyrites (Dowa Mining)	Shioda (Okayama) In Sakuhara Mining	400t of hard pre-baked powder is used for plastic magnet.
Koda Kogyo	1,000 -	- 500	- 300 300	Waste liquor from ferrous chloride production (Nihon Kokan-Fukuyama)	Hiroshima Hiroshima Hiroshima, Ohtake (Hiroshima)	Production capacity of pre-baked powder (for hard and soft) is estimated to be smaller than 1,000t of simple iron oxide.
Tone Sangyo	150	850	-	Waste liquor from ferrous chloride production (Kawasaki Steel Corp. - Chiba, Mizushima, etc.)	Gyoda (Saitama), Tatebayashi (Gunma) Okayama	
Kashima Denshi Zairyo	-	1,000	-	Waste liquor from ferrous chloride production (Sumitomo Metal Ind. - Kashima)	Kashima (Ibaragi)	All output is supplied to Sumitomo Special Metal.
Kawasaki Steel Corp.	-	300	-	Chiba, Mizushima Seitetusho	In Chiba Seitetusho	Operation started in May 1985 and they are at the stage of sample shipment now.
Saikai Kogyo	-	350	500	Waste liquor from ferrous chloride production (Kawasaki Steel Corp. - Mizushima)	Onoda (Yamaguchi)	Subsidiary of Kawasaki Steel Corp. They are reduction the production of hard pre-baked powder and planning the complete shift to soft pre-baked powder in future.
Magne	100	600	-	Waste liquor from ferrous chloride production (Nisshin Steel - Kure, Sakai)	Chiba	One-fifth of the total shipment is exported to Korea and Taiwan.
Nishin Ferrite	-	550	-	Waste liquor from ferrous chloride production (Nisshin Steel - Kure, Sakai)	Nishin Steel Corp (In Shunan Seisakusho)	Operation started in October 1984 and now reaches 60% (330t) of full capacity
Chemilite Kogyo	1,050	-	-	Waste liquor from ferrous (Shin Nittetsu)	Kimitu Seitetusho (Chiba)	
Morishita Bengara Kogyo	100	-	-	Waste liquor from ferrous chloride production	Mie	Iron oxide for soft ferrite.

h-BN (Denki Kagaku Kogyo)

Although h-BN has been attracting attention due to its outstanding heat resistance, corrosion resistance and insulation performance, we have not yet seen the practical use of the advantageous substance. Consequently, sales volume of h-BN has not reached the expected amount due also to its high price. 60% of its production is presently consumed as moulding materials. No further price cut is expected.

Synthetic Diamond (Tomei Diamond Kogyo)

In 1984 Sumitomo Electric Industries Ltd. developed a large drop of synthetic diamond and drew public attention. However, as the artificial diamond for IC board presently involves problems in cutting and pre-coating prior to making substrate, it has not yet been put to practial use. For acoustic device, Sony and Kenwood adopt it for speakers. High price of the synthetic diamond is a barrier in increasing demand. Considering the present situation, we just can say that "the price might lower in future."

(V) User Trend by Material

1) Laminated Ceramic Capacitor

Material Used: $BaTiO_3$, MgO, TiO, $SrCO_3$, $BaCO_3$, $Pb(Zr, Ti)O_2$, etc.

(a) Laminated Ceramic Capacitor

Outline

Ceramic capacitors are classified as follows.

(Classification of Ceramic Capacitor)

Ceramic Capacitor (porcelain)
- *for Temperature compensation (class I)
  --- mainly used for LC filters
- *General high dielectric constant (class II)
- *Semiconductor capacitor (class III)
- *Laminated capacitor
- *Laminated chip capacitor (others)

Rapid increase is currently seen in demand for semiconductor ceramic capacitors and laminated ceramic capacitors.

(b) Production Statistics of Capacitors

(by Product Type)

Type / Year	Variable		Fixed					
			Ceramics		Others		Total	
	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount	Q'ty	Amoount
1980	329	15,314	17,545	69,937	13,074	185,769	30,619	255,706
1981	370	16,219	21,475	81,715	16,319	209,545	37,794	291,260
1982	303	11,795	23,642	89,577	15,725	195,308	39,367	284,885
1983	409	14,545	32,376	113,526	20,349	227,812	52,725	341,338
1984	470	15,612	43,946	157,018	26,638	297,329	70,584	454,347

From Miti Statistics Unit: (Q'ty: Million pcs.)
(Amount: Million yen)

The growth rate in 1984 over 1980 in volume was:

Gross growth rate including variable capacitors 230%
Fixed capacitors 231

Ceramic capacitors (as part of fixed capacitors) 250

Other non-ceramic capacitors 204

The growth rate of ceramic capacitor comes out on top greatly contributing toward the entire growth of the capacitor industry.

(c) Trend in Laminated Ceramic Capacitor Sales

Type / Year	Ceramic capacitor					
	Laminate		Others		Total	
	Q'ty	Amount	Q'ty	Amount	Q'ty	Amount
1982	29	125	207	771	236	896
1983	57	234	267	901	324	1,135
1984	92	355	347	1,215	439	1,570
1985	110	420	330	1,150	440	1,570
1990 (prospect)	220	840	440	1,452	660	2,292
1995 (prospect)	443	1,780	562	1,686	1,005	3,466

Unit: Q'ty: 100 million pcs.
Amount: 100 million yen

Note: Figures for 1985 and on are based on major manufacturers' forecasts.

(d) Production by Manufacturers (laminated ceramic capacitor)

(1) Volume

(Unit: 100 million pcs.)

Manufacturer	1982	1983	1984	1985 (prospect)
Murata Mfg.	11	21	35	41
T D K	8	17	27	33
Kyocera	6	11	15	18
Matsushita Denshi Buhin	3	6	11	13
Others	1	2	4	5
Total	29	57	92	110

(2) Value

(Unit: 100 million yen)

Manufacturer	1982	1983	1984	1985 (prospect)
Murata Mfg.	47	86	137	145
T D K	38	77	116	142
Kyocera	17	29	38	45
Matsushita Denshi Buhin	12	23	40	48
Others	11	19	24	40
Total	125	234	355	420

Performance Analysis

In 1984, the market for laminated ceramic capacitor was approximately over 9 billion pieces in volume and 35 billion yen in value. The expanding application of laminated ceramic capacitor resulted in production increase by most manufacturers. However, due to the shortage of supply for the chip type, production of the chip type increased. In turn, this has led to the current shortage of the dip type.

2) Piezoelectric Device (Filter, Buzzer)

Materials Used:
PZT, PLZT, ZrO, Crystal, $LiNbO_3$, etc.

a) Outline

<u>Market Position and Application of Piezoelectric Ceramics</u>

Piezoelectric ceramics is considered as being kind of oscillator.

$$\text{Pressure} \; \underset{\text{(electric distortion effect)}}{\overset{\text{(Piezoelectric effect)}}{\rightleftarrows}} \; \text{Voltage}$$

Among those providing piezoelectric effect and electric distortion effect, it can be classified as one of the ceramic oscillators, excluding crystal oscillator.

- Oscillator
  - Piezoelectric type oscillator
    - crystal oscillator
    - ceramic oscillator
  - Magnetic strain type oscillator
    - metal magnetic strain oscillator
    - ferrite oscillator

Ceramic oscillators which are usually called piezoelectric ceramics, have broad application area as follows:

Ceramic Oscillator (piezoelectric ceramic)
- Filter (Band, Pass, Filter)
- Ignition cock (for gas equip. & cigarette lighters)
- Ultrasonic wave (microphone, delay line)
- Sensor (pick-up)
- Others (light-effect parts, buzzer, etc.)

Although ignition cock and piezoelectric buzzer are grouped in the product of late start, they have developed unique applications showing stable growth in share.

Clevite Co. of U.S developed the piezoelectric ceramic material named PZT and at the same time obtained wide range patents.

In 1965, three-composition piezoelectric ceramics containing composite Perovskite and PZT was developed by Matsushita Electric Group.

Difference between Piezoelectric Buzzer and Piezoelectric Speaker

Product	Thickness & Device	Frequency Range
Piezoelectric buzzer	200 - 400	2KHz - 8KHz (fixed)
Piezoelectric speaker	less than 150	500Hz - 2KHz (variable)

The lowest frequency of the present piezoelectric speaker is fairly high and difference between piezoelectric buzzer and piezoelectric speaker is not clear.

Basically ideal, piezoelectric speaker should provide thickness less than 60 and frequency range from 200 Hz to 1 KHz. However, technologies to produce the required products in full scale are yet unborn.

Therefore, present piezoelectric speakers do not differ much from piezoelectric buzzers.

Piezoelectric Speakers

Piezoelectric speakers are classified as follows by their driving method.

Speaker
- Dynamic (electrodynamic) type
- Magnetic (electromagnetic) type
- Capacitor (electrostatic) type
- Piezoelectric type
- Electric discharge type

Because the frequency band of the present piezoelectric speaker is from 500 Hz to 2KHz, the resulting sound is somewhat cracking which sounds uncomfortable to the human ear. Where the frequency band between 200 Hz and 1 KHz is realized, a comfortable sound would be achieved as the frequency band is almost equivalent to that of human's. In addition to this, when a thinner speaker become materialized, the application would amazingly expand.

Practically, each and every device which produces any electronic sounds could be replaced by piezoelectric speakers. In order to lower the lowest frequency, the technology to bake thinner oscillator without an open-pore is urgently required.

Piezoelectric Ceramic Filter

Filters are so produced to pass the specific frequency energy above and below certain level (or that within a specific range) and shut out (or pass) the energy of other frequency range. They are categolized by function and by material as follows:

- Filter
  - Passive filter
    - LC, RC filter
    - Piezoelectric filter
      - Crystal filter
      - Ceramic filter
      - Surface elastic wave filter
    - Magnet distortion filter
    - Mechanical filter
  - Active filter
    - RC active filter
    - Digital filter

Of these, piezoelectric ceramic filters are classified by use for low frequencies or for high frequencies with major applications for TV and FM/AM radio sets.

Since advanced selectivity required for today's high performance FM/AM sets crucially calls for more sophisticated selection devices, piezoelectric filters, especially ceramic filters become widely used in place of LC type filters. (Among piezo-electric filters, ceramic filter especially have many advantages as follows: they can be produced in mass as compared with crystal filters and are easy to be converted into various shapes. They are compact in size and economical.)

Major Applications of Piezoelectric Ceramics (piezoelectric components)

1. Filters

Ladder type ceramic filter -	pocket bell, high grade receiver, portable communication equipment
Ceramic discriminator-------	wave detector for high grade receiver, portable radio equipment, movable radio equipment
"Cerap" --------------------	sonic frequency trapping for monochrome/color TV set and VTR
"Ceraminator" --------------	SIF wave detecting circuit for monochrome/color TV set and VTR and FM wave detecting circuit
SIF ceramic filter --------	SIF circuit for monochrome/color TV set and VTR
"Pyzonator" ----------------	TV image middle frequency wave trapping and filtering, AFC circuit for TV set
Lead filter ----------------	pocket bell, tranceiver, catch phone, multi-sound receiver for TV set, publicity radio equipment, radio equipment for taxi, traffic signal controller, automatic controller, telemeter, tele-controller, radio buoy
ZnO surface wave filter ---	VIF circuit for TV set and VTR

2. Ultrasonic Applications

Ultrasonic ceramic microphone -	wireless remote controller for various electronic appliances, ultrasonic approaching switch
Ultrasonic delay ray -------	replay circuit for color TV set (PAL, SECAM, NTSC), drop-out compensation circuit for VTR, frame adjusting circuit for TV camera
Ultrasonic atomizer unit --	ultrasonic humidifier, atomizer for liquid (water, oil, etc.)
Ultrasonic humidifier -----	ultrasonic humidifier for home use
Ultrasonic cleaner --------	ultrasonic cleaner
Ultrasonic transducer -----	ultrasonic flaw detector, fish detector, ultrasonic microphone (in water), ultrasonic cleaner

3. Other Applications

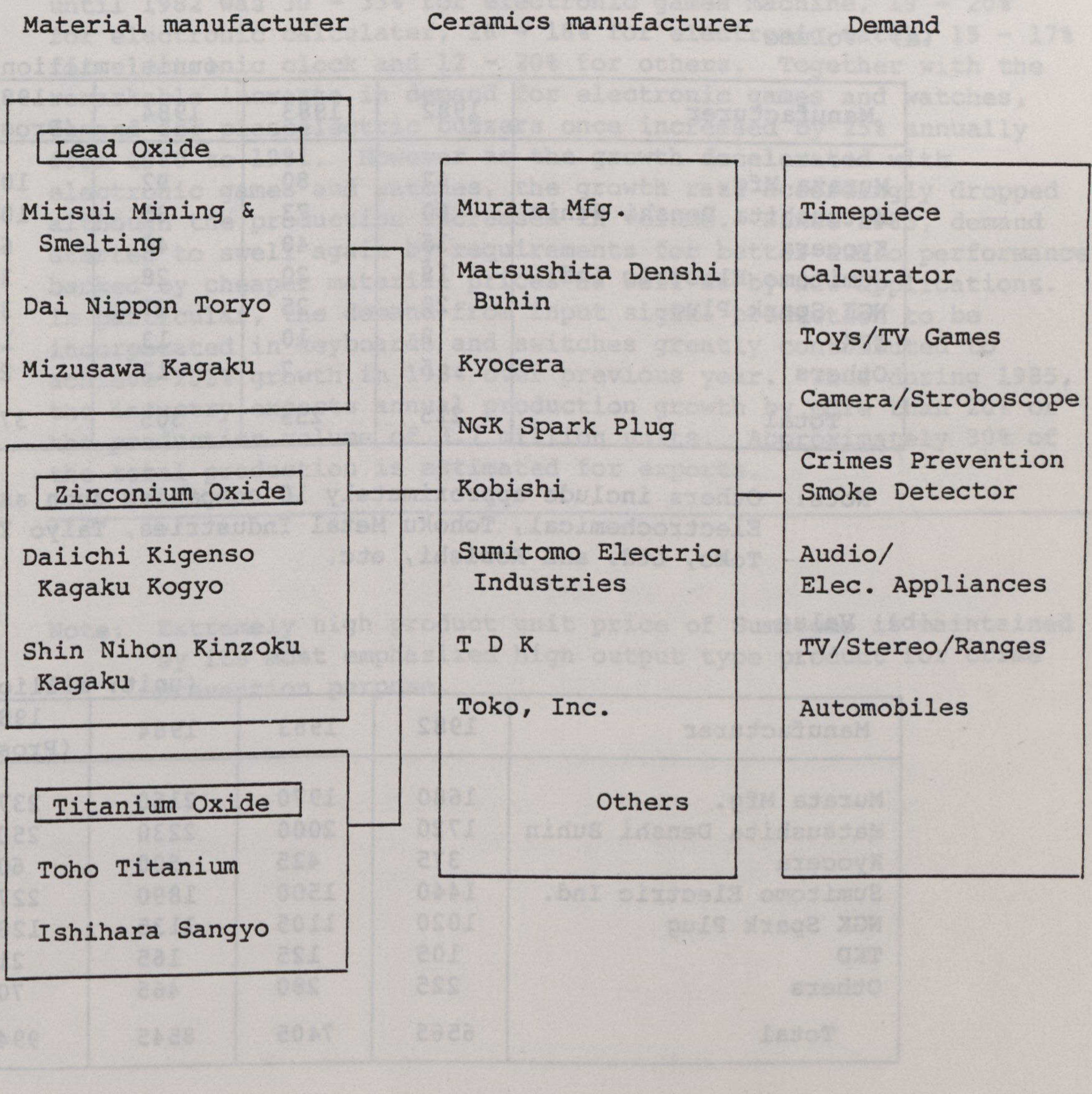
Piezoelectric buzzer ------	informing, confirming and alarming for various electronic appliances
Manometer sensor ----------	electronic blood pressure sensor, sensors for vibration and shock
Audio optical element -----	newspaper facsimile, laser printer, optical record, laser processing, optical scanner image display, spectrum analyzer, high speed spectroscope, color resolver, color mixer

Market Structure of Piezoelectric Ceramics

Participating Manufacturers

The main component of a piezoelectric buzzer or a piezoelectric speaker is the PZT ceramics, main component of which is $PbZrO_3$ - $PbTiO_3$.

The main material of PZT ceramics is lead oxide, zirconium oxide and titanium oxide. Refer to the chart below for ceramics manufacturers and users.



(b) Market Trend

Since the statistical data on the piezoelectric device filter and buzzer industry are neither available at the industrial associations nor at the governmental agencies, the followings are the estimations obtained from interviews with major domestic manufacturers. PZT is the trade name for $PbTiO_3$-$PbZrO_3$ developed by Vernitron Co. - former Clevite Co. - of U.S. Data include PZT and a product of the type later developed by Matsushita Denshi Buhin.

Piezoelectric Buzzer

(a) Volume

(unit: million pcs.)

Manufacturer	1982	1983	1984	1985 (Prospect)
Murata Mfg.	67	80	92	105
Matsushita Denshi Buhin	60	73	85	100
Kyocera	35	40	48	60
Sumitomo Electric Ind.	18	20	28	35
NGK Spark Plug	22	25	27	32
TDK	8	10	13	18
Others	5	7	12	20
Total	215	255	305	370

Note: Others include approximately 10 companies such as Fuji Electrochemical, Tohoku Metal Industries, Taiyo Yuden, Toko, Ltd. and Kobishi, etc.

(b) Value

(unit: million yen)

Manufacturer	1982	1983	1984	1985 (Prospect)
Murata Mfg.	1680	1970	2160	2370
Matsushita Denshi Buhin	1720	2000	2230	2500
Kyocera	375	425	500	600
Sumitomo Electric Ind.	1440	1500	1890	2275
NGK Spark Plug	1020	1105	1135	1280
TKD	105	125	165	215
Others	225	280	465	700
Total	6565	7405	8545	9940

(c) Change in Piezoelectric Buzzer Production

Year	Q'ty (million pieces)	Value (million yen)
1980	150	5060
1981	190	6090
1982	215	6565
1983	255	7405
1984	305	8545

The distribution in percent of the piezoelectric buzzer application until 1982 was 30 - 33% for electronic games machine, 19 - 20% for electronic calculater, 16 - 18% for electronic watch, 15 - 17% for electronic clock and 12 - 20% for others. Together with the remarkable increase in demand for electronic games and watches, demand for piezoelectric buzzers once increased by 25% annually from 1980 to 1981. However as the growth decelerated with electronic games and watches, the growth rate accordingly dropped although the production increased in volume. Since 1983, demand started to swell again by requirements for better audio performance backed by cheaper material prices as well as by new applications. In particular, the demand from input signal production to be incorporated in keyboards and switches greatly contributed to achieve 203% growth in 1984 over previous year. Thus during 1985, the industry expects annual production growth by more than 20% or the production volume of 3.7 million units. Approximately 30% of the total production is estimated for exports.

Note: Extremely high product unit price of Sumitomo is maintained by its most emphasized high output type product for crime prevention purpose.

Piezoelectric Filter

(Business Results of the top-3 Manufacturers)

(a) Volume

(Unit: million pcs.)

Manufacturer	1982	1983	1984	1985 (Prospect)
Murata Mfg.	410	435	455	480
Matsushita Denshi Buhin	80	95	125	160
Kyocera	45	60	70	80
Others	10	30	50	80
Total	545	620	700	800

Note: Others include TDK followed by Nihon Ceramic and NGK Spark Plug.

(b) Value

(Unit: million yen)

Manufacturer	1982	1983	1984	1985 (Prospect)
Murata Mfg.	1480	1520	1500	1440
Matsushita Denshi Buhin	360	380	420	480
Kyocera	200	240	240	240
Others	45	120	165	240
Total	2085	2260	2325	2400

Recently Murata Mfg. ranked at the top in market share has become threatened by late-starters, causing their share to decline.

3) Thermistor

Material $BaTiO_3$, ZnO, PbO, Si

(a) Outline

As is well known, thermistor is the abbreviation of Thermally Sensitive Resistor and is the generic term for the specific resistors having extremely great resistance against temperature fluctuations.

Thermistors classified by material are as follows:

- Thermistor
  - Sintered Type Metal Oxide Thermistor
  - Glass Thermistor
  - Plastic Thermistor
  - Thin Film Thermistor

    (Thermistor material evaporated on ceramic plate or on glass plate)
  - Thick Film Thermistor

    (Apply printing ink containing the mixture of pre-baked thermistor material and glass powder through screen process on ceramic substrate, then sintering.
  - PTC Thermistor
    - $BaTiO_3$ Ceramics
    - Zinc Oxide Ceramics
    - Lead Oxide Ceramics
    - Silicon
    - Plastic

Presently in terms of the value, the demand is shared almost in halves between NTC thermo sensors (sintered metal oxide thermistor) and PTC thermistors mainly for fixed-temperature heat generation and contactless operation. Demand for PTC thermistors has markedly increased for its low price and high reliability; more specifically, for its large plus-temperature coefficient as well as for its somewhat siwtchable temperature-resistance characterisitcs different from ordinary thermistors, PTC thermistors have pioneered new application areas such as thermal controls, overheating prevention devices or thermal timers for home electric appliances. Such areas are expected to further expand as equipment electronization and sophistication further advance.

(b) Market Trend

Production Statistics and Recent Market Trend of Thermistor

According to the production statistics on thermistors and the statistics by MITI on the current market trend, thermistor production has changed as shown in attached table since 1980.

The statistics indicate that in 1984 the growth in volume was 135% and in value was 196%, both over 1980. Especially in 1983 and on, the industry experienced a continuous high growth. Although, 1982, the growth of consumer equipment once slowed down, demand for thermistors as thermo sensors swelled again as the sales of consumer equipment recovered in 1983. Ever since, new application areas, where thermistors were not positively utilized, have been pioneered to date.

As aforementioned, thermistors can be classified into two categories: ie., PTC thermistor (positive thermal characteristic) and NTC (negative thermal characteristic). PTC thermistor was first used for demagnetizing color TV and compressor drive, by utilizing current control function. But recently, along with its application to heat generation at constant temperature, demand for PTC thermistors has been rapidly expanding, utilized for electronic jars, pots, electronic mosquito killers, VTRs (anti-dew cylinder heater), automobiles (for gasoline carburation), oil fan heaters and soldering irons.

On the other hand, demand for NTC thermistors is also growing for the use of audio-equipment, fan heaters, microwave ovens, air conditioners, refrigerators, OA equipment (PPC, facsimile, etc.) and for automobiles (radiator, thermometer, fuel jet injection system and gasoline leveling unit).

Year	Production Volume (1,000 pcs.)	Value (million yen)
1980	123,666	4,942
1981	137,720	5,946
1982	124,328	6,289
1983	140,798	8,171
1984	167,042	9,701

Statistic by MITI

The reason for large growth in value compared with that of production volume is because of the extremely strong high-quality-oriented trend on the market. Manufacturers participating in the thermistor market put utmost emphasis on the quality improvement of chips along with the technology development for peripheral circuits.

In so far as the NTC thermistors are concerned, demand for high reliability glass mold type is gradually superseding the disc type, which has been the mainstream product for its low price. The glass mold type is mainly used to air-conditioner sensor or as meet sensor.

Recently, as custom-grade PTC/NTC thermistors have become welcomed to the market, changes in average unit price of thermistors accordingly have become difficult to obtain. However, based on MITI statistics, the situation should presumably be as follows:

Change in Average Unit Price of Thermistors by Type

(piece/yen)

Type		1982	1983	1984	1985
NTC	General	12	11	10	95
	High Reliability	600	528	405	294
PTC	General	55	55	55	55
	Custom	432	439	428	425
Average Unit Price		50.7	57.9	58.1	57.8

What must be noted is the price down of high-reliability NTC glass mold type. Some others show slight price down, however, customgrade products make the price investigation complexed.

Changes in Production by Manufacturer

The followings figures are estimates based on the data obtained from interviews with manufacturers.

(a) Volume

(Unit: 10,000 pcs.)

Manufacturer	1982	1983	1984	1985 (prospect)
Shibaura Denshi Seisakusho	4,340	4,700	4,900	5,500
Ohizumi Seisakusho	2,000	2,200	2,700	2,800
Unison	1,750	2,100	2,400	2,600
Ishizuka Denshi	1,080	1,300	1,550	1,700
TDK	990	1,150	1,400	1,500
Takara Kogyo	1,100	1,000	1,250	1,400
Others	1,140	1,650	2,500	3,500
Total	12,400	14,100	16,700	19,000

* The number of thermistor manufacturers has remarkably increasing in recent year. Though the number of companies is not exactly known, it is considered to be 20 or around.

(b) Value

(Unit: million yen)

Manufacturer	1982	1983	1984	1985 (prospect)
Shibaura Denshi Seisakusho	1,590	1,867	1,960	2,365
Ohizumi Seisakusho	574	613	682	730
Unison	210	231	240	247
Ishizuka Denshi	310	362	392	443
TDK	1,790	2,271	2,610	2,835
Takara Kogyo	132	110	125	133
Others	1,684	2,716	3,691	4,247
Total	6,290	8,170	9,700	11,000

Changes in Thermistor Sales in Volume and in Value by Type, with Forecast until 1995

Type	Year	1982		1983		1984		1985		1990		1995	
NTC	General	103	1240	112	1232	126	1260	138	1310	223	2007	315	2835
	High reliability	3	1800	4	2110	7	2840	10	2940	25	5000	56	10080
	Sub Total	106	3040	116	3342	133	4100	148	4250	248	7007	371	12915
PTC	General	12	660	16	880	24	1320	30	1650	57	2850	111	5550
	Custom	6	2590	9	439	10	4280	12	5100	25	8843	48	11835
	Sub Total	18	3250	25	4828	34	5600	42	6750	82	11693	159	17835
Total		124	6290	141	8170	167	9700	190	11000	330	18700	530	30300

Volume million pcs.

Value million yen

Breakdown of Other Manufacturers in Table (b)

(Unit: million yen)

Year	1982	1983	1984	1985
Others	1684	2716	3691	4247
PTC	1460	2557	3121	4057
Murata	803	1406	1717	2231
Matsushita	657	1151	1404	1826
TDK PTC	1790	2271	2479	2693
NTC	-	-	131	142
PTC Total	3250	4828	5600	6750

Thermistor

Changes in Production of NTC and PTC

Unit: 10,000 pcs.

Item		1982	1983	1984	1985
NTC	Q'ty Growth rate	10,610 100	11,630 110	13,300 125	14,700 139
PTC	Q'ty Growth rate	1,790 100	2,470 138	3,400 190	4,300 240
Total	Q'ty Growth rate	12,400 100	14,100 114	16,700 135	19,000 153

70 to 80% of the manufacturers included within the "Others" category in previous table manufacture PTC. 17.9 million pieces total PTC production in 1982 consists of 9.9 million by TDK and 8 million by Matsushita and Murata.

PTC exceeds NTC in growth rate.

The reason is that PTC, in addition to its major application for mosquit killers or TV circuits, currently has become used for VTR head heaters, automobiles or dryers. However, as production of mosquito killers has been on the decrease, Unison so far focussing on mosquito killers, stopped production of PTC thermistors.

4) Varistor

Materials: Pbo, Se, Si, Tio, Zno

(a) Outline

Varistor is a kind of special resistors similar to the thermistor. At the same time, it is the general term for the solid devices which provide excellent resistivity response as impressed voltage fluctuates, showing non-linear volt-ampere characteristics.

- Varistor
  - Diode Varistor
    - Cuprous Varistor
    - Selenium Varistor
    - Silicon Varistor
    - Silicon Zener Diode
  - Ceramic Varistor
    - Titanium Oxide Varistor
    - Newly standardized product: used as semiconductor capacitor ...... Titanium Oxide Strontium Varistor ..... Taiyo Yuden, Murata, Matsushita etc.
    - Silicon Carbide Varistor
    - Zinc Oxide Varistor

As shown in the chart above, varistors are classified into diode varistors and ceramic varistors. Due to their excellent surge current absorptiveness, production of ceramic varistors is swelling to stand abreast of diode varistors in their volume on the market.

b) Market Trend

Statistics on Varistor Production

Year	Production (1,000 pcs.)	Value (million yen)
1980	319,254	4,073
1981	360,165	6,987
1982	313,964	6,788
1983	419,766	8,850
1984	535,876	13,523

As seen from the table, rapid growth continued since 1982 when the depressed audio market recovered. In addition, drastic increase in the demand for varistors to be built in micro-motors used for VTRs, OA equipment or TV sets has largely contributred toward the growth.

Further in 1984, with the strengthening of noise control requirements, varistors for ordinary equipment circuit began to sell for noise and surge prevention purposes.

About 55% of the varistors annually produced are the ring varistors to be build in micro motors as spark elimination device between governer contact and commutator·brush for noise reduction purpose.

Use of ring varistors

Consumer use: 70 - 80% (Mainly for VTRs and audio equipment: loading for reel, capstan motor for drum.)

Industrial Use: 20 - 30% (OA equipment)

About 75% of ceramic varistors are the ZnO.

Production of ZnO Ceramic Varistors by Manufacturer

(a) Volume

(Unit: million pcs.)

Manufacturer \ Year	1982	1983	1984	1985 (prospect)
Matsushita Denshi Buhin	–	–	3	4
	4	5	5	6
Ishizuka Denshi	2	3	4	4
	1	1	2	2
Taiyo Yuden	2	3	4	5
	–	–	–	–
Marukon Denshi	–	–	–	–
	2	2	3	4
T D K		1	1	2
	–	–	–	–
Unison	–	–	–	1
	–	1	1	1
Others	1	1	3	4
	1	1	1	1
Total	13	19	27	35

* Ceramic varistors produced by Taiyo Yuden are the tin oxide type (SnO).

** Upper column shows ring varistors surge lower column: absorber

Note: Others include 5 to 7 companies such as Hokuriku Electric Industry Sanken Electric, Mitsubishi Mining & Cement and Ohizumi Seisakusyo.

Taiyo Yuden and TDK put emphasis on low prices ring varistors (Taiyo Yuden recently developed circuit use varistors.)

While Marukon Denshi is specialized in circuit use ones, Matsushita Denki and Ishizuka Denshi, produce both types. In response to the market needs, production of ZnO ceramic varistors by these manufacturers is gradually on the increase.

(b) Value

(100 mil. yen)

Manufacturer \ Year	1982	1983	1984	1985 (prospect)
Matsushita Denshi Buhin	-	-	3	4
	12.5	15.5	16	19.5
Ishizuka Denshi	2.5	3.5	4	4
	3	3	6	6
Taiyo Yuden	2.5	3.5	4	5
	-	-	-	-
Marukon Denshi	-	-	-	-
	5	6	10	14
T D K	-	1.5	1	2
	-	-	-	-
Unison	-	-	-	1
	-	2	2	2.5
Others	1.5	1.5	3	4
	4	4.5	5	6
Total	30	41	54	68

* Taiyo Yuden produces tin oxide type (SnO) varistors

Production by Type in 1984

Product name	Product type		Volume (10 mil.pcs.)	Value (100 mil.yen)	Average @ (yen)
ZnO / SnO) Varistor	Ring Varistor		16	19	11.9
	Surge adsorption use varistor (circuit use)	Disc Type	10	28	28.0
		Box Type / Others	1	7	700.0
	Total		27	54	20.0

The unit price of the ring varistor went down below 10 yen, affected by the steep price decline from the beginning of this year.

b) Infrared Sensor

Material Used: $LiTaO_3$, PZT, $PbTiO_3$

(a) Classification of Infrared Sensor

Domestically full scale use of infrared sensors started only 5 years ago in 1979. Prior to this period, infrared sensors were the mere small-lot imported products.
After 1982, large number of infrared sensors have come into use mostly for consumer products (in particular, for security equipment).

Classification of Infrared Sensors and Major Manufacturers

- Infrared Sensor
  - Thermal type
    - Pyroelectric type
      - Single crystal
      - Ceramics
      - PVDF (organic film)
    - Thermopile
    - Thermistor bolometer
  - Particle type ... Utilizing photoelectric effect

Although the particle type is superior in its physical properties, in response speed and in sensitivity, they are not suited for consumer products, due to high price and the cooling system using liquid nitrogen.
Presently, the mainstream of application of infrared sensors is to the consumer products in terms of application volume. In relation to this, infrared sensors for consumer application must satisfy requirements with handling convenience and economy. In that sense, pyroelectric type dominates the infrared sensor market.
As aforementioned, pyroelectric type is classified into single crystal, ceramics and organic film by material used. Among these, the organic film is exclusively supplied by Matsushita Electric Industrial Co., Ltd. The reason being the high cost of PVDF material along with the high technology required for processing. Matsushita is the only domestic participant to this market sector and the demand situation for their organic film products is not considered buoyant.
As shown in attached Table, single crystal type includes several different sub-types such as lithium tantalate, SBN and the inorganic type like TGS (triglycine sulfite). At present, only lithium tantalate type is in some demand. PZT and $PbTiO_3$ are in the ceramics type category. Presently in Japan, only PZT is marketed.
Evaluation of physical properties for ceramics and single crystal products is as stated in the reference. However,as the ceramic (PZT) is more profitable than the single crystal (on the cost aspect), PZT is widely used for the consumer products.

Table 1. Major Pyroelectric Material

Material	Curie Temp. Tc(°C)	Specific Inductive Capacity	Coefficient of Pyroelectricity ($C.cm^{-2}.K^{-3}$)	Specific Heat at Constant Volume c' ($g.cm^{-3}.K$)	$\lambda/\varepsilon \cdot c'$ (C.cm.J)
TGS (Inorganic)	49	35	4.0×10^{-8}	2.5	4.6×10^{-10}
$LiTaO_3$ (Single crystal)	618	43 54	1.8 2.3×10^{-8}	3.2	1.3 1.35×10^{-10}
PZT (Ceramics)	200 270	380 1800	1.8 2.0×10^{-8}	3.0	0.2 0.4×10^{-10}
Deformed PZT (Ceramics)	220	380	17.9×10^{-8}	3.1	1.5×10^{-10}
$LiNbO_3$ (Single crystal)	1200	30	0.4 0.5×10^{-8}	2.8	0.4 0.6×10^{-10}
$PbTiO_3$ (Ceramics)	470	200	6.0×10^{-8}	3.2	0.94×10^{-10}
SBN (Single crystal)	115	380	6.5×10^{-8}	2.1	0.8×10^{-10}
PVDF (Organic Macromolecular)	120	11	0.24 0.4×10^{-8}	0.33	0.9 1.5×10^{-10}

Note: TGS: $(NH_2\text{-}CH_2\text{-}COOH)_3H_2SO_2$, Glycine Sulfate
PZT: $(PbxZryTizO_3$
Deformed PZT: $[Pb(SnSb)O_3\text{-}PbTiO_3\text{-}PbZrO_3]$
SBN: $[Srx\ Bay\ Nb_2O_6]$ normally x=0.48, y=0.52
PVDF: Crystalline macro molecule of polyvinyl fluoride $[(CH_2\text{-}CF_2n]$ or PVF_2

Pyroelectric Type Infrared Sensor

Type	Domestic Production	Import
Single crystal ($LiTaO_3$)	Sanyo Electric Co., Ltd. Matsushita Denshi Buhin (Matsushita Giken)	Plessy Eltic
Ceramics (PZT)	Murata Mfg. Nihon Ceramic Horiba, Ltd.	Plessy Mullard
Organic (PVDF)	Matsushita Electric Insdustrial Co., Ltd. Matsushita Communication Industrial Co., Ltd.	

(Reference)

Kinds of Pyroelectric Materials

Table 1 shows properties of pyroelectric materials taking into consideration the fundamental properties. The table contains values which can be calculated from substance constant of material as performance index, but other values should also be considered depending on using wave length zone and frequency zone as mentioned before. The values in the table has, give only rough standard. Each pyroelectric material is briefly mentioned below.

1. TGS (Triglycin Sulphate)

TGS crystal has excellent performance indices such as pyroelectric coefficient, dielectric constant, dielectric loss and specific heat. The good qulity crystal can easily be manufactured and the IR beam absorption begins from 2um. Surely it is a good pyroelectric material. However, the reason why it is not widely used for industrial products is a high cost of grinding because of wate soluble crystal, a big sensitivity dependence due to low Tc (490°C) and a low using temperature (hard to use above 40°C and impossible to use above 49°C).

2. $LiTaO_3/LiNbO_3$ Single Crystal

There no weakness pointed out for TGS and $LiTaO_3$ is one of best materials second to TGS in terms of performance index. The dielectric constant for $LiTaO_3$ is small ranging from ε=40 to 50, which is preferable. In case that the area of element is small, the capacity of element becomes smaller than the capacitance of outside circuit (FET gate capacity and staray capacitance), which causes reduction in sensitivity and slow response.

$LiTaO_3$ crystal is currently used for pyroelectric IR sensor element for commercial applications such as crime prevention system and cooker because of relatively large property values, a wide range of using temperature (-20 - 100°C), easy procurement small variation of properties and possible production in a large scale. Pyroelectirc plate with about 50 μm thickness is commercially available.

3. $PbTiO_3$, PZT Ceramics

$PbTiO_3$ is a strong dielectric material having excellent properties as pyroelectric and piezoelectric material such as hihg curie temperature, high spontaneous polarization and small dielectirc constant. Therefore, at first, it was expected to be a piezoelectric material at high temperature and frequency. As pure $PbTiO_3$ ceramic is difficult in sintering, the high density, high resistance ceramic is obtained by adding sintering aid or forming solid solution.

Pyroelectric properties for PLZT ($PbTiO_3$-$PbZrO_3$-La_2O_3) have been studied for various compositions. Compositions of La4/Ti65/Zr35 and 7/65/35 have maximum pyroelectric coefficient but high dielectric constant (ε=680, 1860) which lowers the performance.

PZT ceramic is a typical piezoelectric ceramic being commercialized in a large scale. The Curie temperature ranges from 250 to 450°C depending on composition and the dielectric constant is 250 - 400, which indicates a appropriate pyroelectric material.

Evaluation of each crystal is as follows at the present.

(1) Lithium niobate ($LiNbO_3$)

Single zone crystal growth method is designed for $LiNbO_3$ to apply the DC electric field to crystal at the final stage of crystal growth, utilizing the nature of similar melting point to Curie temp. By this method, air bubble and subgrain are greatly reduced and the optical quality becomes high.

(2) Lithium Tantalate ($LiTaO_3$)

The crystal for surface elasticity wave element becomes blown or yellow because of Pt-Rh crucible being used. These colors are not an obstacle for the use of pyroelectric application. The use of 99.9% level raw material leads a satisfactory property of crystal.

(3) Strontium Barium - Niobate ($Sr_{1-x}BaxNb_5D_{15}$)

The crystal growth from molten liquid of congruent composition gives as high qulity crystal of striation-free, core-free and 10/cm of transition density.

(4) Lead Germanate ($Pb_5Ge_3O_{11}$)

Following points should be considered for growth of high quality crystal: (a) to mix and crush raw material with through care, (b) even heating with small temperature slope, (c) only one usage of molten composition, (d) not to raise temperature above 800°C, (e) grow under other atmosphere than oxygen such as argon, and (f) crystal growing rate not exceeding 4 mm/hour.

4. Polymer Film (PVF_2 etc.)

Research for piezoelectric and pyroelectric properties for organic polymer film had been made on biopolymers such as cellulose and collagen, but since Kawai found that a big piezoelectricity exists in polyvinylidene fluoride (PVF_2), researches have been shifted to this polymer. Researches for piezoelectric/pyroelectric elements of PVF_2 are underway from the features peculiar to polymer film such as flexibility, thin film and possible large area.

b) Market Size and Application

(1) Infrared Sensor

The market size of infrared sensor is as follows.

(Estimation based on the data obtained from the Murata personnel in charge of SS Sensor and from the Central Laboratory of Sanyo Electric Co., Ltd.)

1) Volume

(Unit: 1,000 pcs)

Year / Type	1983	1984	1985 (prospect)	1984 Ratio
Infrared sensor	4,536	5,720	7,104	100
Thermal type sensor	4,296	5,420	6,744	94.8
Pyroelectric sensor	4,200	5,300	6,600	(92.7)
Others	96	120	144	(2.1)
Grain type sensor	240	300	360	5.2

2) Value

(Unit: 100 yen)

Year / Type	1983	1984	1985 (prospect)	1984 Ratio
Infrared sensor	28	34	40	100
Thermal type sensor	25	30	36	88.2
Pyroelectric sensor	24	29	35	(85.3)
Others	1	1	1	(2.9)
Grain type sensor	3	4	4	11.8

Demand for infrared sensors has remarkably increased since 1982 when the manufacturers of weak current electric appliances adopted them for producing security products.

(2) Pyroelectric Sensor

As explained previously, pyroelectric sensors are roughly divided into three different categories by types: single crystal, ceramics and PVDF.

By type and by manufacturer production and market situation in 1984 is shown in the table below

<u>Production and Market Situation by Type and by Manufacturer in 1984</u>

	Type	Manufacturer	Volume (1,000 pcs./year)	Market Share (%)	
Domestic	Single crystal	Sanyo Electric	1,200	25.5	38.3
		Matsushta Denshi Buhin	600	12.8	
	Ceramics	Murata Mfg.	1,580	33.6	51.5
		Horiba, Ltd.	600	12.8	
		Nihon Ceramic	240	5.1	
	Organic (PVDF)	Matsushita Electric Ind. Co., Ltd.	480	10.2	10.2
		Matsushita Industrial Co., Ltd.			
	Sub total		4,700	100 88.8	
Import			600	11.2	
Total			5,300	100	

* Imported product domestically marketed seems to be either one of the single crystal type or the ceramics type.

(3) Application

Variety of application by type is as shown below (1984).

(Unit: 1,000 pcs.

Application / Type	Crimes Prevention Equip.	Elec. Appliances	Calcu. Equip.	Toys & Civil Use	Research Specific Uses	Total
Thermal	3,180	1,060	482	530	168	5,420
Pyroelectric	3,180	1,060	410	530	120	5,300
Others	-	-	7.2	-	48	120
Grain	-	-	240	-	60	300
Total	3,180	1,060	722	530	228	5,720
Distribution by Application	55.6	18.5	12.6	9.3	4.0	100

Application of Pyroelectric Devices

Security

Area of Application	Actual Cases
Disaster prevention	Early detection of fire Safety maintenance of oil tank Monitoring of air and gas in building equipment
Crime prevention	Invasion alarm Body counter
Search and rescue	Search for victims after fire Search and rescue of victims on sea, in snow, etc.
Environment control	Waste water from plant Hot water draining control Waste oil control

Energy Saving

Area of Application	Actual Cases
Electronic power supply	Effective temperature control of microwave oven, oilstove and other heating equipment Temperture sensor for energy saving design of air conditioner and refrigerator Temperature measuring instruments for motor, power transformer and electronic component
Nuclear Power	Hot waste water control in nuclear power plant Detection of abnormal temperature
Plastic Rubber	Plastic moulding process control such as temperature measurement of moulding resin and die
Automobile	Measurement of automobile exhaust gas Temperature measurement of engine and radiator
Food	Temperature control Packaging process control
Civil Engineering and Construction Agriculture and Atmospheric Condition	Temperature control of freezer Analysis of temperature and gas in greenhouse environment for cultivation
Petroleum and Chemicals	Temperature control of explosive and/or inflammable materials Reaction temperature measurement
Medical Science and Health Care	Measurement of temperature distribution on human body Measurement of human body motion
Metal and Metallurgy Iron and Steel	Temperature monitoring Measurement of temperature distribution Measurement of board thickness Mesurement of rod count
Machinery and Processing	Temperature measurement of burning gas Temperature measurement of materials in cutting process Temperature control of oil hydraulic machine

Recently concern about security has been growing and accordingly, demand in this field has shown a rapid increase. Users of these sensors are the major electric appliance manufacturers such as Matsushita, Hitachi, Toshiba as well as the signal manufacturers such as The Nippon Signal, Kyosan Electric Mfg. and Daido Signal. Alarm manufacturers and automobile parts manufacturers are also the users of infrared sensors.

Infrared Sensor

(1) Price

Manufacturer	Product Number of Major Product	Price (Yen)	
		Large Lot	Small Lot
Murata Mfg.	(Resin case type) F001P (Hermetic seal type) E611S 066S	150-200 1,000-1,300	300-400 3,000
Horiba, Ltd.	(Single type) P2LS-F-WS (Dual type) P2LS-F-US	900-1,200	3,000-5,000
Nihon Ceramic	(Single type) SS10 (Dual type) SS02 (4 element type) SS05	900-1,000	2,800-3,500

1) Infrared sensors were first adopted for crime prevention devices and the area of application later expanded to automatic door, thermometer and FA equipment.

2) Consequently, high precision products priced at 1000 yen level came into request.

3) Products priced at 150 - 200 yen are mainly used for toys.

4) All three manufacturers listed above have no fixed prices, but they trade price quoted prices. A large difference exists between a big order or a promissing client who might have continuous trade in the future and a small order or an experimental use.
A distinctive feature of this market. Big order here means a constant purchase of more than 1,000 unit of sensors per month. Small order means a spot purchase less than 1,000 sensors per month. Manufacturers set price within the above range in consideration, of various trade conditions as well as the strategic value of individual user.
Price difference by product grade does not exist except for resin case type.

(2) 5-year Demand Forecast

Comprehensive evaluation based on the information from the Central Laboratory of Sanyo Electric Co., Ltd. and Horiba, Ltd.

1) Demand for pyroelectric sensor has shown consistent growth since 1983. (approx. 25% per year in volume)
In 1986 and 1987, some 20% annual growth can be expected, supported by active demand from the overseas market.

2) In 1988 and on, the demand in the overseas market will somewhat decrese. On the other hand, new domestic demand caused by new application, (e.g. emergy conservation in relation to lighting and automatic door) will continue to swell with the expected annual growth of about 20%.

3) In terms of materials the demand for Ceramics and PVDF will increase in particular. Demand for single crystal will also expand in volume, however its share in the entire pyroelectric type sensors will decrease. The reason is that, according to the present demand structure, the use of single crystal is limited to mainly for home electric appliances and the development of new applications in the promissing field has not yet been accelerated.

4) Price

Along with the development of mass production system, prices will go down by 10% to 15% toward 1990.

Summary

Demand Forecast of Pyroelectric Sensor

Year	1986	1987	1988	1989	1990
Volume (1,000 pcs.)	7,920	9,500	11,400	13,700	16,400
Value (100 mil. yen)	40	46.5	55	65	75

$\underbrace{1986 \quad 1987}$ Growth supported mainly by overseas market factors

$\underbrace{1989 \quad 1990}$ Mainly by new domestic demand

Product Share by Material Type

1984 Share

Single Crystal	38(%)
Ceramics	52
Organic	10

1990 Share (Prospect)

Single Crystal	30(%)
Ceramics	50
Organic	15

Summary

Sales forecast on research items in 1985, 1990 and 1995.

(With too many factors for change, forecast by Lest Squares Method or Growth Curve Method does not seem appropriate. Accordingly we applied a technique somewhat similar to the Delphi Method by interviewing the key marketing personnel from major manufacturers of the sector.)

1) Volume

(Unit: 100 million pcs.)

Product Name / Year		1985	1990	1995
Laminated Ceramics Capacitor		110.0	220.0	443.0
Thermistor		1.9	3.3	5.3
Varistor (ZnO)		3.5	7.3	11.8
Piezoelectric Device (PZT)	Filter	8.0	16.7	28.3
	Buzzer	3.7	7.2	11.7

2) Value

(Unit: 100 million yen)

Laminated Ceramics Capacitor		420	840	1,780
Thermistor		110	187	303
Varistor (ZnO)		68	136	220
Piezoelectric Device (PZT)	Filter	24	29	35
	Buzzer	99	175	282

(VI) Super Fine Particles of Metal and Ceramics

Along with the advancement of electronic materials, those with higher function and of extremely small size, i.e. super fine particles below 1 m as is strongly required. In particular, lowering the sintering temperature by using the mixture of super fine particles and super fine supporting material would directly raise the production costs. On the other hand, demand for lower material (or component) price is very strong due to depressed export market and severe price competition. In general, these contradictory requirements can be analyzed as follows:

(a) If material cost is 10% lower with equivalent quality, electronic component manufacturers would rush to such material, regardless of whether the supplier is experienced or not.

(b) If cost is up by 20% to 30%, though with quality improved by 10%, such product will not be used.

(c) If cost goes up by 10%, with quality up by 30%, suchproduct would be negotiable.

This cost - quality correlation is also applicable to binders.

It seems to be a very challenging and at the same time a very laborious task to break through the barriers mentioned above, especially with (c).

(VII) Evaluation Method of Functional Materials and Organizations Providing Evaluation Services

1) Evaluation Method

Laboratories or Analysis Institutions require informations on the material structure as well as its prospective application for evaluation. An evaluation method generally applicable has not been established yet.

* Reference

"Report on the Study for Standardization of Fine Ceramics" by Fine Ceramics Association; March 1986

2) Organizations Providing Evaluation Services

(a) Public Organization

°Nagoya-shi Industrial Research Institute
3-4-41, Rokuban, Atsuta-ku, Nagoya 456
Tel: 052-661-3161

Persons in charge: Mr. Kuwahara or Mr. Kato

*Joint research is client's premiss by temporary

°Fine Ceramics Center

Temporary Office: Nagoya Sakae Bldg.
5-1, Takehira-cho, Higashi-ku, Nagoya 467
Tel: 052-962-6048

*Operation starts in April 1987

∘National Research Institute for Metals, Science and Technology Agency

2-3-12, Nakameguro, Meguro-ku, Tokyo 153
Tel: 03-719-2271

Research Cooperation Staff

*Offering general consultation based on their analysis for example on bending strength etc.

(b) Private Organization

∘Toray Research Center

Miyako Bldg. 3-3, Nihonbashi Muromachi, Chuo-ku, Tokyo 103
Tel: 03-245-5633

*Comprehensive analysis available at their facilities in Shiga Pref.

∘Matsushita Techno-Research

3-15 Yagumo Nakamachi, Moriguchi-shi, Osaka 570
Tel: 06-909-1121 (ext. 2121, 2122)

*Comprehensive analysis available.

∘Sumika Analysis Center

Chiba Office

9-1, Kitasode, Sodegaura-machi, Kimitsu-gun, Chiba
Tel: 0438-62-1105

∘Ishikawajima Inspection & Measuring

Tokyo Office: 1-20-40, Toyosu, Koto-ku, Tokyo
Tel: 03-534-3417

Inspection & Measuring Material Test Section

∘Mitsubishi Metal Corp., Central Laboratory

Mitsubishi Metal Technical Center

1-297, Kitabukuro, Ohmiya-shi, Saitama 330
Tel: 0486-44-2971