Polyaniline Conductive Paints using Polystyrene, Polyester and Polyurethane Resin made from Facile Blending Method

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Abstract

Conductive paints of polyaniline (PANI)/dodecyl benzene sulfonic acid (DBSA) composited with polystyrene (PS), polyester (PET) and polyurethane (PU) resin were prepared through a facile blending method. The extraction of PANI/DBSA from the aqueous reaction mixture was done by using a mixture of toluene and methyl ethyl ketone (MEK) (toluene : MEK = 1 : 1 v/v). Then, the electrical, thermal stability and tensile properties of the prepared conductive PANI/DBSA composite films were evaluated. Almost all of the PANI/DBSA-PS, -PET and -PU composite films were found to possess relatively good conductivity and low surface resistivity for an electrostatic discharge (ESD) even at low PANI/DBSA content. Even when the PANI/DBSA content in the PANI/DBSA-PS and -PET composite was 2.5 wt %, the electrical conductivity and surface resistivity were found to be $3.92 \times 10^{-4} \text{ Scm}^{-1}$, $8.51 \times 10^6 \text{ } \Omega\text{cm}^{-2}$ and $4.62 \times 10^{-2} \text{ Scm}^{-1}$, $7.22 \times 10^4 \text{ } \Omega\text{cm}^{-2}$, respectively. Additionally these composite films exhibited good transparency. The highest conductivity ($3.28 \times 10^{-1} \text{ Scm}^{-1}$) of the composite films was obtained when the PANI/DBSA content in PANI/DBSA-PS composite was 25 wt %. PANI/DBSA-PS composite film possessed the best thermal stability and the PANI/DBSA-PU composite films showed the lowest thermal stability of all evaluated samples. On the other hand, PANI/DBSA-PET composite films possessed the most elasticity when the PANI/DBSA contents were 10 and 20 wt %. However, PANI/DBSA-PU composite film possessed the most elasticity when the content was 5 wt %. PANI/DBSA-PS composite films possessed the lowest elasticity.

Key-words : Polyaniline, Conductive polymers, Composites, Dodecylbenzenesulfonic acid, Organic solvent, Extraction, Polystyrene, Polyester, Polyurethane, Thermal stability, Tensile property

1. Introduction

Polyaniline (PANI) is one of the most fascinating conductive polymers, and is studied for practical applications all over the world. PANI has shown a vast potential in many applications due to its comparatively high conductivity upon doping by protonation, good

environmental stability and ease of synthesis.¹⁻⁴⁾ The dispersibility of PANI in common solvents, including toluene and methyl ethyl ketone (MEK), has restricted its applications, but this problem has been improved by the use of functionalized protonic acid, such as dodecyl benzenesulfonic acid (DBSA) or camphor sulfonic acid as dopant,⁵⁻⁷⁾ and by the introduction of some substituent groups such as alkyl groups and sulfonic acid groups onto the backbone of PANI.⁸⁻¹²⁾ Furthermore, Kuramoto and co-workers reported that PANI synthesized in aqueous or organic system by one-step chemical oxidative polymerization in the presence of anionic surfactant such as DBSA could be easily achieved. These PANI/DBSA have showed good dispersibility and processability.¹³⁻¹⁹⁾

We reported earlier the preparation of conductive

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paint made with PANI/DBSA and poly (methyl methacrylate) (PMMA) through facile blending method.²⁰⁾ In that report, we employed the method reported by Kuramoto and co-workers,¹⁴⁻¹⁹⁾ for the *direct and easy* extraction of PANI/DBSA by adding an organic solvent into the synthesis mixture. The extracted PANI/DBSA showed excellent processibility in a mixture of co-solvent (toluene : MEK = 1 : 1 v/v). In particular, we found that PANI/DBSA blended into the conductive paint was efficiently dispersed and the conductive films coated on glass slides possessed relatively good conductivity, high enough for the utilization as electrostatic discharge (ESD) material, and exhibited good transparency.

In this paper, we synthesized PANI/DBSA through a simple extraction of the aqueous reaction mixture with a co-solvent of toluene and MEK (toluene : MEK = 1 : 1 v/v). Then, we prepared PANI/DBSA conductive paints through facile blending method with polystyrene (PS), polyester (PET) and polyurethane (PU) resin. We investigated the conductivity, thermal stability and the electrical resistance in tensile test of the resulting PANI/DBSA conductive paint coated on glass slides or amorphous polyester (APET) sheet.

2. Experimental section

2.1 Chemicals

Aniline sulfate and PS (DP 2000) resin were purchased from Wako Pure Chemical Industries, Ltd. DBSA and ammonium persulfate (APS) were obtained from Tokyo Kasei Kogyo Co. Ltd. and Mitsubishi Gas Chemical Co. Inc., respectively. PET resin (elitel UE 9200 : Mw 15000) and PU resin solution (NIPPOLLAN 5199 : liquid polycarbonate-diol type, PU resin 30 wt %) were obtained from UNITIKA Ltd. and Nippon Polyurethane Industry Co., Ltd., respectively. All reagents were of analytical grade and were used as received. Ion-exchanged water was used. Toluene, MEK, methanol and acetone were also used without purification.

2.2 Synthesis of PANI/DBSA in aqueous system

The polymerization was carried out by the chemical oxidation of aniline sulfate in the presence of DBSA. Aniline sulfate (15 mmol) was completely dissolved in ion-exchanged water (300 mL). DBSA (30 mmol) was added into the aniline sulfate solution and stirred vigorously at 0 ~ 5 °C. Into the resulting mixture, 50 mL of aqueous solution including APS (37.5 mmol) was slowly added. After completion of the addition of APS aqueous solution, the reaction mixture was stirred at 0 ~ 5 °C for 6 h, followed by further stirring at room

temperature for 18 h. Consequently, a dark green PANI/DBSA dispersion in the aqueous system was obtained. Then, the resultant PANI/DBSA was directly extracted with co-solvents of toluene and MEK (toluene : MEK = 1 : 1 v/v) with a separating funnel to give the corresponding PANI/DBSA organic dispersion.

2.3 Preparation of PANI/DBSA-PS, -PET and -PU organic dispersions and the composite films

A 20 wt % solution of PS and PET resin in co-solvents (toluene : MEK = 1 : 1 v/v) and a 30 wt % solution of PU resin in co-solvents (toluene : MEK : isopropyl alcohol 15 : 45 : 10 w/w) were added into the resultant PANI/DBSA organic dispersion (see above) in a mortar, where the PANI/DBSA content in PANI/DBSA-PS, -PET and -PU composite were 25, 20, 15, 10, 7.5, 5 and 2.5 wt %, and mixed until the mixture became uniform. Then, the mixtures of PANI/DBSA-resins blends in organic dispersion were completely dried with hot air while stirring the mixture with a pestle in order to remove the co-solvents contained in the mixtures, and dried under reduced pressure for 24 h. Subsequently, the desired PANI/DBSA-PS, -PET and -PU composites were obtained (denoted as C-PSx, C-PETx and C-PUx, where x = PANI/DBSA content). In order to investigate the conductivity, the surface resistivity and the volume resistivity, composite films of PANI/DBSA-PS, -PET and -PU were prepared as follows. A 10 ~ 15 wt % uniform dispersion of the PANI/DBSA-PS and -PET composite and a 5 ~ 10 wt % uniform dispersion of PANI/DBSA-PU composite were prepared by dispersing into a co-solvent (toluene : MEK = 1 : 1 v/v) (denoted as P-PSx, etc.). The obtained dispersions were used to cast films of PANI/DBSA-PS, -PET and -PU composites on

Fig. 1 Representative PANI/DBSA-PS, -PET and -PU composite films, F-PS5, F-PET5 and F-PU5. (巻頭カラー写真参照)

a glass slide (denoted as F-PSx, etc.). Fig. 1 shows the representative PANI/DBSA-PS, -PET and -PU composite films (F-PS5, F-PET5 and F-PU5).

2.4 Evaluation of electrical resistance in tensile test on PANI/DBSA-PS, -PET and -PU composite films

The organic dispersion of PANI/DBSA-PS, -PET and -PU prepared by above method was coated on APET sheet (500 μm thickness). Then, the shape for tensile test, which was coated with the dispersions, (denoted as S-PSx, etc.) was prepared as Fig. 2. The method of tensile test using the samples meets the ISO527-3 standard. The machine RTC-1310 (ORIENTEC Co., Ltd.) was used for tensile test, and the tensile speed of samples was 100 mm/min. The extending percentage of measurement site (10 mm before tensile test) on the center of the shape was about 500 %. The change in electrical resistance of the measurement site before and after tensile test was measured.

2.5 Measurements

UV/vis/NIR measurement was carried out with a JASCO V-570. The conductivity, surface resistivity and volume resistivity were measured with a Loresta-GP (Mitsubishi Chemical Corporation) using the standard *four-probe* method (with error of $\pm 1.0\%$). The

Fig. 2 The shape used for tensile evaluation of the change in electrical resistance.

change in electrical resistance of the measurement site before and after tensile test was measured by using Digital Multimeter 7537 02 (Yokogawa Electric Corp.). TGA thermograms of the selected samples were recorded with a Shimadzu Simultaneous DTG-TG model DTG-50 operated at a heating rate of 10 $^{\circ}\text{C}/\text{min}$ from room temperature to 600 $^{\circ}\text{C}$.

3. Results and discussion

3.1 PANI/DBSA synthesis

The polymerizations of aniline sulfate were carried out in aqueous systems in the presence of APS, in which DBSA was used as dopant. After addition of APS solution into the resultant mixture, the white suspension of the reaction mixture gradually turned to dark green. The formation of PANI/DBSA was confirmed by UV/vis/NIR spectroscopy.

3.2 UV/vis/NIR spectra of PANI/DBSA

UV/vis/NIR spectra of PANI/DBSA synthesis dispersion and the organic dispersion were observed in order to confirm whether the state of the PANI/DBSA changed before and after the extraction. Fig. 3 shows UV/vis/NIR spectra of PANI/DBSA synthesis dispersion (before extraction) and the organic dispersion (after extraction). The spectrum of PANI/DBSA synthesis dispersion indicated a shoulder-like bipolaron absorption around 400 nm and a strong absorption of polaron band over 700 nm. The spectrum showed an absorption around 350 nm corresponding to the $\pi\text{-}\pi^*$ transition of the benzenoid ring. Therefore, the spectrum had the typical absorptions of an emeraldine salt with three absorptions around 350, 400 and 700 nm. Concurrently, the spectrum of PANI/DBSA organic dispersion also indicated a typical emeraldine salt. This showed that the PANI/DBSA extracted into the organic co-solvent was in almost the same state as the PANI/DBSA existing

Fig. 3 UV/vis/NIR spectra of PANI/DBSA synthesis dispersion (before extraction) and PANI/DBSA organic dispersion (after extraction).

Fig. 4 (1) TGA thermograms of PANI/DBSA-PS film (F-PS10) and PS resin.

Fig. 4 (2) TGA thermograms of PANI/DBSA-PET film (F-PET10) and PET resin.

Fig. 4 (3) TGA thermograms of PANI/DBSA-PU film (F-PU10) and PU resin.

in the synthesis dispersion.

3.3 Thermal analyses of PANI/DBSA-PS, -PET and -PU composite films

Thermal analyses were performed to investigate the thermal stability of PANI/DBSA-PS, -PET and -PU composite films. Figs. 4 (1) to (3) show TGA thermograms of selected composite films (F-PS10, -PET10 and -PU10) as compared to the films of their respective resin. Fig. 4 (1) indicated that the PANI/DBSA-PS

composite film (F-PS10) possessed superior thermal stability than PS alone, possibly because of the stability-inducing interaction between the backbone of PS and PANI/DBSA in the film matrix. However, the PANI/DBSA-PET film (F-PET10) and -PU film (F-PU10) showed inferior thermal stability than their respective resins alone, (Figs. 4 (2) and (3)). As summary, F-PS10 possessed the best thermal stability, and F-PU10 had the lowest thermal stability of all the

Table 1 Electrical properties of PANI/DBSA-PS composite films.

Run	Film	PANI/DBSA content (wt%)	Conductivity (Scm^{-1})	SR ^a (Ωcm^{-2})	Volume resistivity (Ωcm)
1	F-PS25	25	3.28×10^{-1}	1.02×10^4	3.05×10^0
2	F-PS20	20	1.18×10^{-1}	2.82×10^4	8.47×10^0
3	F-PS15	15	1.31×10^{-1}	3.81×10^4	7.61×10^0
4	F-PS10	10	5.42×10^{-2}	6.15×10^4	1.85×10^1
5	F-PS7.5	7.5	4.24×10^{-2}	1.18×10^5	2.36×10^1
6	F-PS5	5	4.04×10^{-2}	1.24×10^5	2.48×10^1
7	F-PS2.5	2.5	3.92×10^{-4}	8.51×10^6	2.55×10^3

^a SR means surface resistivity.

Table 2 Electrical properties of PANI/DBSA-PET composite films.

Run	Film	PANI/DBSA content (wt%)	Conductivity (Scm^{-1})	SR ^a (Ωcm^{-2})	Volume resistivity (Ωcm)
1	F-PET25	25	2.20×10^{-1}	1.52×10^4	4.56×10^0
2	F-PET20	20	1.26×10^{-1}	3.96×10^4	7.91×10^0
3	F-PET15	15	1.09×10^{-1}	2.29×10^4	9.14×10^0
4	F-PET10	10	1.51×10^{-1}	3.30×10^4	6.61×10^0
5	F-PET7.5	7.5	7.09×10^{-2}	4.70×10^4	1.41×10^1
6	F-PET5	5	6.99×10^{-2}	7.16×10^4	1.43×10^1
7	F-PET2.5	2.5	4.62×10^{-2}	7.22×10^4	2.17×10^1

^a SR means surface resistivity.

Table 3 Electrical properties of PANI/DBSA-PU composite films.

Run	Film	PANI/DBSA content (wt%)	Conductivity (Scm^{-1})	SR ^a (Ωcm^{-2})	Volume resistivity (Ωcm)
1	F-PU25	25	1.53×10^{-3}	3.28×10^6	6.55×10^2
2	F-PU20	20	1.51×10^{-2}	3.32×10^5	6.64×10^1
3	F-PU15	15	3.07×10^{-2}	1.63×10^5	3.26×10^1
4	F-PU10	10	1.52×10^{-2}	3.29×10^5	6.58×10^1
5	F-PU7.5	7.5	7.70×10^{-3}	1.30×10^6	1.30×10^2
6	F-PU5	5	4.50×10^{-3}	1.11×10^6	2.22×10^2
7	F-PU2.5	2.5	Over measurement range		

^a SR means surface resistivity.

investigated composite films.

3.4 Electrical properties of PANI/DBSA-PET, -PS and -PU composite films

Table 1 shows the conductivity, surface resistivity and volume resistivity of F-PS25 to F-PS2.5. The conductivity of the films gradually decreased, as the PANI/DBSA content in PANI/DBSA-PS decreased. However, the conductivity of F-PS2.5 was much decreased compared to the other films.

Table 2 shows the conductivity, surface resistivity and volume resistivity of F-PET25 to F-PET2.5. The conductivity of the films gradually decreased, as the PANI/DBSA content in PANI/DBSA-PET decreased.

Table 3 shows the conductivity, surface resistivity and volume resistivity of F-PU25 to F-PU2.5. Compared to the PANI/DBSA-PS and -PET composite films, the conductivity behavior of the PANI/DBSA-PU composite films was different. The conductivity of

PANI/DBSA-PU composite films F-PU25 to F-PU15 increased as the PANI/DBSA content decreased, and further decrease of the % loading of PANI/DBSA in F-PU15 to F-PU5 exhibited a slight drop in conductivity.

Fig. 5 shows the graph between the conductivity of PANI/DBSA-resin composite films and PANI/DBSA content in the composite films. The conductivity of PANI/DBSA-PS and -PET composite films gradually increased as the PANI/DBSA content in the films increased. However, the conductivity of PANI/DBSA-PU composite films increased as the PANI/DBSA content in the films increased from 5 to 15 wt%, and the conductivity of the films decreased as the PANI/DBSA content increased from 15 to 25 wt%.

Fig. 6 shows the optical micrographs of F-PU25, F-PU15 and F-PU5. A lot of aggregation of PANI/DBSA was observed in F-PU25 (Fig. 6 (a)). However, little aggregation of PANI/DBSA was observed in F-PU15

Fig. 5 The conductivity of PANI/DBSA-resin composite films.

Fig. 6 The optical micrographs of F-PU25 (a), F-PU15 (b) and F-PU5 (c). (巻頭カラー写真参照)

(Fig. 6 (b)), and there is very little aggregation of PANI/DBSA in F-PU5 (Fig. 6 (c)). The reason why the conductivity behavior of the PANI/DBSA-PU composite films showed inconsistency is that the PANI/DBSA content greatly surpasses the miscibility threshold of PU resin in F-PU25, in which PANI/DBSA can not be efficiently dispersed and the dispersibility of PANI/DBSA was gradually improved to a certain degree (between F-PU25 and F-PU15), as the PANI/DBSA content gradually decreased. Below that level PANI/DBSA is well-dispersed in PU resin and the conductivity of the PANI/DBSA-PU composite films gradually decreased as the PANI/DBSA content of the films decreased. In the case of F-PU2.5, the conductivity rapidly decreased to below the measurable range (below $10^{-4} \text{ S cm}^{-1}$). For this reason, it was considered that the percolation threshold of electrical property was between F-PU5 and F-PU2.5.

Based on the conductivity and volume resistivity

Fig. 7 The states of PANI/DBSA in PS, PET and PU resin matrix.

results of all the PANI/DBSA-resin composite films, PANI/DBSA showed better compatibility and miscibility with PS and PET resins as compared to PU resin. Especially, in PET resin, the conductivity was relatively good ($4.62 \times 10^{-2} \text{ S cm}^{-1}$) even when the PANI/DBSA content in the PANI/DBSA-PET composite was as low as 2.5 wt %. Therefore, we deduced that the charge mobility mechanism within the matrixes of these composites is as follows : free charges delocalize by the intra- and inter-hopping between conductive islands and also inter-connected pathway of PANI/DBSA within the matrix of PANI/DBSA-PS and PET composites. When the PANI/DBSA content is high, the hopping process progresses with ease as plenty of conductive islands and inter-connected pathways exist in the composite matrix. As the PANI/DBSA content was reduced drastically (as in F-PS2.5), significant increase of volume resistivity was observed, most probably due to loss of inter-connected pathway and increase of distance between conductive islands that disrupt the conduction of free charges.

On the other hand, the results also show that the compatibility between PANI/DBSA and PU resin was very poor compared to that of PS and PET resin. Furthermore, when excess of PANI/DBSA is present in the PU resin matrix, PANI/DBSA exhibited a tendency to form serious aggregations and particles. As a result, the PANI/DBSA aggregates did not disperse evenly in the PU resin matrix and thus inhibited the conduction of free charges. The intra- and inter-hopping of charges between conductive island of PANI/DBSA within the matrix of PANI/DBSA-PU composites was retarded (Fig. 7).

We reported PANI/DBSA conductive paint using PMMA resin prepared through this facile way, and that these paints could be utilized for the application of

Fig. 8 The sample before and after tensile test (S-PU10). (巻頭カラー写真参照)

Table 4 The change of electrical resistance value before and after tensile test.

Samples	Electrical resistance value (Ω)		R^a/R^b	Tensile ratio (%)
	R^b	R^a		
S-PS20	3.75×10^4	2.07×10^6	55.2	500
S-PS10	7.44×10^4	1.32×10^7	1770	490
S-PS5	2.92×10^5	Over measurement range		500
S-PET20	2.77×10^4	9.27×10^4	3.35	490
S-PET10	6.10×10^4	1.90×10^5	3.11	480
S-PET5	6.64×10^4	5.98×10^5	9.01	500
S-PU20	4.60×10^5	3.46×10^6	7.52	500
S-PU10	4.20×10^5	3.05×10^6	7.26	490
S-PU5	2.09×10^6	7.42×10^6	3.55	490

R^b means electrical resistance value before tensile test.

R^a means electrical resistance value after tensile test.

ESD.²⁰⁾ Tables 1 to 3 also show the surface resistivity of the PANI/DBSA-PS, -PET and -PU composite films. Based on the above results, almost all of the films showed suitable surface resistivity for the application of these composites as ESD material between 10^4 to $10^{10} \Omega\text{cm}^{-2}$. Therefore, the PANI/DBSA organic dispersions containing PS, PET and PU reported in this paper can also be utilized for the application of ESD. It is expected that this facile method of obtaining PANI/DBSA conductive paint, through simple blending, could be extended to other types of polymer resins.

3.5 Tensile property of PANI/DBSA-PS, -PET and -PU composite films

The organic dispersions of PANI/DBSA-PS, -PET and -PU prepared by above method were coated on APET sheet (500 μm thickness) and cut out shape as shown in Fig. 2 in order to evaluate the change in electrical resistance of the composite films before and after tensile test. The desired samples coated from dispersion of P-PS20 were denoted as S-PS20 and so on. Fig. 8 shows

the shape of S-PU10 before and after tensile test.

The samples for the tensile test were extended to about 500 % at the measurement site. The changes in electrical resistance before and after tensile test are as shown in Table 4.

The ratio of electrical resistance after tensile test (R^a) against electrical resistance before tensile test (R^b) is an indication of the elasticity of the composite films. The ratio of R^a/R^b in the PANI/DBSA-PS composites was very high and rapidly increased as the PANI/DBSA content decreased. The ratio of R^a/R^b in the PANI/DBSA-PET composites gradually increased as the PANI/DBSA content decreased, whereas that in the PANI/DBSA-PU composites gradually decreased as the PANI/DBSA content decreased.

For all of the PANI/DBSA-PS composite films on the APET sheet, when the composites were delicately scrubbed by a cotton-tipped swab, the composites were easily peeled off and shattered into small pieces. But, in the case of PANI/DBSA-PET and -PU composite films, both remained intact after similar scratch tests were performed. These results showed that PANI/DBSA-PS composite films possessed the lowest elasticity after tensile test and a large amount of cracks formed. In the case of S-PS5, the conduction pathways of charges in the PANI/DBSA-PS composite film were completely disrupted after tensile test. This explains the significant increase of resistivity of PANI/DBSA-PS composite films as compared to the other composite films tested. While on the other hand, in the case of PANI/DBSA-PET and -PU, these composite films showed superior elasticity even after 500 % stretching and the absence of cracks implied that the conduction pathways of charges on these composites were not seriously disrupted, as evidence by the resistivity before and

Fig. 9 The states of PANI/DBSA-PS, -PET and -PU composite before and after tensile test.

after tensile test (Fig. 9). In terms of the ratio of electrical resistance after tensile test against before tensile test, the PANI/DBSA-PET composite films possess more elasticity than the PANI/DBSA-PU composite films against stretching when the PANI/DBSA content is relative high (10 and 20 wt %). However, when the PANI/DBSA content is low (5 wt %), the PANI/DBSA-PU composite films possess more elasticity than the PANI/DBSA-PET composite films.

One of the most efficient ways to add ESD property to plastic products such as APET sheet is to coat them with conductive paint. Plastic products are generally electrical insulators. The end product may need to undergo several steps such as moulding, stretching and so on. Stretching is involved in conventional industrial processes and unavoidable in manufacturing ESD material. Therefore, the elasticity of the coating film is very important. The above results show PANI/DBSA-PET and -PU composite are suitable for production involving stretching steps, but PANI/DBSA-PS composite is not suitable for that.

4. Conclusion

We successfully prepared conductive paint of PS, PET and PU containing PANI/DBSA by using a facile blending method. The PANI/DBSA organic dispersions were obtained through a simple extraction of the aqueous reaction mixture of PANI/DBSA with the co-solvent (toluene : MEK = 1 : 1 v/v). All the PANI/DBSA conductive paints except P-PU2.5 can be utilized for ESD even when the PANI/DBSA content in the composition is as low as 2.5 wt % (at PANI/DBSA content in PANI/DBSA-resin composite = 2.5 wt %). The films prepared from these conductive paints exhibited good transparency, since almost all of the PANI/DBSA component of these composite films was effectively dispersed in PS, PET and PU resin. It was considered that the present good conductivity of these

composites was obtained by the efficient dispersion of PANI/DBSA in these composites. By comparing the thermal analyses, PANI/DBSA-PS composite film possesses the best thermal stability while the PANI/DBSA-PU composite film possesses the lowest thermal stability. The PANI/DBSA-PET composite films showed better electrical properties compared to PANI/DBSA-PS and -PU composite films. On the tensile property of the electrical resistance, PANI/DBSA-PET composite films possessed more elasticity than any other composite films when the PANI/DBSA content was relative high. However, when the content was low, PANI/DBSA-PU composite films possessed more elasticity than any other composite films. PANI/DBSA-PS composite films possessed the lowest elasticity.

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ポリスチレン、ポリエステルおよびポリウレタンを用いた簡易混合法により得られる ポリアニリン導電性塗料

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要 旨

水系のポリアニリン (PANI) / ドデシルベンゼンスルホン酸 (DBSA) 合成液から PANI/DBSA をトルエン-メチルエチルケトン混合溶剤 (1 : 1 v/v) により抽出し、ポリスチレン (PS)、ポリエステル (PET) およびポリウレタン (PU) と複合化する簡易混合により PANI/DBSA 導電性塗料を得た。われわれはこの導電性塗料による PANI/DBSA-樹脂複合体フィルムの電気特性、熱安定性、引っ張り試験について評価した。PANI/DBSA-PS、-PET および -PU 複合体フィルムは、PANI/DBSA 含有率が低い場合においても静電気放電 (ESD) にとって比較的優れた導電性、低い表面抵抗率を示し (PANI/DBSA の含有率が 2.5 wt % において PANI/DBSA-PS、-PET 複合体フィルムの導電率および表面抵抗率はそれぞれ $3.92 \times 10^{-4} \text{ Scm}^{-1}$, $8.51 \times 10^6 \text{ } \Omega\text{cm}^{-2}$ および $4.62 \times 10^{-2} \text{ Scm}^{-1}$, $7.22 \times 10^4 \text{ } \Omega\text{cm}^{-2}$)、透明性も優れていた。評価したフィルムの中では PANI/DBSA の含有率が 25 wt % の PANI/DBSA-PS 複合体フィルムが最も高い導電率を示した。複合体フィルムの熱安定性の調査においては PANI/DBSA-PS 複合体フィルムが優れた熱安定性を示し、PANI/DBSA-PU 複合体フィルムが最も劣っていた。一方、複合体フィルムの引っ張り試験での電気特性においては PANI/DBSA 含有率が 10, 20 wt % においては PANI/DBSA-PET 複合体フィルムが、5 wt % においては PANI/DBSA-PU 複合体フィルムが最も優れていた。PANI/DBSA-PS 複合体フィルムは引っ張り試験での電気特性が最も劣っていた。