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Monitoring of Degradation Process of Commercial ME Tapes under High Humidity Environment by AC Impedance Techniques

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The corrosion resistance of several kind of ME (Metal Evaporated) tape has been investigated both in mild sulfuric acid solution and NaCl solution by electrochemical impedance spectroscopy. It was found that the degradation of ME tapes was accelerated with increasing the concentration of sulfuric acid. There was no significant change in corrosion resistance when the concentration of NaCl was under 3.5 wt%. However, the impedance value decreased when the concentration of NaCl was up to 10 wt%. The degradation of backside of ME tapes was also investigated by AC impedance measurements. The results showed that the impedance behavior of backside plastic film changed with the concentration of sulfuric acid even at the beginning of immersion, implying the changing of the permeability for the backside of ME tapes. It was also found that the corrosion resistance of DVC (Digital Video Cassette) ME tape was better that that of Hi-8mm ME tapes in sulfuric acid solutions. Also, the backside of DVC ME tape showed better water resistance than that of Hi8 ME tapes.

Keywords : *metal evaporated tape, digital video cassette, electrochemical impedance spectroscopy, sodium chloride, corrosion resistance*

1. Introduction

Metal evaporated (ME) tape has been widely used for 8 mm VCR systems and digital video systems (Digital Video Cassette, DVC). It is also used as storage media for computers. It is well known that ME tape has high recording performance and potential advantages in the future.[1] However, the corrosion resistance will become very important when the information saved in ME tape needs to be archived for a long time. In some special case, ME tape needs to be good enough to keep its performance in a high humidity corrosive environment. Therefore, it is very important to evaluate its reliability as a function of time of exposure to an aggressive atmosphere. In this study, the corrosion resistance of several kind of ME tape has been investigated both in mild sulfuric acid solution and NaCl solution by electrochemical impedance spectroscopy.

2. Experimental

2 different type of commercial ME tapes, Hi-8 mm ME video tape and DVC tape were used during this project. After being cleaned by deionized water, the ME tape was attached to a plastic plate and connected to copper wire by silver paste. The edges of ME tape were then sealed with epoxy resin. Sulfuric acid (H_2SO_4) with a concentration ranging from $5x10^{-4}$M to $5x10^{-6}$M was used in conjunction with a supporting electrolyte ($2x10^{-1}$M K_2SO_4). NaCl solution with a concentration range from 1wt% to 10wt% was also used in this project. Measurements were conducted by employing a three-electrodes configuration. A platinum sheet ($2.0x2.0cm^2$) and SSE (Ag/Ag^+) were used as counter and reference electrode, respectively. All potentials presented in this work are referenced to SSE. The impedance characteristics as a function of time were investigated by EIS. A sinusoidal perturbation of 20mV was applied and the frequency was scanned from 100KHz to 10mHz. Immersion tests were also conducted in this study. Changes in tape morphology were observed by optical microscope during immersion tests and after the EIS tests.

3. Results and discussion

3.1 Impedance behavior of Hi-8mm ME video tape in NaCl solution

Fig. 1 shows the changes in impedance behavior of TDK

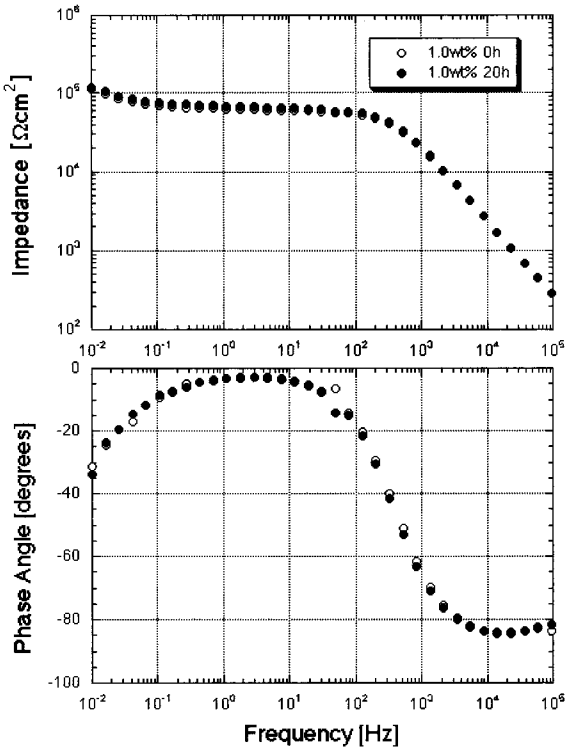

Fig. 1. Changes in impedance behavior for Hi8 mm TDK video tape in 1.0 wt% NaCl solution.

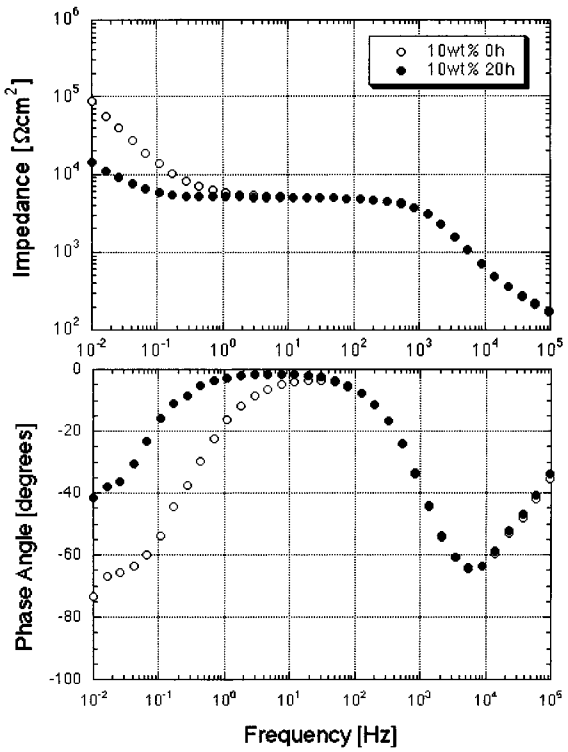

Fig. 2. Changes in impedance behavior for Hi8 mm TDK video tape in 10 wt% NaCl solution

Hi-8 mm ME video tape in 1.0 wt% NaCl solution. In high frequency area, the impedance increased when frequency shifted to lower direction. The phase angle is near 90 degree in this area, meaning a strong capacitive element exists. It is known that ME tape consists several layers of different materials, including protective DLC (Diamond-Like Carbon), Magnetic layer, plastic film. According to the authors' formal report,[2] Impedance behavior at high frequency area is considered to represents the DLC layer. The effect of DLC layer on old type SONY ME video tape was greatly reduced in the previous study. However, in this research, even trying to reduce the effect of DLC layer with the same method, it still occurs in the final results, which means the corrosion resistance of DLC layer has been improved since then. The impedance becomes stable among the frequency area from 100Hz to 100mHz.

And then, it increased slightly When the Frequency shifted to low frequency side. After 20h immersion, no obvious change was found in impedance behavior. It indicates that Hi8-mm TDK ME tape is stable in 1wt% NaCl solution. The impedance at low frequency is considered to represents the corrosion resistance of ME tape.[2] Therefore, the evaluation of corrosion resistnace for ME tape can be done by comparing the impedance value at

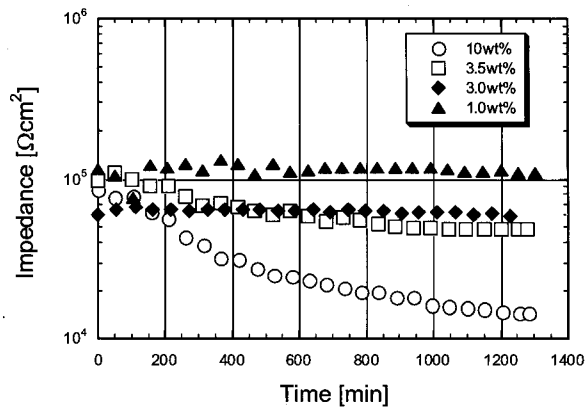

Fig. 3. Changes in impedance at 10 mHz for Hi8 mm TDK tape in NaCl solutions.

low frequency. Fig. 2 shows the changes in impedance behavior of TDK Hi-8 mm ME video tape in 10 wt% NaCl solution. By increasing NaCl concentration to 10 wt%, the impedance value at a range of 100 kHz to 1Hz became smaller than that in 1.0 wt% NaCl solution. After 20h immersion, there is no significant change in impedance in a frequency range from 1 Hz to 100 kHz. But the impedance at low frequency side decreased with immersion time, meaning that the degradation of ME tape was accelerated in 10 wt% NaCl solution. Fig. 3 shows

the changes of corrosion resistance (impedance at 10 mHz) for Hi-8 mm TDK ME tape in NaCl solution with different concentration. After 20h immersion, no big changed was found in impedance behavior when the concentration of NaCl is below 3.0 wt%. The corrosion resistance began to decrease when the concentration of NaCl is above 3.5 wt% and became worse in 10 wt% NaCl solution.

3.2 Impedance behavior of Hi-8mm ME video tape and DVC ME tape in H_2SO_4 solution

The authors investigated the impedance behavior of old type Hi-8 mm SONY ME video tape.[2] In this research, in order to evaluate the corrosion resistance of different type of ME tapes, similar experiments were conducted on different type of ME tapes. Fig. 4 shows the impedance behavior for Hi-8 mm TDK ME video tape in sulfuric acid with different concentration after 24h immersion. The impedance behavior did not changed in $5x10^{-5}$M and $5x10^{-6}$M H_2SO_4 solution during 24h immersion. It means that corrosion resistance of TDK ME tape is good and stable. On the other hand, the impedance was small and unstable when the concentration of H_2SO_4 solution was raised to $5x10^{-4}$M. It found by observation that the magnetic metal layer disappeared after 20 minutes immersion and the tape became transparent, meaning that only plastic film was left. Therefore, it is considered that the impedance behavior showed in Fig. 4 after 24h immersion in $5x10^{-4}$M H_2SO_4 solution does not represent the corrosion resistance of metal layer but may reveal some information about the DLC layer and plastic film. Recently, one of the large market for ME tape is digital video camera system. All digital video cassettes (DVC) are made by ME tapes. Fig. 5 shows the impedance behavior for TDK ME digital video tape in mild sulfuric acid with different concentration after 24h immersion. The same trend can be seen that the impedance at low frequency area decreased with the increasing of concentration of H_2SO_4. Comparing to Fig. 4, the impedance of DVC tape was higher than that of Hi-8mm tape under the same condition, which means the corrosion resistance is better that than of Hi-8mm tape. Immersion test showed that DVC tape lasted about 40 minutes until it became transparent because of losing magnetic metal layer. This is well consistent with the results of impedance measurements.

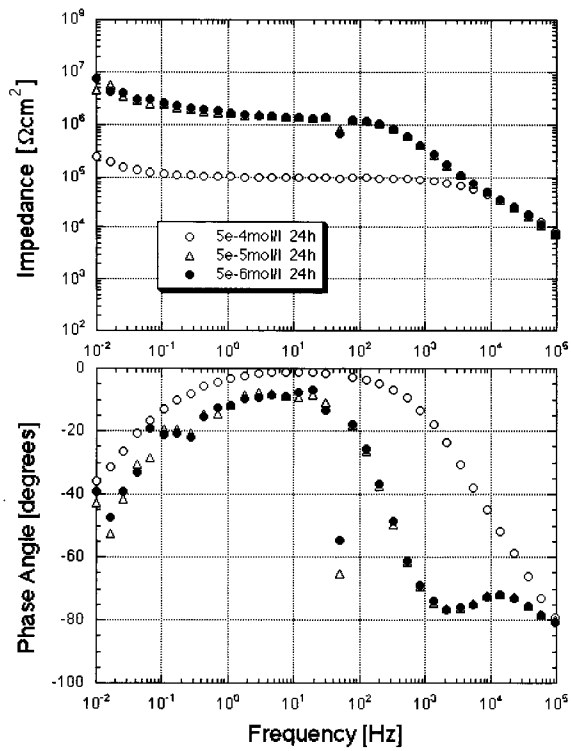

Fig. 4. Impedance behavior for Hi8 mm TDK video tape after 24h immersion in H_2SO_4 solution with different concentration.

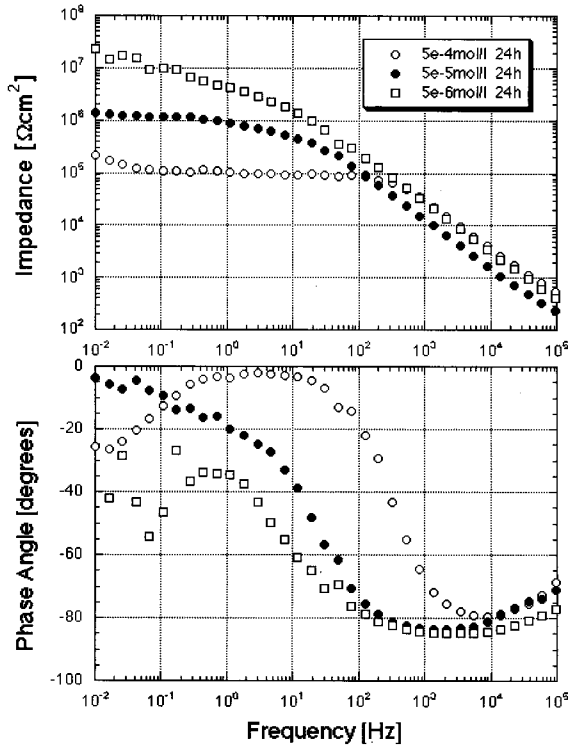

Fig. 5. Impedance behavior for TDK DVC ME tape after 24h immersion in H_2SO_4 solution with different concentration.

3.3 The effect of electrolytes on the permeability of ME tape

Water and ultraviolet (UV) rays are the most common reasons for the degradation of organic materials. In the case of ME tape, plastic film is used to support the magnetic metal layer. Organic polymer such as PET is widely used as supporting film. Therefore, it is considered that

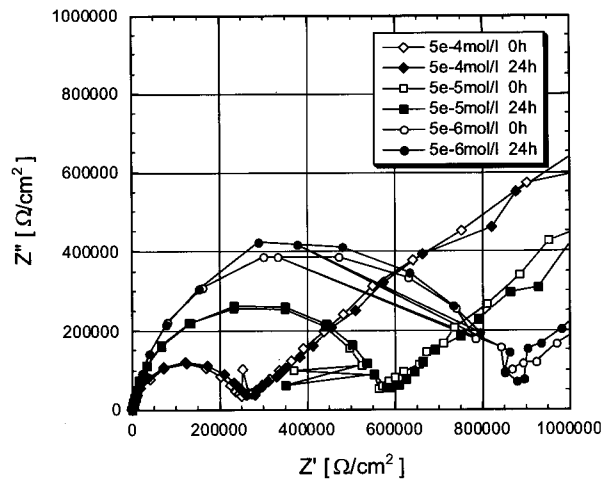

Fig. 6. Changes in impedance behavior for the backside of Hi8 mm TDK ME tape with time in H_2SO_4 solution with different concentration.

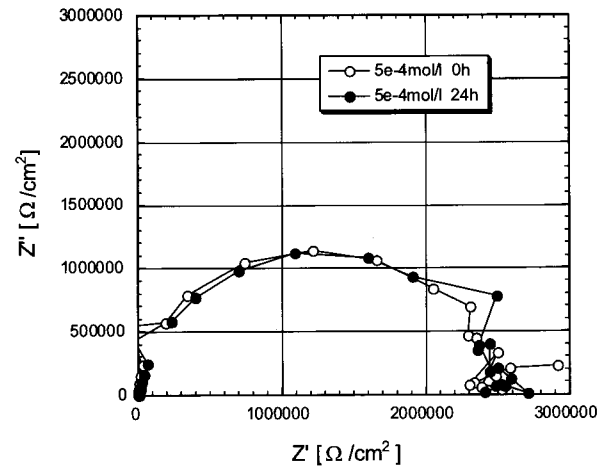

Fig. 7. Changes in impedance behavior for the backside TDK DVC ME tape with time in $5x10^{-4}M$ H_2SO_4 solution.

the degradation of plastic film due to the existence water (a high humidity environment) may cause serious problems on the performance of ME tape. The permeability of the backside of ME tape (the plastic film) was investigated by electrochemical impedance measurements. Fig. 6 shows the changes in impedance behavior for the backside of Hi-8 mm ME video tape during 24h immersion in H_2SO_4 solution with different concentration. Under the tested condition, the impedance value did not changed during 24h immersion, which implies that the backside of ME tape is very stable.

The changes of impedance behavior for the backside of TDK DVC ME tape with time in $5x10^{-4}M$ H_2SO_4 solution is shown in Fig. 7. Same as the result shown in Fig. 6, no obvious change was found during 24h immersion. The impedance value is larger than that of Hi-8 mm TDK ME tape (Fig. 6), indicating that the corrosion resistance of DVC tape is much better.

On the other hand, however, the resistance of plastic film represented by the diameter of the half circle in Fig. 6 decreased with the increasing of concentration of H_2SO_4 solution even at the beginning of immersion. It is believed that the resistance of plastic film in aqueous solution generally depends on the permeability of the film. Therefore, it is considered that increasing the concentration of electrolytes (H_2SO_4) can cause damage on the plastic film and then change the permeability of the film. This is a very useful information for selecting the type of plastic film for ME tape, especially when it is going to be used in a very aggressive environment with high humidity.

4. Conclusions

It was found that the degradation of ME tapes was accelerated with increasing the concentration of sulfuric acid. The corrosion resistance decreased when the concentration of NaCl solution was above 3.5 wt%. The impedance behavior of backside plastic film changed with the concentration of sulfuric acid, implying the changing of the permeability for the backside of ME tapes. It was also found that the corrosion resistance of DVC ME tape was better that that of Hi-8 mm ME tapes in sulfuric acid solutions. Also, the backside DVC ME tape showed better water resistance than that of Hi-8 mm ME tapes.

References

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