Properties of Conformal Antenna for Mobile Phone by Laser Direct Structuring

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A triple-band antenna was developed and fabricated by LDS (Laser Direct Structuring) process. The effects of the plating rate and heat treatment condition were investigated and the gains of fabricated antennas were measured at various frequencies. The laser irradiated surface shows clearly that there are prominence and depression. It shows anchoring effect between a plating material and ablation surface. The plating rate was decreased when the plating material is exhausted in the solution. This solution needs to refreshed by the new aid solution. The copper plating thickness is decreased with the increase of heat treatment temperature in the same time but it does not change other condition. The gain of LDS antenna showed higher than the generally processed antenna. This result was related with practical use of the dimension and effective dielectric constant.

Keywords : LDS, Conformal antenna, Gain, Electroless plating, Effective dielectric constant

1. INTRODUCTION

Recently, 3D-MID (Three Dimensional Molded Interconnected Devices) technology is a major issue in the various industrial regions[1]. The boundary of this technology is three-dimensional injection molded electronic circuit boards and plastic parts with integrated conductive patterns. There are 3D-MID technologies such as "Two Shot Injection Molding", "Film Molding", "Hot Embossing" and "Laser Direct Structuring"[2-5].

Especially, the Laser Direct Structuring (LDS) technology is more spotlighted than other types. It is a laser irradiation patterning method on material surface, which has many advantages in radio frequency area. There are many benefits such as design freedom (unnecessary of photo lithography and etching), miniaturization (efficient use of dimension), easy handling of layout changes (just do change of laser irradiation position), low hard tooling cost (modification of injection mold) and more rapid process.

The LDS process has short fabrication steps. The first step is injection molding (dielectric base frame material). The second step is patterning with laser irradiation on material surface (activation of radiator dimension). The final step is metallization by electroless or electro plating process, which completes antenna fabrication.

In this paper, the change of plating rate with heat treatment conditions and the gains of LDS antennas were characterized at various frequencies.

¶ This paper was based on the invention disclosed in published patent "Antenna producing method using Laser Direct Structuring and antenna produced thereby" (application no. 10-2006-0002261).

2. EXPERIMENT

2.1 Fabrication of antenna

Specimens were fabricated by three-step as follows. The process is injection molding, laser irradiation and plating. Firstly, a dielectric base frame was fabricated by injection molding with the resin (for the LDS process). Then, they were dried at various temperatures (60 ~ 210 `C) and duration (30 ~ 120 min). Secondly, radiator dimension was activated by laser irradiation machine (LPKF, MicroLine 3 160I). Irradiate conditions of the laser were 1,300 nm and 2,000 Hz. Finally, deposition of the conduction material was used by a general electroless plating process. The plating conditions depend on various material (copper and nickel) and duration (30 ~ 120 min). The fabrication conditions and process were shown in Table 1, 2 and Fig. 1.

The fabricated antennas have triple bands of the operation. These bands are GSM850 (824 ~ 894 MHz), GPS (1574 ~ 1577 MHz) and DCS1900 (1850 ~ 1990 MHz).

2.2 Characterization

The morphology of laser irradiated surface was observed by Scanning Electron Microscopy (JEOL, JSM-6700F). The plated thickness was measured by X-Ray Fluorescence (SII Nano Technology, SFP9200). The gains of antennas were analyzed by Network Analyzer (Agilent, 8753D) at the anechoic chamber (E.M.W. Antenna).

Table 1. Conditions of plating.

Parameter	Conditions
Cu & Ni Plating Time (Min)	30, 60, 90, 120
Plating formation*	C, C + N

* C = Copper, N = Nickel

Table 2. Conditions of heat-treatment.

Parameter	Conditions			
	1	2	3	4
Heat treatment temperature (˚C)	60	90	120	210
Heat treatment Time (Min)	30	60	90	120

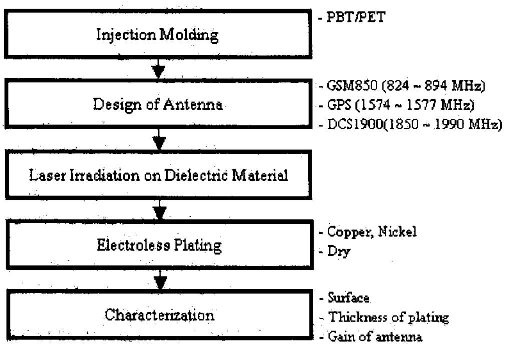


Fig. 1. Measurement procedure.

3. RESULT AND DISCUSSION

3.1 Laser irradiated and plated surface

Figure 2 shows the SEM images of specimens.

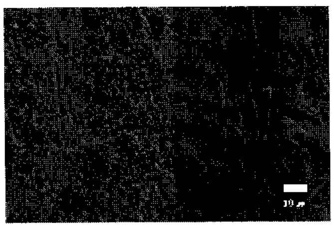
The laser irradiated surface is left area and non-irradiated surface is right area in Fig. 2 (a) and (b).

The laser irradiated surface shows clearly that there are prominence and depression. This is called to "Micro Roughness". It is created by the thermal energy of laser. The core mechanism is splitting the organic ligands and metal atoms by radiating laser beam with high energy. The micro roughness shows an anchoring effect between the plating material and the ablation surface[6].

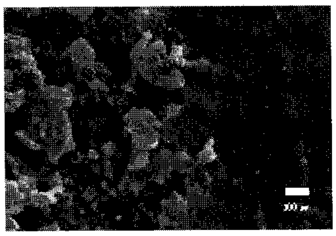
Figure 2(c) shows the morphology of plated surface. The plating material is bonded on the boundary of the laser irradiated surface.

3.2 Plating thickness with time

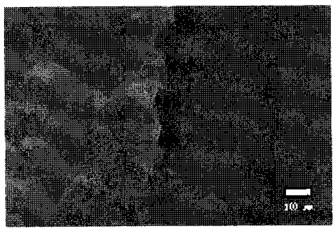
The change of copper plating thickness and rate with various plating time is shown Fig. 3. The plating condition is set with plating time of 30, 60, 90 and 120 minutes.



(a) Laser irradiated surface (left area, × 100)



(b) Laser irradiated surface (left area, × 1000)



(c) Plated surface (left area, × 1000)

Fig. 2. SEM images of surface.

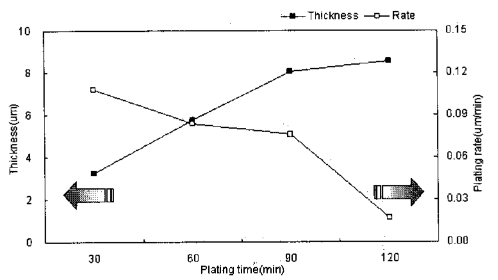


Fig. 3. The plated thickness and rate with copper plating time.

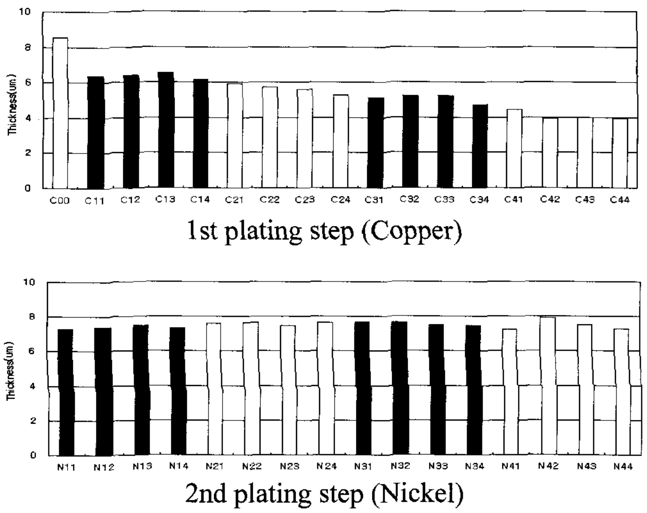


Fig. 4. Plated thickness with various plating time and dry conditions.

It was found that the slope of plating thickness increased with the plating time when from 0 to 90 minute and decreased suddenly from 0.08 um/min to 0.02 um/min after 90 minutes. This result suggests that the plating metal is diminished with time in solution. In other words, it implies that the plating environment is not suitable after 90 minutes. Therefore this solution needs to be refreshed. The refresh method is adding the new aid solution. Thus the control of plating condition is a main factor when an antenna is fabricated in LDS process.

3.3 Effect of heat treatment conditions

The plating thickness of dielectric material with dry condition is shown in Fig. 4.

The specimen number is CXX or NXX. The letter C or N is the plating material copper and nickel respectively. Among 2 numbers after letter C or N in Table 2, the first number is the heat treatment temperature and the second number is the heat treatment time. C00 is non-heat treatment before plating process.

Figure 4 (a) shows the plated thickness in the 1st electroless plating step. The copper plating thickness is decreased with an increase of the heat treatment temperature in the same time but it do not change with an increase of the heat treatment time at the same temperature. This result suggests that the heat treatment temperature is more affecting than the heat treatment time. In general, the dielectric material is got stress in the injection molding process[7]. This stress affects adhesiveness between the plating material and the antenna base frame. It is loosened by heat treatment. Thus, suitable heat treatment condition is necessary before plating process.

Figure 4 (b) is the nickel plated thickness in the 2nd electroless plating step. It is plated on the copper plated surface. The nickel plated thickness is not variety with increase of the heat treatment temperature and the time. This result suggests that the loose of surface is finished after the 1st plating step.

3.4 Gain of antenna

The gain of LDS antenna and the plate antenna are shown in Fig. 5. This result shows that the gain of LDS antenna is higher than that of the plate antenna at various frequencies. This result is related with two factors as follows.

The First factor is the efficient use of dimension of dielectric material. The base frame dimension of LDS fabrication process antenna (LDS antenna) and general fabrication process antenna (plate antenna) is shown in Fig. 6. It was found that the LDS antenna used base frame dimension (805 mm^3) is wider than the plate antenna (390 mm^3) because the plate antenna process could not use a curved and a bended surface of dielectric material. This result suggests that the LDS process is more advantageous (practical use of dimension) than the general fabrication process for gain of antenna.

The second factor is effective dielectric constant of material.

$$\lambda = \frac{c}{f} \times \frac{1}{\sqrt{\epsilon_{re}}} \tag{1}$$

Where λ is wavelength, c is the speed of light in vacuum (3×10^8 m/s), f is frequency (Hz), ε_{re} is dielectric constant. The dielectric constant is changed by gap of radiator and base frame. It called to "effective dielectric constant". Increase of the effective dielectric constant is related with increase of antenna property. It increases when the gap is decreased between conduction part and base frame part. LDS antenna can decrease the gap because this process is direct plate on base frame. Details of this result are found reference[8].

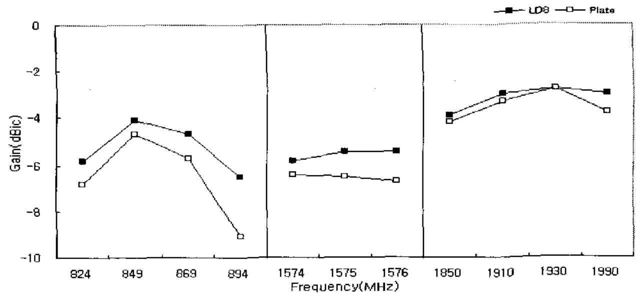
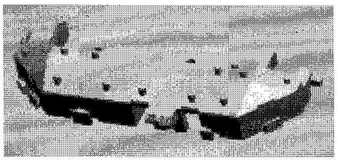
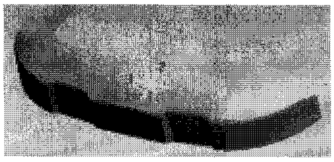


Fig. 5. Gain of antenna with fabricated process at various frequencies.



(a) Base frame of general process antenna



(b) Base frame of LDS process antenna

Fig. 6. Surface dimension of LDS process antenna and general process antenna.

4. CONCLUSION

In this paper, a triple band antenna was fabricated and characterized. The methods of antenna fabrication were the LDS process and the general process.

The laser irradiated surface showed anchoring effect between a plating material and ablation surface.

The plating rate was decreased when the plating material is exhausted in the solution. This solution needs to be refreshed by the new aid solution.

The copper plating thickness is decreased with the increase of heat treatment temperature at the same time but it does not change other conditions.

The gain of LDS antenna showed higher than the generally processed antenna. This result was related with practical use of dimension and effective dielectric constant.

These results suggest that the LDS process is more advantageous than the general process for the conformal antenna.

REFERENCES

[1] J. Gehring, "With radiation crosslinking of engineering plastics into the next millennium", Radiat. Phys. Chem., Vol. 57, p. 361, 2000.

[2] S. Beil, H. Horn, A. Windisch, C. Hilgers, and K. Pochner, "Photochemical fuctionalization of polymer surfaces for subsequent metallization", Surf. Coat. Technol., Vol. 161-119, p. 1195, 1999.

[3] M. Cavallini, M. Murgia, and F. Biscarini, "Direct patterning of tris-(8-hydroxyquinoline)-aluminum (III) thin film at submicron scale by modified micro-transfer molding", Surf. Coat. Technol., Vol. 161, p. 96, 2002.

[4] S. H. Hong, J. H. Lee, and H. Lee, "Fabrication of 50 nm patterned nickel stamp with hot embossing and electroforming process", Microelectro. Eng., Vol. 84, p. 977, 2007.

[5] X. C. Wang, H. Y. Zheng, and G. C. Lin, "Laser induced copper electroless plating on polyimide with Q-switch Nd:YAG laser", Appl. Surf. Sci., Vol. 200, p. 165, 2002.

[6] H. Horn, S. Beil, D. A. Wesner, R. Weichenhain, and E. W. Kreutz, "Excimer laser pretreatment and metallization of polymers", Nucl. Instr. And Meth. B, Vol. 151, p. 279, 1999.

[7] G. G. Kim, J. A. Kang, J. H. Kim, S. J. Kim, N. H. Lee, and S. J. Kim "Metallization of polymer through a novel surface modification applying a photocatalytic reaction", Surf. Coat. Technol., Vol. 201, p. 3761, 2006.

[8] S. H. Park and W. M. Seong, "Microwave properties of organic-inorganic composite material antenna with various fabrication method of conduction material", J. of KIEEME(in Korean), Vol. 19, No. 9, p. 832, 2006.