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Abstract

Effect of dispersant on the dispersion stability and film formation of Ni paste in Multi-layered ceramic capacitor

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MLCC is one of the condensers used electronic devices. It stores electricity and supplies stable electricity to an electric circuit. Recently the miniaturization of electronic components is strongly required to increase the packaging density as the integration and microminiaturization of electronic devices. Therefore scores of nano particle is used in MLCC process. Ni paste including nano particle is coated to form thin film and is followed by drying process. It is not easy to disperse nano particle and severe coating defects such as crack, curl, delamination, and deformation appear after drying process. These affect fatally final products. To control these types of coating defects, it is important to understand the microstructure of
fluid as well as drying behavior because industrial coating fluid is complex fluid system containing particles, binders, additives, solvent and dispersant etc. In these components, dispersant can affect the microstructure of fluid and drying behavior even with small amount. Two types of paste showed different film uniformity after drying just changing 1wt% dispersant type. Furthermore dispersion stability and drying development showed reverse behavior. In order to analyze this phenomenon, in this study, we investigate the effect of dispersant on the dispersion stability and film formation. Four Ni paste and eight model suspensions including different dispersant types and particle types were prepared. We characterized the dispersion stability of fluid by observing sedimentation behavior and measuring rheological properties and adsorbed amount of dispersant. Furthermore drying behavior was characterized by measuring drying stress development. As a result, we understood mechanism of the phenomenon through analyzing relationship between dispersion stability, adsorption and drying stress.

**Keywords:** MLCC, paste, dispersant, dispersion stability, adsorption, drying behavior,

**Student Number:** 2010-20973
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Chapter 1 Introduction

1.1 MLCC

Recently the miniaturization of electronic components is strongly required to increase the packaging density as the integration and microminiaturization of electronic devices. Consequently, MLCC is introduced to substitute the common disk type ceramic condenser. As MLCC is one of the condensers used electronic devices, it stores electricity between metal plates filled with a dielectric substance and supplies stable electricity to an electric circuit whenever necessary.

Ni is preferred as the internal electrode material because of cost advantage and high capacitance. Larger capacitance with thinner dielectric layers is the goal of fabrication technology for MLCC. MLCC technology has been progressed under the goal of larger capacitance with thinner dielectric layers, which can be realized with finer dielectric and electrode powders [1]. MLCC comprises of inner electrode, ceramic dielectric layer and electrode. For inner electrode, Ni paste is used, which is composed of Ni particles, polymer binders, dispersant, solvent, and various additives. Paste is a system with high concentration of particles in polymer, which is required to control the dispersion stability and rheological properties [2].

MLCC is manufactured by Ni powder made of a ceramic manufacturing process. In other words, raw materials that have fixed
ratio are mixed and they calcine at constant temperature. They become paste after adding binder such as PVB or EC to help extrude and they are casted. Then inner electrodes are printed on the sheet and stacked with dielectric layers alternately. After burning out binder, electrodes cover inner electrodes to be a terminal.
Figure 1.1. MLCC structure
Figure 1.2. MLCC process
1.2 Dispersant

In coating process to provide optimal performance, particles must act each other independently in the coating film and must remain well dispersed throughout manufacture, storage, application and film formation. Unfortunately, colloidal dispersion is inherently unstable and it must be stabilized against the flocculation that might occur. Thus, dispersant is needed to prevent aggregation and improve the separation of particles [3]. Coating liquid is complex fluid containing particles, binders, additives, and dispersant. Among these components, the dispersant can affect the microstructure of fluid and drying behavior even with small amount. Dispersant is a kind of surfactant. It creates electrostatic repulsion or steric hindrance by being adsorbed on particle surface [4]. In this study, we use a kind of two types of dispersant which make steric hinderance. Dispersant can lead steric stabilization when particles covered with dispersant molecules and the tails of molecules are extended out freely moving in the medium [5]. The dispersant can be adsorbed on the particle surface via an acid–base reaction, forming the dispersant layer. [6,7]. There are three to accomplish as a dispersant. First, the effective area of the particle surface must be adequately covered by dispersant molecules [6]. Second, the portion of dispersant molecules directed outwards into the liquid phase must coordinate with that phase [8]. Third, a barrier must be created around each particle capable of preventing other particles from coming into direct contact [8].
Dispersant forms adsorption layers on the particle surface in mediums. These adsorption layers prevent particles from re-agglomeration. Furthermore these adsorption layers exhibit electro-repulsive force or steric hindrance effect. Thus it helps particle dispersion of higher particle concentration; consequently stable suspension can be obtained.

There are factors that dominate in dispersant adsorption. Adsorption is affected by shape and size of the dispersant molecule, orientation of the dispersant molecule on the particle surface and concentration of dispersant to the reach the maximum adsorption capacitor.
Figure 1.3. Schematics of dispersion mechanism by steric hindrance
1.3 Sedimentation of particles

Sedimentation of particles has long been characterized continuously [10]. Sedimentation can be either gravitational (1g-force), or centrifugal (many g-force) [11]. Stokes’ law is the most basic equation of gravitational sedimentation. Through this, sedimentation velocity defined below is obtained and it only applied when flow does not exist [12].

\[ V_s = \frac{(\rho_f - \rho_p) \times d^2 \times g}{18 \times \mu} \]

Where \( \rho_f \) denotes fluid density \( (kg/m^3) \), \( \rho_p \) particle density \( (kg/m^3) \), and \( \mu \) viscosity of medium (Pa.s).

However it is limited to particles of relatively large size, because small particles (<0.1mm) take too long time to analysis and Brownian motion of small particles are too large to allow effective settling. Small particles are extended to centrifuge sedimentation [11]. Therefore Stokes’ law must be modified in this system which includes 200nm particles, considering particle-particle interaction.

1.4 Rheological properties of coating material

Many IT industries need to use the concentrated suspension as coating liquid including nano-sized particles, polymeric binders,
dispersant, and other additives. In most cases the coating liquid is complex fluid which shows complex microstructure and flow behavior during processing, and sometimes it leads to unexpected coating defects. Therefore, it is necessary to understand flow properties of coating liquid and obtain well dispersion state of the particles to control the coating process [13]. This requires proper characterization of the dispersion state. One of the characterization methods is rheological measurement [14]. Rheological analysis is a useful tool to characterize the dispersion stability and flow behavior of coating liquid. Through the rheological properties, the microstructure of liquid is analyzed, especially dispersion state of particles in suspension that is related to properties of final product. Various functional materials are prepared depending on processing needs, but sometimes factors satisfying its functional needs could lead poor dispersion state [15].

1.4 Drying process

Understanding drying behavior is the one of the great important thing to the industry such as capacitor, display, secondary battery and so on, since most final coating products are used as solid state. Drying process is very complicated because it involves solvent evaporation, solidification of polymer, flow of solvent, particle networking and so on. Furthermore, mass and heat transfer control was considered by complex transport and thermodynamic behavior of coating liquid [16]. Thus sometimes deformation such as segregation of particle and crack appears after drying process.
Chapter 2 Experimental

2.1 Materials

2.1.1 Ni paste

Ni pastes were composed of a commercial Ni particles powder that has a mean particle diameter of 200nm, polymeric binders, each dispersant A, B, solvent and additives. Ethyl cellulose (EC) was used as a polymeric binder. Poly(vinyl butyral)(PVB) was used as another polymeric binder and organic solvent was used as a suspending medium. Ni pastes were prepared by adding about 50wt% particles, 25wt% polymeric binders, 1wt% dispersant and additives. There were four pastes. The paste A–1 and paste A–2 contained same dispersant A, but different types of Ni particles. The paste B–1 and paste B–2 contained dispersant B and they also used different types of Ni particles. In addition compositions remained same. Therefore they changed the types of dispersant and particle. The information of compositions is summarized in Table 1. To establish an equilibrium dispersion system of pastes, 3-roll mill was used.
<table>
<thead>
<tr>
<th>Paste</th>
<th>Ni particle (wt%)</th>
<th>Polymer binders (wt%)</th>
<th>Dispersant (wt%/Ni)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>46.5</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>B-1</td>
<td>46.5</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>A-2</td>
<td>46.5</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>B-2</td>
<td>46.5</td>
<td>2.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Notation and composition of Ni paste
2.1.2 Model suspension (Ni/ dispersant)

In order to find effect of dispersant, model suspensions were simply made up 50wt% Ni particles, dispersant and solvent. In this study, ratio of each dispersant in suspension was changed as 0.2wt%, 1wt%, 3wt%, 5wt% by Ni weight. The information of composition is summarized in Table 2(a). To approach an equilibrium dispersion system, suspensions were ultrasonicated for 10 minutes at 80% power (SONICS, Vibra cell).

2.1.3 Model suspension (Ni/binders/dispersant)

In order to measure the rheological properties and drying stress of suspensions, 50wt% Ni particles, each dispersant, 25wt% binders and solvent were prepared. The information of composition is summarized in Table 2(b). Viscosity of suspensions included only Ni particles and dispersant was too low to measure the rheological properties by ARES.

Suspensions including Ni particles and dispersant were ultrasonicated for 10 minutes at 80% power (SONICS, Vibra cell). After adding binders in suspensions, they were mixed by a mechanical stirrer for 3 hours. To find proper mixing time by a mechanical stirrer, rheological properties were measured after mixing for 1 hour and 3 hours. The frequency sweep tests of Ni pastes were performed from 0.1 rad/s to 100 rad/s at strain 1 wt% after delay time 600 sec. Figure 2.1 shows there are no difference between two mixing times. Therefore 1 hour was enough to mix.
<table>
<thead>
<tr>
<th>Set</th>
<th>Ni particle (wt%)</th>
<th>Dispersant type (wt%)</th>
<th>Dispersant (wt%/Ni)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>A</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>B</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>B</td>
<td>5</td>
</tr>
</tbody>
</table>

(a) Ni/dispersant system

<table>
<thead>
<tr>
<th>Set</th>
<th>Ni particle (wt%)</th>
<th>Polymer binders (wt%)</th>
<th>Dispersant type (wt%)</th>
<th>Dispersant (wt%/Ni)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>2.5</td>
<td>A</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>2.5</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
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<td>2.5</td>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>2.5</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>2.5</td>
<td>B</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>2.5</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>2.5</td>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>2.5</td>
<td>B</td>
<td>5</td>
</tr>
</tbody>
</table>

(b) Ni/binder/dispersant system

Table 2. Composition of model suspension
Figure 2.1. Frequency sweep test of model suspension to find appropriate mixing time
2.2 Characterization

2.2.1 Sedimentation

Sedimentation is the tendency for particles to sink in the suspension in which they are entrained and come to rest against a barrier. This is due to their motion through the fluid in response to the force acting on them. These forces can be caused by gravity, centrifugal acceleration or electromagnetism. [17]

Each suspension was kept in a vial to the height of 4cm and sedimentation behavior of suspensions was observed as time passed. In order to take pictures that showed sedimentation behavior, digital camera (IXUS 90IS, CANON INC, JAPAN) was used.

2.2.2. Rheometry

Rheological measurements were performed on a controlled strain type rheometer (ARES, TA Instruments) at 25°C. 50mm parallel plate geometry was used to measure the Ni paste and model suspensions and gap size was 1mm. Each sample was loaded and relaxed for 600sec prior to measurement.
2.2.3 Adsorption

The conventional solution depletion method was used to determine the adsorbed amount of dispersant on particle surface [18]. Suspensions were prepared to quantify the adsorbed amount of dispersant by increasing dispersant concentration from 0.2wt% to 5wt%. Each suspension had 50wt% of Ni particles. After dispersed by ultrasonicator for 10 minutes at 80% power (SONICS, Vibra cell), the suspensions were centrifuged for 1 hour and 30 minutes at 12000rpm (Mega 17R, Science industrial). The supernatant solutions were obtained and kept vials. In order to measure the mass of free dispersant in supernatant solutions, solvent was evaporated in a 80°C oven for 48 hours. All masses were measured before and after the evaporation.

2.2.4 Drying stress development

The beam deflection method was used to measure the stress development during drying process. This method is related to stress in a coating film adhered to a rigid substrate [19, 20]. Stress measurement is made up drying chamber, position sensing detector and optic unit [21]. During drying process, coating film shrinks in a chamber due to solvent evaporation, cross-linking and so on. The tensile stress develops in the coating layer because of the shrinkages [22]. In Fig. Then the substrate coated liquid deflects. Laser and position sensing detector are used for detect the
deflection of substrate. Following formulation which is related by deflection of a substrate to stress in an adhered coating film was derived by Corcoran [23].

\[
\sigma = \frac{dE_r^3}{3cL^2(t+c)(1-\nu)} + \frac{dE_c(t+c)}{L^2(1-\nu_c)}
\]

Where denoted \(d\) deflection, \(E\) elastic modulus, \(t\) thickness, \(L\) coating length, \(\nu\) position ratio respectively. Subscription \(s\) means substrate and \(c\) means coating film after drying.
Figure 2.2. Schematic diagram of the stress measurement apparatus
Chapter 3. Results and discussion

3.1 Ni paste

3.1.1 Sedimentation

Coating liquid is complex fluid containing particles, binders, additives, and dispersant. Among these components, the dispersant can affect the microstructure of fluid and drying behavior even with small amount. As concentration of dispersant increase, dispersion state of suspension could change. Therefore, concentration of dispersant could effect on the MLCC film formation.

Dispersion stability is the first consideration for the preparation Ni paste. In this study, sedimentation behavior was observed to investigate how dispersant can effect on the dispersion stability. As changing of dispersant types, pastes behaved differently. Fig 3.1 showed that the Ni pasteA−1 which contained dispersant A was more stable than Ni paste B−1 including dispersant B. Furthermore, Fig also showed Ni paste A−2 was more stable. It shows same tendency. The results suggest dispersant A could more affect the dispersion stability relatively than dispersant B regardless types of particles.
Figure 3.1. Sedimentation of (a) paste A-1 and paste B-1 (b) paste A-2 and paste B-2
3.1.2 Rheological properties

The frequency sweep tests of Ni pastes were performed from 1rad/s to 100rad/s at strain 1% after delay time 600sec. Fig 3.2 shows the storage modulus (G’) as a function of paste type. Pastes including dispersant A (paste A-1, paste A-2) had higher storage modulus (G’) than paste including dispersant B (paste B-1, paste B-2). It means paste A-1 is more elastic than paste B-1 and paste A-2 is also more elastic than paste B-2. At low frequency, frequency behavior such as G’ or G” reflects the microstructure of the particle dispersion in particular [2]. Thus we can recognize that pastes including dispersant A, regardless particle, had higher G’. In other words they are more stable than pastes including dispersant B irrespective of particle. These results accord closely with the result of sedimentation.
Figure 3.2. Frequency sweep test of (a) paste A-1 and (b) paste B-1
3.1.3 Drying stress

3.1.3.1 Drying stress development

The drying process can be explained balance between capillary pressure, attractive force and repulsive force of particle interaction. When the pressure exceeds the maximum repulsive pressure that can be supplied by interparticle potentials, the particles aggregates each other [24]. In high concentration of particles it is very easy to overcome repulsive force so particles are aggregate [24].

Dying stress was measured by the beam deflection method. Pastes were coated on substrate and measured the deflection during drying stress. They were dried in a at 80°C oven. In Fig, Paste B-1 with worse dispersion state showed higher drying stress than Paste A-1. It means particles in Paste B-1 were packed more densely during drying. In comparison with film uniformity after drying, coating defects more appeared in paste A-1 which had lower drying stress. According to Fig, Paste B-2 also had higher drying stress and lesser coating defects than paste A-1. Both paste B-1 and B-2 showed higher drying stress than pastes composed of dispersant A. It might be related with film uniformity after drying process. These results imply pastes composed of different dispersant types showed reverse behavior between dispersion stability in liquid and drying stress development.
Figure 3.3. Drying stress development during drying of (a) paste A-1 and (b) paste B-1
Figure 3.4. Drying stress development during drying of (a) paste A-2 and (b) paste B-2.
3.1.3.2 Effect of film thickness after drying

During experiments we realized film coating thickness might affect to final drying stress even though calibrated instrument. Thus we performed experiments with changing coating film thickness. Results were indicated Fig 3.5 according to film thickness. Final drying stress decreased as increasing film thickness regardless dispersant types. In addition, the gap between paste A and paste B was bigger at thin film thickness. In MLCC manufacturing paste is coated on substrate very thinly. Thus, this drying stress gap would indicate the effect of dispersant on film formation at thinner film thickness. It is important to control film thickness whenever drying stress data are compared. In all cases, paste B showed higher stress. It clarifies that paste B was packed d
Figure 3.5. Final drying stress data of paste A and paste B as a function of film thickness after drying process
3.2 Model suspension

3.2.1 Sedimentation

In order to see the interaction between particles and dispersant, sedimentation behavior of suspension was observed with different concentration of dispersant at each case in Fig 3.6. We changed dispersant concentration around 1wt% by Ni which concentration of dispersant is the same as paste. Particles of suspension A rarely settled down even at 0.2wt% by Ni and suspension A didn’t change dispersion stability with increasing concentration. It always became stable any concentration of dispersant. On the other hand, dispersion stability of suspension B was improved increasing concentration of dispersant appreciably. Furthermore, suspension A was more stable than suspension B at the same concentration. They showed entirely different sedimentation behavior. Suspension A was stable without sedimentation over 14days, however, particles in suspension B tent to form aggregates and settle down just in a day even at 5wt%. It means that 0.2wt% of dispersant A is strong enough to promote a good dispersion of particles, but higher concentration of dispersant B is needed to disperse particles. In other words, optimum concentration of dispersant A is lower than concentration of paste A that is 1wt%, however, optimum concentration of dispersant B is higher than concentration of paste B. For this reason, pastes showed different dispersion stability at the same concentration of dispersant.
Figure 3.6. Sedimentation of (a) suspension A and (b) suspension B with different ratio of dispersant. 0.2wt%/Ni, 1wt%/Ni, 3wt%/Ni, 5wt%/Ni
3.2.2 Rheological properties

3.2.2.1 Strain sweep test

Suspensions showed non-Newtonian behavior which exhibit both viscous and elastic properties. This viscoelastic property of the suspensions can be established between the interactions and forces such as Brownian force, hydro dynamic interaction, interparticle forces, van der Waals attraction, steric interaction and double layer repulsion. There are various factors such as particle size, surface chemistry and ingredients [25]. In this study, concentration ratio of each dispersant and types of dispersant also affected this property. In order to find linear region for frequency sweep test, strain sweep tests were performed at frequency of 1rad/s. Fig 3.7 shows the dynamic modulus as a function of concentration ratio of each dispersant. The value of modulus increased and linear region became shorter with increasing the ratio of dispersant.

3.2.2.2 Frequency sweep test

Frequency sweep tests were performed at strain of 1%. Suspension behavior originates from the characteristics at high frequency, and suspension behavior reflects the microstructure of particle dispersion at low frequency [2]. In this work, we focused
Figure 3.7. Strain sweep tests of (a) suspension A and (b) suspension B with different concentration of dispersant. 0.2wt%/Ni, 1wt%/Ni, 3wt%/Ni, 5wt%/Ni
dispersion stability. In figure 3.8, the value of storage modulus increased with increasing concentration of dispersant in both suspension A and suspension B. Furthermore, suspension A had higher storage modulus than suspension B at all concentrations. It implies that suspension A formed stronger network than suspension B. This result is in accord with sedimentation result.
Figure 3.8. Frequency sweep test of (a) suspension A and (b) suspension B with different concentration of dispersant. 0.2wt%/Ni, 1wt%/Ni, 3wt%/Ni, 5wt%/Ni
3.2.3 Adsorption

Adsorbed amount was measured by changing ratio of each dispersant. Absolutely adsorbed amount of both dispersants also increased, as concentration of dispersant increased, in Fig 3.8. At the same concentration of dispersant, absolutely adsorbed amount of dispersant A is lower than B. In addition, graph of absolutely adsorbed amount of dispersant B showed sharper slope than A with increasing concentration of dispersant in table 3. It can be compared with sedimentation results that higher concentration of dispersant B is needed to disperse particles. Even though dispersant B is more adsorbed on particles at the same concentration, an ability to disperse particles is lower than dispersant A. Therefore dispersant A can have a better influence on dispersing particles efficiently than dispersant B.
Table 3. Absolute adsorbed amount and percentage of adsorption

<table>
<thead>
<tr>
<th>Absoute adsorbed amount(mg) /percentage(%)</th>
<th>0.2wt%/Ni</th>
<th>1wt%/Ni</th>
<th>3wt%/Ni</th>
<th>5wt%/Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersant A</td>
<td>20.11mg</td>
<td>93.47mg</td>
<td>200.43mg</td>
<td>299.37mg</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>92.96%</td>
<td>64.44%</td>
<td>59.55%</td>
</tr>
<tr>
<td>Dispersant B</td>
<td>20.11mg</td>
<td>72.77mg</td>
<td>137.01mg</td>
<td>193.89mg</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>72.38%</td>
<td>45.43%</td>
<td>38.59%</td>
</tr>
</tbody>
</table>
Figure 3.9. Absolute adsorbed amount on dispersant A and B with increasing concentration of dispersant. 0.2wt%/Ni, 1wt%/Ni, 3wt%/Ni, 5wt%/Ni
3.2.4 Drying stress development

In order to understand drying characteristic of suspensions, drying stress was measured by the beam deflection method. Fig. shows final drying stress of suspensions at 0.2wt%Ni, 1wt%Ni. As concentration of each dispersant increased, drying stress also increased. Suspension B showed higher drying stress at each concentration and more wide variation than suspension A. This result is accord in the adsorbed amount. Drying stress was increased according to increase adsorbed amount of dispersant. It implies drying stress seems to be closely related to absolute adsorbed amount of dispersant.
Figure 3.10. Final drying stress data of suspension A and B with different ratio of dispersant
Chapter 4 Conclusion

The dispersant can affect the dispersion stability and drying behavior of paste even with small amount. Paste A and Paste B composed of different dispersant type. They showed different behavior in liquid and drying process by just changing 1wt% different dispersant type. Paste A with better dispersion stability in liquid showed lower drying stress that means particles were not packed densely and had more coating defects than paste B. In order to analyze this phenomenon; we investigated the effect of dispersant on the dispersion stability and film formation by sedimentation, rheology, adsorption and drying stress development. Through analyzing model system, this phenomenon is understood. Dispersant A could disperse particles effectively even with smaller amount than dispersant B, however dispersant B needs more amount to disperse particles. But dispersant B is more adsorbed on particle than dispersant A. It means dispersant B has inefficient ability to disperse particle even though it is more adsorbed on particle. However higher adsorbed amount of dispersant B would affect to develop stress higher during drying process. Absolute adsorbed amount of dispersant would be related to drying stress. Furthermore it would be associated with film uniformity. From these mechanisms, we can understand why dispersion stability and film uniformity show reverse behavior.
Reference


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M.S. thesis, Seoul National University, 2009


국문 초록

MLCC는 전자 제품의 내부에서 전기호르몬을 안정적으로 유지하고 방해 전자파를 막아주는 역할을 하는 핵심 부품이다. 최근 전자 제품의 소형화 및 경량화 추세에 따라 MLCC 박층화가 핵심 공정으로 요구되면서, 공정에 적용되는 Ni 파우더 입경이 수십 나노 수준에까지 이르고 있다. 이러한 나노 입자를 포함하는 MLCC 용 Ni paste는 코팅 및 프린팅 공정을 거쳐 얇은 필름으로 코팅되고 그 후 건조 공정을 거친다. 이러한 공정 과정 중 paste의 나노 입자들의 분산을 제어 하는 것은 쉽지 않으며, 건조 공정 후 수축, 크랙, 덜란 등의 코팅 결함이 나타나 최종 제품에 영향을 끼치고 있다. 따라서 paste의 내부 구조와 건조 거동을 이해하는 것은 중요하다. 이러한 paste는 입자, 고분자 바인더, 첨가제, 분산제 등을 포함하는 복잡한 시스템이다. 이 중 분산제는 소량만으로도 paste에 영향을 미친다. paste에서 분산제의 종류만을 바꿨을 뿐인데 건조 후 필름 특성이 다른 현상을 볼 수 있었다. 본 연구에서는 이러한 현상에 대해 하기 위해, 분산제가 액상에서의 분산 안정성과 건조 거동에 미치는 영향을 살펴 보았다. 분산제의 종류와 입자가 다른 paste에서, 침강안정성과 유변 물성을 통해 분산 안정성을 관찰 하였고, 건조 스트레스를 측정을 통해 건조 거동을 살펴 보았다. 그 결과 분산 안정성과 건조 거동이 반대로 나타나는 것을 확인하였다. 따라서 분산제의 종류와 농도를 변수로 분산 안정성과 흡착량의 관계와 흡착량과 건조 스트레스와의 관계를 파악하여 위의 현상을 이해 하였다.

핵심어: MLCC, 페이스트, 분산제, 분산 안정성, 흡착, 건조 거동