Electromagnetic Interference Shielding Using ITO Nano-branch and Metal Nano-Particle Decoration

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ABSTRACT

The ITO branches were used for transparent and flexible electromagnetic interference shielding devices. Nano branch structure is expected to increase EMI shielding efficiency through inter-reflection with each branch. In order to increase the electromagnetic absorption rate of the ITO branch, novel metal nanodot is decorated. The application method to the transparent substrate is transfer using NaCl as sacrificial layer.

1 INTRODUCTION

The various electromagnetic waves are occurred since the use of electronic devices. Decades ago, the intensity of electromagnetic waves was very weak, with very little impact on the human body or other devices. However, with the development of technology, electromagnetic waves generated from wireless Internet, mobile phones, Bluetooth, satellites, etc. have reached a level that is harmful to human health and degrades the function of other electronic devices. [1-2] As the technology is advanced, the generation of stronger electromagnetic waves is inevitable. Therefore, the electromagnetic interference (EMI) shielding technology is being studied and developed.

The basic condition of EMI shielding material for is sufficient electrical conductivity to absorb electromagnetic waves. Therefore, metals, conductive polymers, Carbon material (Graphene, CNT etc.) [3-5] have been studied the most as an EMI shielding material. First, metals are easy to use for electromagnetic shielding because they have a relatively high electrical conductivity. However, there are disadvantages that the mechanical properties are very poor and the corrosion is too easy. In the case of the conductive polymer, various conductive fillers may be applied to the polymer matrix. Depending on the type of filler, the band of the EMI shielding also changes, and the efficiency is also very high. It also has the advantage of simple process. In general, however, they should be relatively thick. This can be difficult to apply to transparent or thin devices. Graphene also has similar advantages and disadvantages as conductive polymers. [6-8]

Various type of research for EMI shielding have been conducted. Among them, the researches on

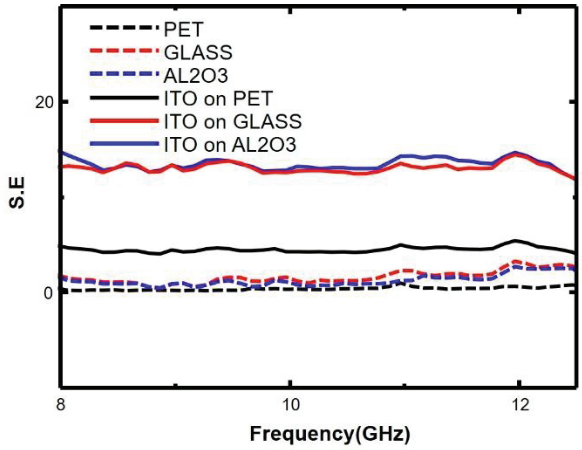


Figure-1 Comparing EMI SE of ITO film and ITO nano branch

transparent EMI shielding materials for flexible and thin devices such as mobile phones, laptops, and pads have been conducted. In this case, metal is usually used. This is because metal becomes nano-sized or extremely thin, the electrical conductivity is reduced but it is transparent. However, as mentioned earlier, metal is a very unstable material, so smaller sizes make it more susceptible to corrosion and destruction. In order to solve this problem, there is an attempt to passivate the surface of metal by thermal oxidation or to increase mechanical properties by applying mechanical stress[9-12].

This study attempted transparent EMI shielding using ITO, which has a relatively low shielding efficiency among existing materials. When the thickness of ITO is sufficient[13-16], it had shielding efficiencies of 20 to 30 dB. but another reason is that it was fragile. However, by implementing a nanostructure, the internal reflection can be increased to increase efficiency. In addition, this nanostructure is transferred to a flexible substrate to suggest the possibility of implementing a transparent and flexible electromagnetic shielding film. At this time, the transfer method used NaCl as a sacrificial layer. We are trying various methods of this transfer.

2 EXPERIMENT

Single crystal Si (100) wafer was used for deposition. Before deposition, the substrate was cleaned with acetone, IPA, and DI water in order. And NaCl was deposited by thermal evaporation in a vacuum chamber of $\sim 10^{6}$ torr. ITO nanostructure was deposited e-beam evaporation. The ITO source for deposition used a 1-10mm shot. PDMS was coated onto the deposited substrate for transfer. Heat treatment on a heating plate was performed for PDMS curing. Thereafter, the PDMS / ITO nano structure membrane was transferred by dissolving NaCl using DI water.

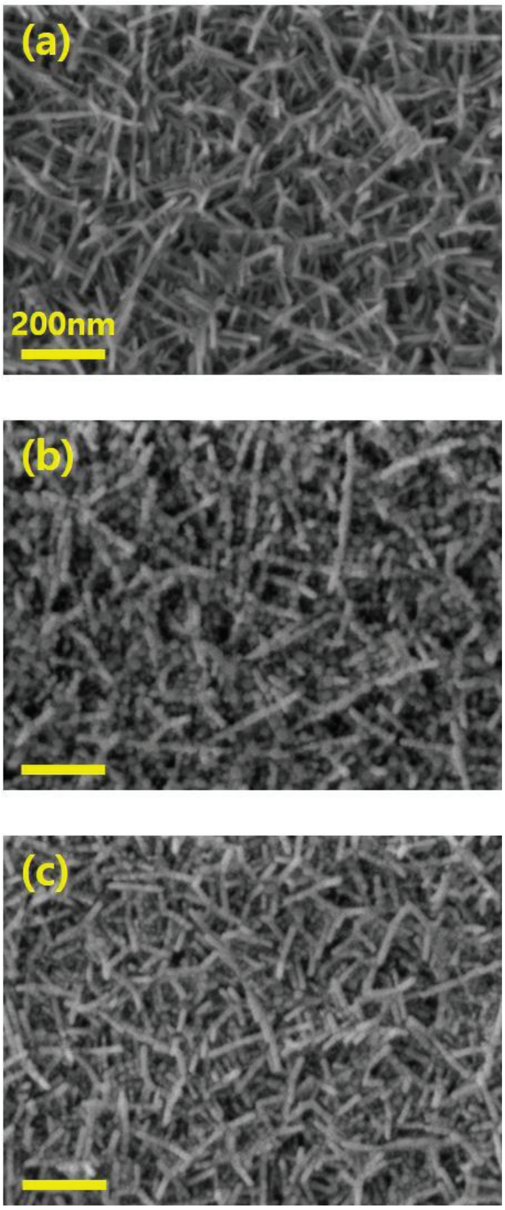
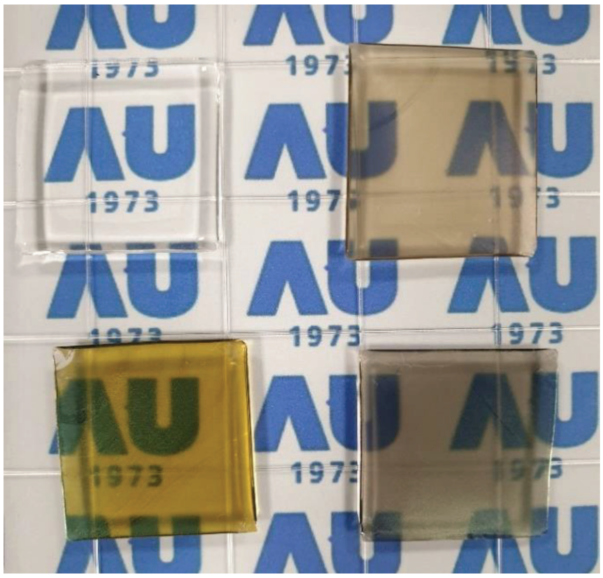


Figure-2 SEM image of (a) ITO branch and (b) ITO branch with Ag nano dot, (c) ITO branch with Au nano dot.



JUST PDMS	ITO Branch
Ag nano dot /ITO Branch	Au nano dot /ITO Branch

Figure-3 The real image of PDMS membrane which transferred ITO Branch of each condition.

3 Result

First, in the figure-1, we compared the EMI shielding effects of ITO film and ITO nano branch. In the case of a thin film, it is approximately 5 dB. In the case of nano branch structure, it is approximately 15 dB. This seems to increase the absorption efficiency by inter-reflection between branches. As a result of deposition on various substrates, the substrate appeared to have no electromagnetic shielding effect.

As shown in Figure 2-a of the SEM image, it can be seen that the ITO was grown in branch shape by the high-temperature vapor deposition. A simple mechanism of branch growth is that when an e-beam is irradiated to vaporize ITO source, Sn is pre-vaporized and deposited on the substrate. The shape of the Sn is nano dot due to characteristic of physical vapor deposition. Thereafter, indium oxide is dissolved in Sn nano dot. Dissolution continues with deposition, and precipitation occurs at the interface of NaCl and Sn nanodots when the solubility limit is reached. This process is the same as the mechanism of VLS (vapor-liquid-solid) method, so it grows into ITO nano-rod. This cycle of growth occurs repeatedly onto the body of the ITO rod, resulting in the formation of branches. Ag or Au nano dots were used to enhance the electromagnetic shielding effect. These nano particles of noble metals increase the absorption

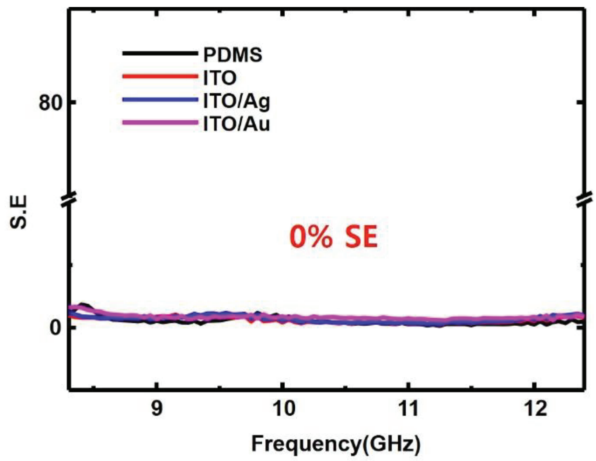


Figure-4 EMI SE of PDMS membrane which transferred ITO Branch of each condition

rate of electromagnetic waves by plasmon effect. Figure 2-b, c in the SEM image shows that the nano particles are on the surface of the ITO branch. Figure 3 shows PDMS with each ITO branch transferred to 2.5 × 2.5 size PDMS. It shows some transparency. We plan to increase it through future research. Figure-4 shows the EMI shielding effect of the ITO nano structure transferred to PDMS. All four cases seem to be ineffective. It seems that all ITO nano branch membranes cracked during transfer.

4 Discussion

It was confirmed that the ITO nano branch is a potential material for EMI shielding. However, when implementing the membrane of the ITO nano branch and the flexible substrate, there was no EMI shielding effect. It is expected that destruction occurred during the transfer of the ITO nano branch. Therefore, as plan, various transfer methods will be tried to implement stable transcription of the ITO nano branch. In addition, various physical properties such as transmittance and mechanical stability of these membrane will be measured.

5 CONCLUSIONS

In this study, ITO nano branch structure was used to increase the reflectivity inside the material, improving the EMI shielding efficiency compared to the general film type. In addition, the structure was transferred to a flexible substrate to implement a transparent and flexible EMI membrane. NaCl was used as the sacrificial layer in the transcription process. However, it can be seen that the EMI shielding efficiency drops dramatically after the transfer. It was expected that ITO nano branch structure cracked during transcription. Therefore, we will try a new transfer method, and realize a transparent and flexible EMI membrane.

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