

# New Coating Materials and Their Preparation by Radiation Polymerization. III. Antifogging Coating Composition

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## Synopsis

Compositions for good antifogging and mar-resistant coatings were investigated. A mixture of hydrolyzed aminoalkylalkoxysilane and hydrophilic vinyl monomer was the best combination. Control of suitable viscosity for coating was carried out conveniently by irradiation. The prepolymer was coated and cured by heating to form an antifogging membrane on various base materials such as inorganic glass, CR-39 resin, and poly(methyl methacrylate). These conditions were studied in relation to some physical properties of the membrane. It was found that antifogging and mar-resistant properties were inconsistent in many cases. A possible way to achieve the best balance between the two properties is discussed.

## INTRODUCTION

As in previous reports,<sup>1,2</sup> the authors developed mar-resistant new coatings consisting of alkoxysilane and vinyl compounds using a radiation polymerization method. These coatings improved the mar resistance or scratch resistance of plastic surfaces greatly.

However, coating techniques will be required in the future to give various useful properties to the surface of transparent materials. Antifogging is one of such surface properties. Fogging of spectacles and windows under large temperature and humidity differences in various places such as in the bath room, dining room, and vehicles is troublesome in daily life. Several trials have been done to produce antifogging layers or membranes on transparent material surfaces. However, most of them have only a temporary antifogging effect which disappears easily with time because they are simply liquid surface reactants or water-proof agents that are not chemically cured and adhered to the basic materials.

Recently, several coating methods for cured resin types have been proposed.<sup>3-5</sup> The durability of these coatings is better than that of any preceding coatings. But the important drawback that the mar-resistance is not long lasting enough for practical use still exists. It is necessary to find a new coating composition that has both sufficient antifogging and mar-resistant properties. The authors tried to apply the fundamental technique for mar-resistant coatings to the antifogging one, using silicon and vinyl combinations and a radiation polymerization method. The combination of hydrophobic alkoxysilane and vinyl compounds was effective for mar-resistant coatings, while a hydrophilic combination of alkoxysilane and vinyl compounds was investigated for an antifogging coating.

The result was successful. This report concerns a screening study on new antifogging coating compositions, their preparation methods including irradiation processes, and the properties of these coatings.

## EXPERIMENTAL

Silicon compounds were supplied by Sinetsu Chemical Co., Ltd., and used without further purification. Hydroxyethyl methacrylate (HEMA) was obtained from Mitsubishi Gas Chemical Co., Ltd., and used after removing the polymerization inhibitor by passing through an ion exchange resin column. Other vinyl monomers were obtained from Tokyo Kasei Co., Ltd., and Shin-Nakamura Chemical Co., Ltd., and used after removing the inhibitor.

Hydrolysis products of a silane coupling agent (alkoxysilane) were obtained usually by reaction of a mixture consisting of silane coupling agent (100 parts), methanol or ethanol (70 parts), and aqueous solution of strong acid, such as sulfuric acid and hydrochloric acid (20 parts) as hydrolysis catalyst, at 67°C for 8 hr. Solvent and catalyst used were commercially available extrareagent grade without further purification. Prepolymer for coating was prepared by irradiating the mixture of the hydrolysis product and vinyl monomers usually at room temperature, controlling the viscosity of prepolymer in the range of 40 to 200 centipoises. The prepared prepolymer solution was coated usually by a dipping method on base material lenses or sheets which were wiped with alcohol or neutral washing agent and dried. Curing of the coated membrane was carried out by hanging the sample on hooks from the upper end of an air oven and heating it at constant temperature.

The adhesiveness of the cured membrane with the base materials was evaluated by a cross-cut test in which 100 squares  $1 \times 1 \text{ mm}^2$  in size were incised on the membrane. An adhesive film tape made by cellophane was attached to the incised part by pressing and was then stripped off quickly from the incised membrane. The degree of adhesiveness is expressed by the ratio of the number of unit squares remaining on the membrane without being removed by the cellophane tape to that of unit squares incised initially.

The mar resistance of the membrane was estimated by measurement of pencil hardness according to JIS-K 5400, haze value after the sand-falling test according to ASTM-673, and visual judgment for injury after scratching by steel wool.

The antifogging property was judged qualitatively from fogging or no fogging after breathing at the sample at 20°C and 60% humidity and half-quantitatively by measuring the time to fogging or dewing on the inner surface of a sample set in a bath equipment as shown in Fig. 1. The water was warmed and kept at constant temperature. The inner surface of the sample is in contact with the internal atmosphere of saturated vapor pressure of the water at this temperature, and the outer surface of the sample is in a determined external room temperature and humidity.

Resistance for reagents was tested by observing the change of appearance and essential properties such as antifogging, mar resistance, and adhesiveness after immersing the sample in various reagents for one week at room temperature.

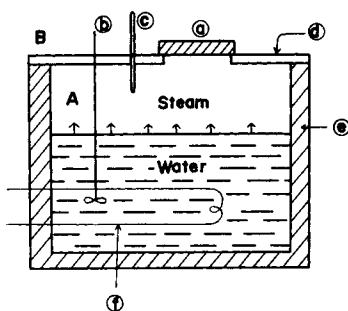


Fig. 1. Apparatus for measurement of antifogging properties: A, inner room; B, outer room; a, sample; b, stirrer; c, thermometer and hygrometer; d, upper lid; f, heater and regulator.

## RESULTS AND DISCUSSION

### Screening of Hydrophilic Compositions for Antifogging Coating

A number of screening tests was carried out to find the antifogging composition having good mar-resistant properties at the same time. Hitherto known antifogging coatings such as hydrogel-type polymer coating have not been satisfactory in mar resistance, and this is the greatest reason why no antifogging coating has been applied successfully for practical use. Some results of the screening tests are summarized in Table I.

In the previous study, the authors found excellent mar-resistant coating compositions by combination of certain silicone and vinyl compounds. In this case, various kinds of silicone and vinyl compounds were then searched for antifogging composition as well as their combinations. Alkoxysilane compounds and hydrophilic vinyl compounds were investigated mainly. However, it was often difficult to make directly a homogeneous mixture of alkoxysilane and vinyl polymers due to their poor compatibility. It was found that hydrolysis products of alkoxysilanes were generally hydrophilic and compatible with hydrophilic vinyl compounds.

The best silicone component was found to be a hydrolysis product of an aminoalkylalkoxysilane such as KBM 603 and KBM 602, in combination with hydrophilic vinyl polymer. Hydrolysis products of alkylsilicates (tetraalkoxysilane) gave excellent mar resistance but rather poor antifogging property in combination with HEMA. As an exception, glycidol showed sufficient antifogging as well as considerable mar resistance in spite of the absence of a silicon component.

Finally, a binary composition system of KBM 603 and HEMA was chosen as the best combination for further investigation in detail.

### Preparation Conditions of Antifogging Coating Composite

The mixture of hydrolyzed KBM 603 and HEMA was irradiated because the viscosity of the original mixture is too small to make a coated membrane of sufficient thickness. As previously studied,<sup>1</sup> it is preferable to use a radiation polymerization method to give the original mixture for mar resistance the suitable viscosity for coating.

Radiation polymerization is also preferable for the preparation of antifogging coating composites having suitable viscosity. The reason is as follows. These

TABLE I  
Screening Result for Antifogging Coating Composition<sup>a</sup>

Run No.	Monomer composition	Catalyst	Curing condition	Anti-fogging	Coating properties		
					Pencil hard.	Mar resistance or surface hardness	H-value, %
1	KBC1003	0.5% PBO	130°C 2 hr	small	6H	18.1	
2	KBE1003	0.5% BPO	130°C 2 hr	small	7H	17.4	
3	KBM303	0.5% HClO <sub>4</sub>	100°C 1 hr	small	8H	14.0	
4	KBM602		140°C 2 hr	rather good	5H	19.9	
5	KBM603		140°C 2 hr	large	5H	18.1	
6	KBM503	0.5% BPO	130°C 2 hr	small	6H	17.6	
7	Si(OEt) <sub>4</sub> -HEMA (90-10)	0.5% BPO	130°C 2 hr	small	6H	14.1	
8	Si(OEt) <sub>4</sub> -HEMA (80-20)	0.5% BPO	130°C 2 hr	small	6H	12.5	
9	Si(OEt) <sub>4</sub> -HEMA (70-30)	0.5% BPO	130°C 2 hr	small	5H	12.3	
10	KBC1003-HEMA (80-20)	0.5% BPO	130°C 2 hr	small	7H	22.4	
11	KBE1003-HEMA (80-20)	0.5% BPO	130°C 2 hr	small	6H	21.8	
12	KBM303-HEMA (80-20)	0.5% HClO <sub>4</sub>	130°C 2 hr	small	8H	17.1	
13	Si(OEt) <sub>4</sub> -HEMA (60-40)	0.5% HClO <sub>4</sub>	130°C 2 hr	small	5H	14.1	
14	KBM603-A9G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	rather good	6H	27.9	
15	KBM603-N3G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	6H	26.4	
16	KBM603-N4G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	5H	27.1	
17	KBM603-H1G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	6H	24.9	

18	KBM603-H2G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	5H	23.8
19	KBM603-H4G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	small	7H	12.4
20	KBM603-M2G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	2H	34.2
21	KBM603-M3G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	B	44.3
22	KBM603-M4G (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	2B	41.2
23	KBM602-HEMA (90-10)	0.5% cobalt naphthenate	100°C 8 hr	large	5H	25.1
24	KBM602-HEMA (80-20)	0.5% cobalt naphthenate	100°C 8 hr	large	5H	26.1
25	KBM602-HEMA (70-30)	0.5% cobalt naphthenate	100°C 8 hr	large	5H	26.9
26	KBM603-HEMA (90-10)	0.5% BPO	130°C 2 hr	large	5H	26.3
27	KBM603-HEMA (80-20)	0.5% BPO	130°C 2 hr	large	5H	27.1
28	KBM603-HEMA (70-30)	0.5% BPO	130°C 2 hr	large	5H	26.9
29	Glycidol-HEMA (70-30)	0.05% HClO <sub>4</sub>	120°C 2 hr	large	4H	32.3
30	Glycidol-HEMA (50-50)	0.05% HClO <sub>4</sub>	120°C 2 hr	large	5H	27.9
31	Glycidol-HEMA (30-70)	0.05% HClO <sub>4</sub>	120°C 2 hr	large	5H	27.8

<sup>a</sup> KBC1003 = vinyltris ( $\beta$ -methoxyethoxysilane); KBE1003 = vinyltriethoxysilane; KBM303 =  $\beta$ (3,4-epoxycyclohexyl)ethyltrimethoxysilane; KBM503 =  $\alpha$ -methacryloxypropyltrimethoxysilane; KBM602 = N- $\beta$ (aminoethyl)- $\alpha$ -aminopropylmethyldimethoxysilane; KBM603 = N- $\beta$ (aminoethyl)- $\alpha$ -aminopropyltrimethoxysilane; HEMA = 2-hydroxyethyl methacrylate; A9G = polyethylene glycol diacrylate; N3G = hydroxypropyl methacrylate; N4G = hydroxybutyl methacrylate; H1G = ethylene glycol monomethacrylate; H2G = diethylene glycol monomethacrylate; H4G = tetraethylene glycol monomethacrylate; M2G = methoxydiethylene glycol methacrylate; M3G = methoxytriethylene glycol methacrylate; M4G = methoxytetraethylene glycol methacrylate. All silane compounds were hydrolyzed and used. Irradiation: 2 hr, dose rate of  $1 \times 10^6$  rads/hr, at room temperature.

composites include alkoxy silane or its hydrolysis product with curing catalyst such as perchloric acid. The curing catalyst has to be mixed first with the original monomeric mixture of silane compound and HEMA, as it is difficult to mix it homogeneously with prepolymerized viscous composite after prepolymerization. Therefore, heating to elevated temperatures as in catalytic polymerization easily causes a quick gelation of silicon component to form a three-dimensional structure. That is, the functional groups of silicon components in the present systems are thermally very sensitive, and formation even of microgel or gel in very small fractions would harm the homogeneity of the membrane.

On the other hand, control of viscosity in the original mixture can be carried out safely and conveniently by irradiation at relatively low temperatures such as room temperature. Effects of irradiation conditions on properties of the coated membrane are shown in Table II. According to these results, under an irradiation dose of  $1 \times 10^5$  R, the haze value of the membrane as well as the antifogging capacity are not good due to insufficient prepolymer viscosity and smaller thickness of the membrane. However, both properties were improved in the dose range of more than  $1 \times 10^6$  R, and they were hardly affected by irradiation dose and temperature in this range. Curing conditions also yield important effects on the properties of the membranes as shown in Table III.

It can be said that mar resistance increases, but the antifogging property decreased with increasing curing time and elevated curing temperature. The antifogging function might be the result of the hydrophilic property of the hydroxy group in hydrolyzed alkoxy silane and HEMA components in polymer, while the mar resistance probably might be given by the three-dimensional structure formation of polymer by the reaction of hydroxy groups to decrease them. As a result, the antifogging and the mar resistance are inconsistent factors with each other in the present coating systems, as later discussed. This might be the most difficult problem to be solved for practical usage.

### Some Physical Properties of Antifogging Coating Compositions

Some properties relating to durability of antifogging coated membranes prepared from the hydrolyzed KBM603-HEMA system are listed in Table IV. According to these results, this coated membrane showed considerable durability

TABLE II  
Effect of Irradiation Conditions on Prepolymerization<sup>a</sup>

Run No.	Irradiation		Coating properties	
	Dose, rads	Temp., °C	Antifogging	H-value, %
1	$1 \times 10^5$	25	3 sec	31.6
2	$1 \times 10^6$	25	10 sec	23.1
3	$2 \times 10^6$	25	transparent dewing	18.2
4	$1 \times 10^7$	25	transparent dewing	24.1
5	$2 \times 10^6$	-45	transparent dewing	24.6
6	$2 \times 10^6$	0	transparent dewing	23.8
7	$2 \times 10^6$	50	transparent dewing	19.2

<sup>a</sup> Composition: hydrolyzed KBM-603, 80 parts, HEMA, 20 parts; acrylic acid, 1 part; dipropargyl maleate, 0.6 part; methanol, 100 parts; cobalt naphthenate, 0.1%. Curing: 100°C, 8 hr. Antifogging test: water 45°C, inner room 43°C, outer room 16°C.

TABLE III  
Effect of Curing Time on Coating Properties<sup>a</sup>

Run No.	Curing time, hr	Coating properties		
		Anti-fogging	Steel wool scratch	H-value after sand falling, %
1	2	large	inferior to CR-39	36.5
2	4	large	inferior to CR-39	23.1
3	8	large	inferior to CR-39	15.4
4	16	rather good	comparable to CR-39	14.3
5	24	rather good	comparable to CR-39	12.3
6	48	small	superior to CR-39	12.1
7	72	small	superior to CR-39	12.3

<sup>a</sup> Composition: same as in Table II. Irradiation: 2 hr,  $1 \times 10^6$  rads/hr, room temperature. Curing: 100°C.

with sunshine exposure and reagent resistance for long times except with acid. However, lower durability for long immersion in water was found as the membrane became turbid or cloudy, and decreased mar resistance occurred perhaps because of water absorption.

Improvement of water resistance was tried by addition of acrylic acid or various polyfunctional vinyl monomers to the base composition. Some results are shown in Table V. Water resistance was improved to some degree by these modifications and suggested the possibility of further improvement in this way.

### Application of Antifogging Coating to Various Kinds of Base Materials

The prepolymer composition prepared by irradiation can be coated on various base materials by conventional painting methods such as dipping, spraying, and brushing. Then the painted membrane can be cured by heating at about 100°C in the oven or by infrared lamp. However, the adhesiveness of cured membranes on base materials depends on the kind of material. The present coating system consisting of hydrolyzed KBM603-poly-HEMA showed good adhesiveness with CR-39 resin and inorganic glass as base materials, while it showed poor adhesiveness with some bases such as poly(methyl methacrylate) and polycarbonate from which cured membrane was easily released by immersion in water.

In order to improve the adhesiveness with these base resins, undercoating by some other composition was investigated. Compositions for undercoating were searched for among components having sufficient adhesiveness between both base resin and antifogging coating composite.

The results are shown in Table VI. It is concluded that the antifogging coating can be applied to any kind of base material without destroying its physical properties by selecting and using suitable compositions for undercoating on base material and then double coating the antifogging composition on it.

TABLE IV  
Properties of Antifogging Coating

Coating properties	Blank (no test) sample	After sunshine exposure	After immersing in reagents for one week					After water absorption for week
			Acetone	Benzene	Ethanol	Engine oil	10% HCl aq. soln.	
Appearance	—	no change	no change	no change	no change	no change	no change	no change
Antifogging	transparent dewing	transparent dewing	transparent dewing	transparent dewing	transparent dewing	transparent dewing	transparent dewing	transparent dewing
Adhesiveness	100/100	100/100	100/100	100/100	100/100	100/100	60/100	100/100
H-value, %	18.2, 17.4	19.3	20.4	20.1	21.3	19.9	28.3	20.4



TABLE V  
Effect of Polyfunctional Monomer Addition

Run No.	Polyfunctional monomer		Coating properties					
			Before water absorption			After water absorption		
			Quantity, g	Anti-fogging	H-value, %	Anti-fogging	H-value, %	H-value, %
1	Dipropargyl maleate	0.25	transparent dewing	14.9	transparent dewing	19.3		
2	Dipropargyl maleate	0.75	transparent dewing	14.3	transparent dewing	20.3		
3	Trimethylolpropane triacrylate	0.10	transparent dewing	20.4	transparent dewing	25.4		
4	Diethyleneglycol dimethacrylate	0.25	transparent dewing	21.4	transparent dewing	31.4		
5	Diethyleneglycol diacrylate	0.25	transparent dewing	18.1	transparent dewing	20.7		
6	Triethylene glycol dimethacrylate	0.25	transparent dewing	20.4	transparent dewing	30.0		
7	Tetraethylene glycol dimethacrylate	0.25	transparent dewing	20.6	transparent dewing	30.6		
8	Polyethylene glycol dimethacrylate	0.25	transparent dewing	21.3	transparent dewing	27.1		
9	Triacryl formal	0.20	transparent dewing	14.2	transparent dewing	18.9		
10	Methylenebisacrylamide	0.10	transparent dewing	25.3	transparent dewing	29.9		
11	Triallyl trimillitate	0.30	transparent dewing	17.4	turbid	24.1		
12	Triallyl isocyanurate	0.30	transparent dewing	23.9	separating from base resin	—		
13	Diallyl phthalate	0.25	transparent dewing	27.6	transparent dewing	28.0		
14	Dipropargyl phthalate	0.25	transparent dewing	18.9	transparent dewing	22.4		

TABLE VI  
Effect of Precoating Agents on Adhesiveness

Run No.	Precoating agent or other surface treatment	Adhesiveness of precoat on base resin	Final coating properties	
			Adhesiveness	Antifogging
1	Cellulose nitrate-acetone-ethanol (1 g-100 ml-100 ml)	100/100	97/100	large
2	Poly(vinyl alcohol)-H <sub>2</sub> O-glycerol (0.5 g-30 ml-70 ml)	100/100	95/100	large
3	Cellulose acetate- <i>p</i> -dioxane (0.1 g-20 ml)	100/100	100/100	large
4	Poly(vinyl acetate) 50% prepolymer- <i>p</i> -dioxane (0.1 g-20 ml)	100/100	100/100	large
5	Poly(methyl methacrylate) prepolymer syrup	100/100	0/100	large
6	APTH	100/100	100/100	large
7	Glow discharge in Tesler coil	—	80/100	large
8	Treatment by chrom acid	—	60/100	large
9	Cellulose nitrate-acetone-ethanol (0.5 g-25 ml-75 ml)	100/100	10/100	large
10	Poly(vinyl acetate) 50% prepolymer-benzene (2 ml-90 ml)	100/100	90/100	large
11	Cellulose acetate- <i>p</i> -dioxane (0.1 g-100 ml)	100/100	40/100	large
12	Poly(vinyl alcohol)-H <sub>2</sub> O-glycerol (0.5 g-50 ml-50 ml)	100/100	70/100	large
13	Allil-H <sub>2</sub> O-ethanol (20 parts-100 parts-50 parts)	100/100	100/100	large
14	KBM603-H <sub>2</sub> O (50 ml-200 ml)	100/100	60/100	large
15	KBM403-H <sub>2</sub> O-ethanol (20 ml-100 ml-50 ml)	became opaque	—	—
16	KBM303-H <sub>2</sub> O-ethanol (20 ml-100 ml-50 ml)	100/100	10/100	large
17	KBM603-epichlorhydrin-H <sub>2</sub> O-ethanol (10 ml-1 ml-1 ml-150 ml)	100/100	100/100	large
18	Poly(methyl methacrylate) prepolymer	became opaque	—	—

APTH = hydrolyzed 3-aminopropyltriethoxysilane, Allil = N,N-bis( $\beta$ -hydroxyethyl)  $\gamma$ -aminopropyltriethoxysilane.

### Aspect for a Balanced Composition Between Mar Resistance and Antifogging

It seemed that two important factors, the antifogging property and the mar resistance, are inconsistent with each other. That is, the greater the antifogging property, the smaller is the mar resistance. This inconsistency may be characteristic of hydrophilic coating compositions including functional silicon components. Generally, use of functional silicons such as alkoxysilane or its hydrolyzed derivatives is essentially important to give sufficient mar resistance necessary for practical use.

However, in the case of its application to antifogging coating, the hydrophilic functional group of silane component, such as a hydroxy group, may be used also for the crosslinking reaction to improve mar resistance, converting it to a hydrophobic crosslinked structure. As a result, the antifogging property and compatibility with hydrophilic vinyl polymer decrease. That both antifogging and mar-resistant properties probably depend on the same functional group of the silane molecule is a difficult problem. Consequently, it seems that various balances of the two properties are obtainable according to various degrees of conversion of hydrophilic groups into hydrophobic structures. If we plot the relative dimensions of these two factors on the vertical axis against compositions of various coating systems consisting of functional silane components and hydrophilic vinyl components, various crossing curves for both factors can be obtainable.

Some examples are shown in Figure 2 and 3. In these figures, certain hydrophilic vinyl monomer systems are combined with various silane components having excellent mar resistance. According to the results of Figure 2(a) and 2(b), the antifogging property of the hydrophilic vinyl component decreases very rapidly with addition of an excellent mar-resistant silane component. This fact

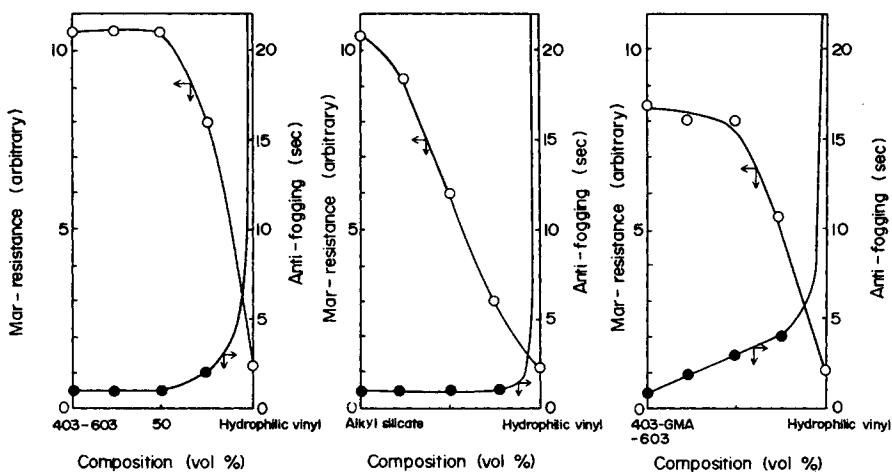


Fig. 2. Relative relationship between mar resistance and antifogging properties of coatings and composition of silicon and vinyl compounds: (a) KBM403-KBM603 (50-50 vol. %) and hydrophilic vinyl compounds system; (b) hydrolyzed alkyl silicate and hydrophilic vinyl compound systems; (c) KBM403-glycidyl methacrylate-KBM603 (45-5-50 vol. %) and hydrophilic vinyl compound system; hydrophilic vinyl compounds = HEMA-HEA-NVP-AAC (23-23-44-10 vol.%) (HEA = hydroxyethyl acrylate, NVP = N-vinylpyrrolidone, AAC = acrylic acid).

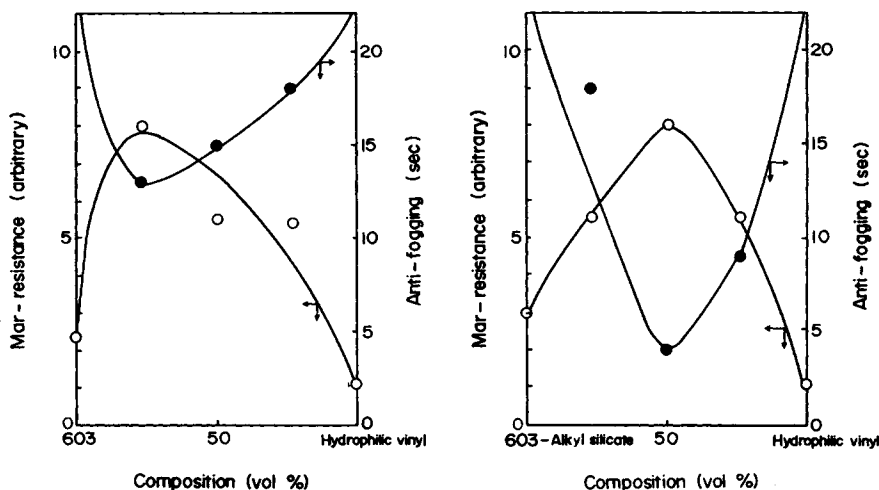


Fig. 3. Relationship between mar resistance and antifogging properties of coatings and composition of silicon and vinyl components: (a) hydrolyzed KBM603 and hydrophylic vinyl compound system; (b) hydrolyzed KBM603-alkyl silicate (90-10 vol. %) and hydrophylic vinyl compound system; hydrophylic compound same as in Fig. 2.

can probably be attributed to poor compatibility of the two components. As a result, we must have relatively poor mar resistance in order to keep relatively good antifogging properties.

A similar tendency is observed in milder form also in Figure 2(c), in which a decrease in the antifogging property with addition of silane component is a little slower than in Figures 2(a) and 2(b). On the other hand, coating systems including a hydrolyzed aminoalkylalkoxysilane such as KBM 603 showed quite different curves relating the two factors as shown in Figure 3(a) and 3(b). In this case, the silane component has mar resistance of moderate extent and better compatibility with the hydrophilic vinyl component in comparison with silanes in Figure 2. According to the results of Figure 3, the antifogging property increases again in silane-rich compositions giving a minimum, while mar resistance decreases in silane-rich compositions after increasing, giving a maximum. The compositions of the minimum and maximum are comparable.

The reason might be that in these systems silane components have large hydrophilic properties in themselves owing to the combination of amino groups with hydroxy groups. Moreover, this silane has good compatibility with the vinyl component owing to the mutual hydrophilic properties. As a result, the antifogging property of the vinyl component does not decrease so quickly upon addition of silane component, and it increases again in silane-rich compositions. This is perhaps why the best balance between the two factors is obtained in a relatively middle composition range of the two components in which values of the two properties are maintained at relatively high levels.

Certainly, hydrophilic silane compounds give relatively better balances, but their mar resistance is not completely satisfactory. The balance can be varied by promoting and finishing the cure of the silane structure. However, as already mentioned, the antifogging property decreases with increasing mar resistance. The inconsistency has not been solved yet. Perhaps the most desirable system may be a combination silane with excellent mar resistance and hydrophilic vinyl

polymer with good compatibility. Any means to improve this compatibility, for example, by more homogeneous copolymerization or copolycondensation between different components, may be important for further progress in the processing of coatings.

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