A Study on AK Shadow Mask with Fe-Ni Alloy Coating for Flat CPTs

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Abstract

This paper investigates the effects of coating such as Invar (Fe-36% Ni), Fe-Ni Alloys and WO_3 on the doming property of aluminum killed (AK) shadow masks, which may be used for flat CPTs. Invar and Fe-Ni Alloys are deposited on AK shadow mask in plasma atmosphere and annealed. WO_3 is screen-printed on the deposited layer. The coating is observed to cause a decrease in the doming property of the shadow masks due to their lower thermal expansion coefficients and anti-doming properties.

Keywords : doming, AK shadow masks, invar(36Ni64Fe), Fe-Ni alloy

1. Introduction

Many types of display devices such as the organic light emitting diode (OLED), plasma display panel (PDP), thin film transistor (TFT)-liquid crystal display (LCD) and cathode ray tube (CRT) have been introduced to the world market. They are continuously developed and improved to ensure further enhancement and continuous use. Among these CRT is well known and has the longest history as the most popular display device because of its merits like cheaper prices and good quality performances. CRT will also increase efforts to survive in the world market by lowering cost and continuously improving quality.

Recently nickel prices have rapidly increased and this price increase has result in the increase in the price of Invar shadow masks. As a result, CRTs using AK shadow masks are in demand in the world market. But, if AK shadow masks are used for CRT doming is a major issue that must be resolved. Many efforts are being put into using AK shadow masks for CRT to replace the invar mask. [1-8]

In this paper, we will present a feasibility study on material coating such as low thermal expansion alloys and electron reflecting WO_3 on AK shadow masks for 21 inch CPT with flat face panel.

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2. Technical Study

When forming Fe-Ni alloy layer as a low thermal expansion metal on AK shadow mask to reduce its thermal expansion coefficient we made two assumplions. First, the Fe-Ni alloy layer on AK shadow mask as a substrate has strong adhesion. Second, the thermal expansion coefficient of the Fe-Ni alloy coated shadow mask is lower than of that of the original AK steel, and accordingly the Fe-Ni alloy layer has low thermal expansion coefficients.

To meet the above requirements, the Fe-Ni layer must be crystalline phase and have a strong bond between the layer and the AK substrate. The crystalline phase and the strong bond can be achieved through annealing.

As the radii of Ni and Fe atoms are 0.124 and 0.125 nm, respectively, the diffusion between the deposition layer and AK steel substrate occurs by substitutional diffusion between the two elements. The diffusion behavior can be expressed as follows [8].

$$D = A \exp(-Q/RT)$$

where D is diffusion coefficient, A is constant, Q is activation energy for diffusion, R is gas constant, and T is temperature (K).

The diffusion parameters of Fe-Ni alloy are given in Table 1. From this table, it can be seen that Ni diffuses into Fe at a faster rate than Fe into Ni, because the constant A of Ni element is larger than that of Fe. This means that the Ni content will decrease more rapidly than the Fe content in the deposition layer during annealing. In order to obtain the desired results such as low thermal expansion coefficient and good adhesion, annealing temperature and time and the layer thickness are the three important factors that must be considered.

Table 1. Diffusion Parameter in Fe –Ni alloy [8]

	A [cm^2/s]	Q [kJ/mol]	T [K]
Fe in Ni	**0.22**	**60.4**	**950~1370**
Ni in Fe	**1.4**	**58.7**	**600~800**

3. Experiment

AK steel with a thickness of 0.22 mm was used as a material of shadow mask, and Ni and Invar were used as clad layer materials. The layer thickness was set as 10 μm. The surface of the AK shadow mask was cleaned and sputter-deposited with Fe-Ni alloy layers with a thickness of about 10 μm in plasma atmosphere. The Fe-Ni deposited AK shadow masks were annealed in hydrogen atmosphere. Two types of deposition experiments were performed, taking into consideration the CRT manufacturing process.

First, Invar was deposited on the AK shadow masks which had already been annealed at 800 ℃ for 30 min in hydrogen atmosphere. The Invar clad AK shadow mask was annealed at temperatures ranging from 600 to 850 ℃ for 13 min.

Second, taking into account the faster diffusion rate of Ni than Fe and the rapid decrease of Ni content in the clad layer during annealing, the Ni layer was sputter-deposited between the Invar layer and the AK shadow mask. The thickness of the Invar/Ni double-layer was controlled to remain 10 μm. The double-layer clad AK shadow mask was annealed at 800 ℃ for 30 min in hydrogen atmosphere. An anti-doming WO_3 layer was screen-printed on the annealed double-layer clad AK shadow mask, and with this, a 21 inch flat type CPT was prepared.

The degree of crystallization in the deposition layer was evaluated using the X-ray diffraction (XRD) method, (Mac Science;MXP3-HF, Cu-K α at 30mA and 40 kV). The composition of the annealed deposition layer was analyzed using the X-ray fluorescence (XRF) analyzer (KITS; SPECTROSPECTRO X-Lab 2000).

Thermal expansion properties of the annealed shadow mask were measured using a thermo mechanical analyzer (Perkin-Elmer; TMA7), and doming properties of CPT were measured according to surface treatments.

4. Results and Discussion

Fig. 1 shows XRD patterns at the 10 μ m Invar clad AK shadow mask annealed for 13 min at various temperatures. It can be seen that Invar layers on the as-received sample which was not annealed and the sample annealed at 600 ℃ remain amorphous as shown in Figs. 1(a) and (b). γ Fe-Ni alloy phase (fcc) is observed at 630 ℃ and the highest peak of γ Fe-Ni alloy phases 650 ℃ as shown in Figs.1(c) and (d). On the other hand, the γ Fe-Ni alloy phase disappears at above 750 ℃ as shown in Figs.1 (g)~(h) due to the reduction of the Ni content in the layer below the solubility limit of Ni in Fe through diffusion.

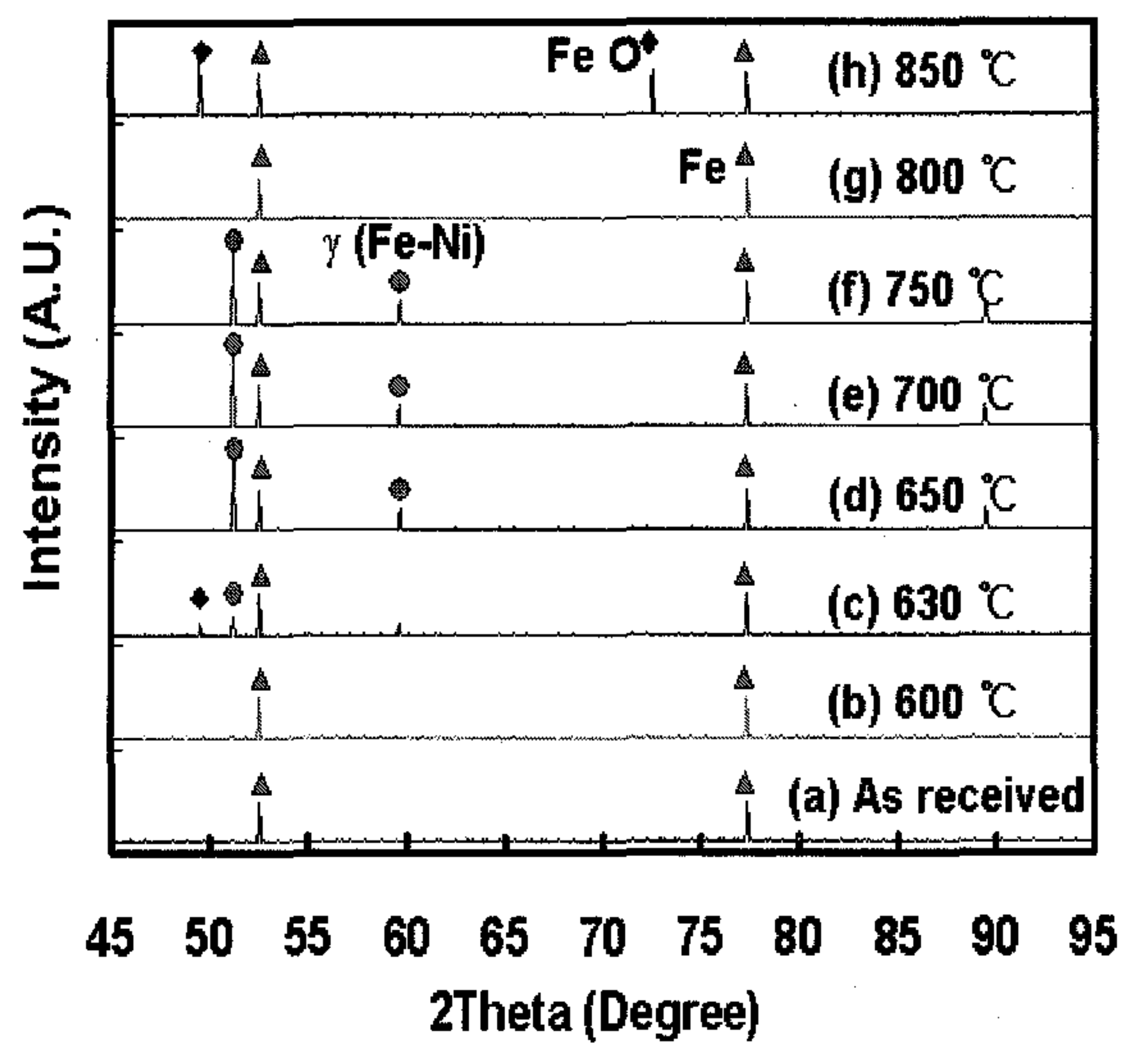

Fig. 1. XRD patterns for 10 μm thick Invar layer on AK shadow mask after annealing for 13 min at various temperatures.

Fig. 2 shows the Ni content in the Invar layer of the clad AK shadow mask annealed at 600 ℃ to 850 ℃ for 13 min in hydrogen atmosphere, and the measured thermal expansion coefficients of the AK shadow mask are given in Table 2.

The Ni content remains about 36 % up to 650 ℃, and above that temperature, the Ni content rapidly decreases because of diffusion of Ni into AK substrate during annealing as shown in Fig. 2. The thermal expansion coefficient of the Invar deposited AK shadow mask decreases by about 8 % at its maximum at 650 ℃ in comparison to that of the as-received sample as shown in Table 2.

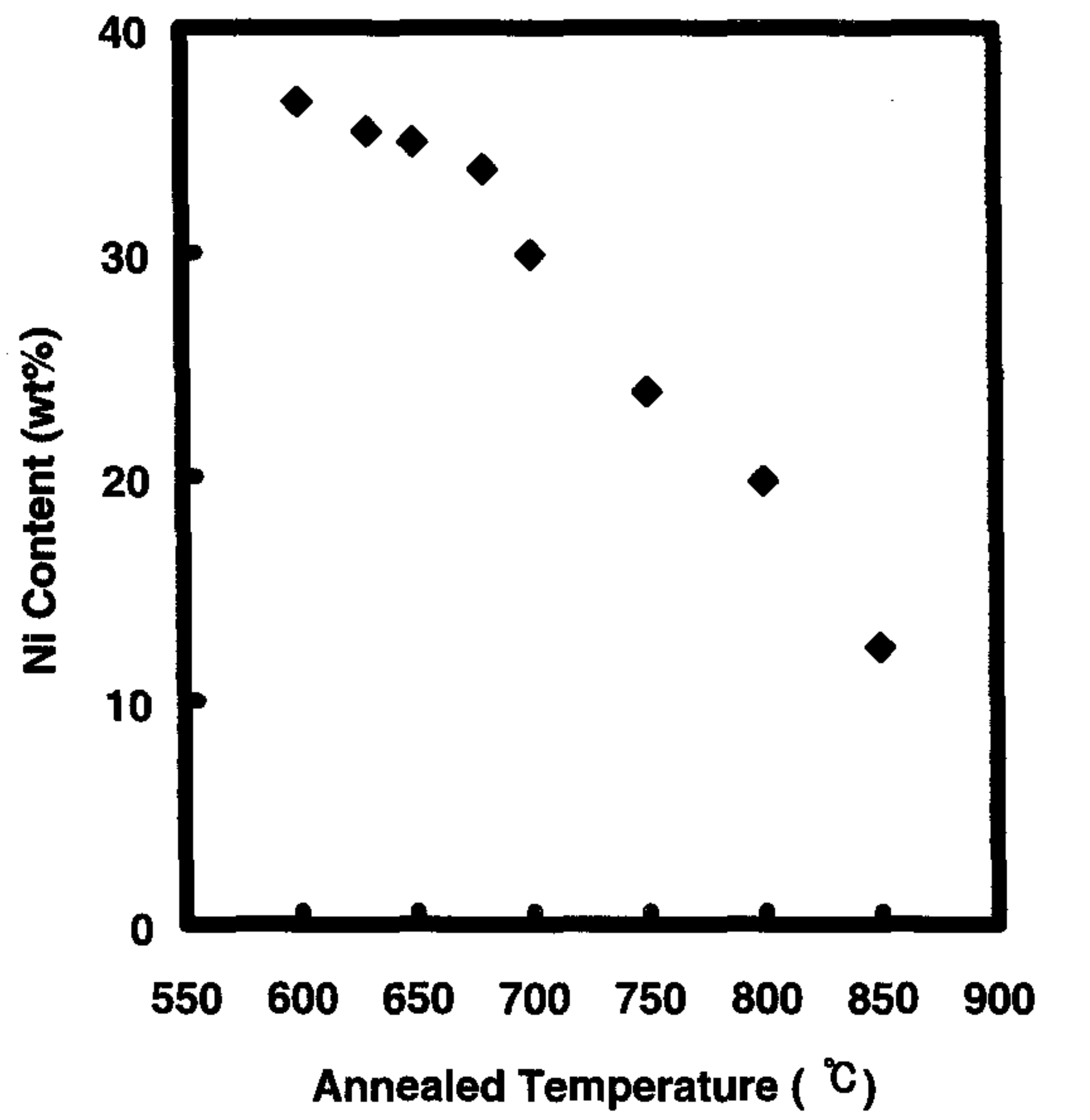

Fig. 2. Ni content in Invar layer on AK shadow mask after annealing for 13 min at various temperatures.

Table 2. Thermal expansion coefficients of 10 μm Invar clad 0.22 mm AK shadow mask after annealing for 13 min at various temperatures.

Annealing Temperature (℃)	Thermal Expansion Coefficient ($\times 10^{-6}$)
As received	11.6
600	11.6
630	11.1
650	10.7
700	11.2
750	11.6
800	11.6

Fig. 3 shows the XRD patterns for the Invar/Ni deposited AK shadow masks after annealing at 800 ℃ for 30 min.

As shown in Fig.3(a), the deposited layer for the as-received sample that was not annealed, is amorphous. When annealed, the crystallized γ- Fe-Ni alloy phases were observed, and these XRD peaks were better developed in comparison to those of the Invar deposited specimens.

Fig. 4 shows the Ni content in the Invar / Ni deposit layer after annealing at 800 ℃ for 30 min in H_2. The Ni content increases with increasing thickness of Ni. A Ni content of 36 % was obtained in the 7.5 μm Invar / 2.5 μm Ni deposit.

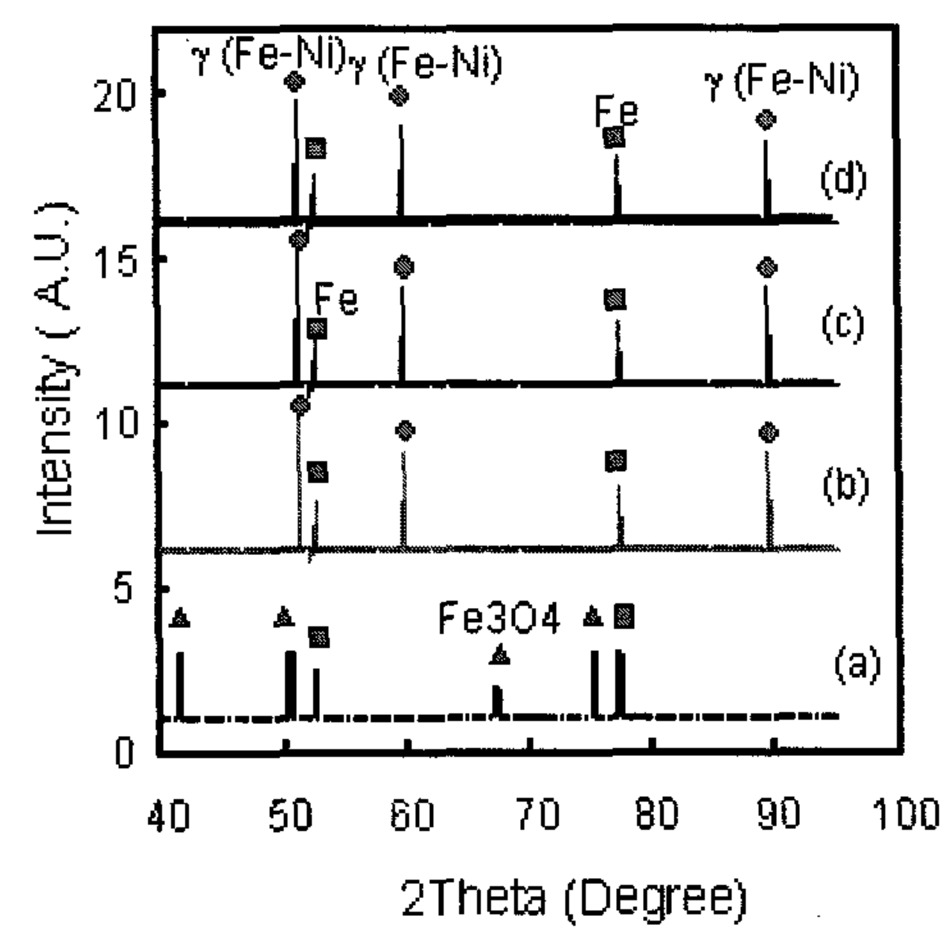

Fig. 3. XRD results of 10 μm Invar/Ni layer on 0.22 mm AK steel sheet after annealing at 800 ℃ for 30 min. (a)10 μm Invar deposition and blackening, (b) 8 μm Invar / 2 μm Ni / AK, (c) 7 μm Invar / 3 μm Ni / AK, (d) 6 μm Invar / 4 μm Ni / AK.

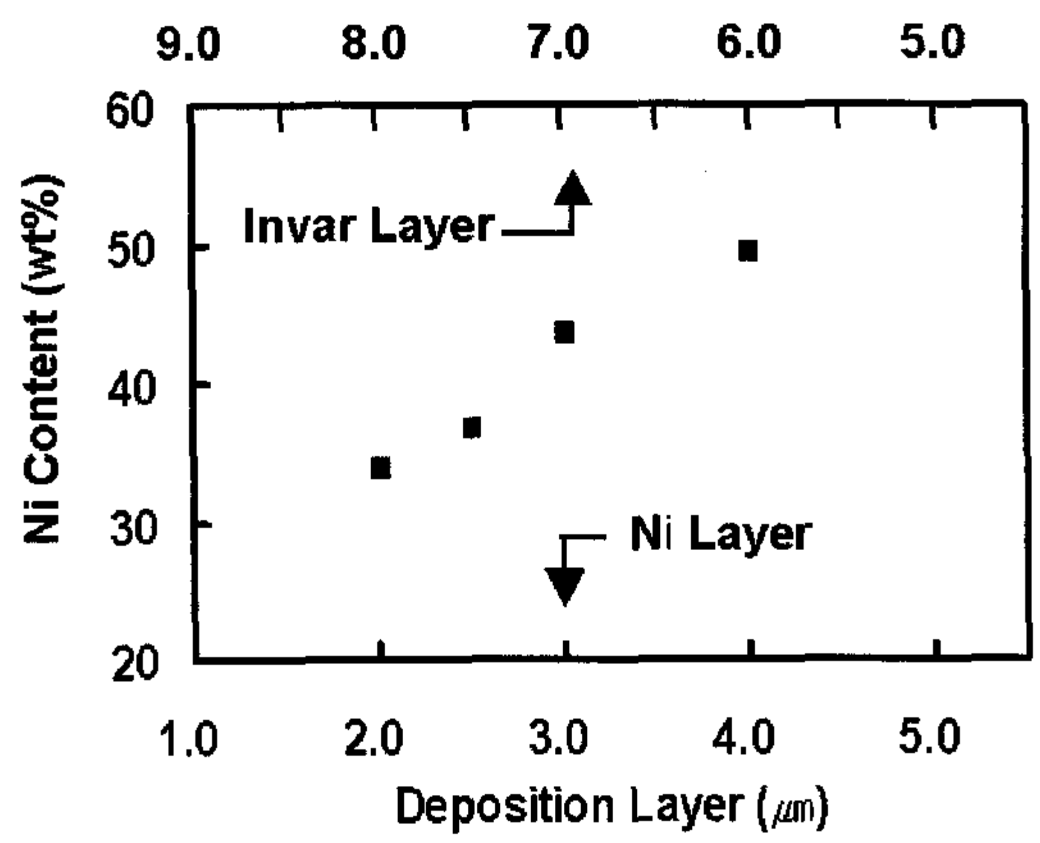

Fig. 4. Ni content in Invar/Ni layers on AK steel sheet after annealing at 800 ℃ for 30 min.

Table 3. Thermal expansion coefficients of Invar/Ni clad AK shadow mask after annealing at 800 ℃ for 30 min.

Deposition Layer (μm)		Thermal Expansion Coefficient (× 10^{-6})
Ni	Invar	
0.0	0.0	11.6
2.0	8.0	10.6
2.5	7.5	10.4
3.0	7.0	10.9
4.0	6.0	11.0

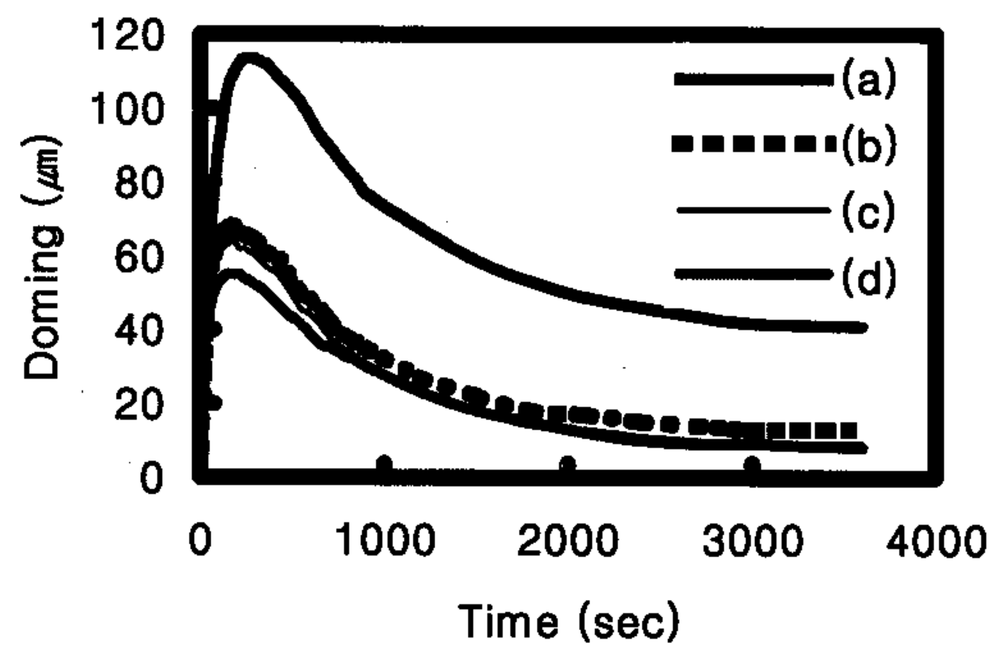

Fig. 5. Raster doming of CRT with surface coated AK shadow mask. (a) AK only, (b) WO_3 / AK shadow mask, (c) WO_3 / 10 μm Invar / AK shadow mask, (d) WO_3 / 7.5 μm Invar / 2.5 μm Ni / AK shadow mask.

Table 3 shows the thermal expansion coefficients of the specimens in Fig. 3. It is natural that the thermal expansion coefficient is minimal in the 7.5 μm Invar / 2.5 μm Ni deposited AK shadow mask, because the Ni content in the deposit is 36 %. The thermal expansion coefficient is equivalent to about 10 % decrease compared with that of AK shadow mask as shown in Table 2 .

Fig. 5 shows the doming properties of 21 inch CPTs with a flat face panel using the WO3 paste-printed shadow mask. The maximum doming property of CPT is seen to have improved by about 9~13% compared with that of CPT with the WO_3 screen-printed shadow mask as shown Figs.5 (b), (c), and (d). This improvement in doming property is caused by the reduction of the thermal expansion property, which is attributed to the low thermal expansion Fe-Ni layers. The dooming characteristic of the CPT with the WO_3 / 7.5 μm Invar / 2.5 μm Ni / AK shadow mask is best among the samples.

5. Conclusion

(1) Two types of Ni-Fe alloy layers on 0.22 mm thick AK steel sheet were formed through sputter deposition in vacuum plasma state. One was a 10 μm thick Invar (Fe-36% Ni) layer and the other was a 10 μm thick Invar/Ni double layer with Ni thickness ranging from 2 to 4 μm.

(2) The deposited layers which were amorphous in as-deposited state were crystallized to Fe-Ni phases (fcc) during annealing. The Invar deposited specimens were annealed at 600 to 850 ℃ for 13 min, and the Invar/Ni deposited specimens were annealed at 800 ℃ for 30 min.

(3) The thermal expansion coefficients of the annealed Fe-Ni-deposited- AK shadow mask decreased by about 10 % at its maximum in comparison with that of the original AK shadow mask.

(4) As a result of the reduction of thermal expansion coefficients followed by the electron reflection of the applied anti-doming materials, doming properties of 21 inch flat CPT improved by about 9~13 % more than CPT with the WO_3 screen-printed AK shadow mask.

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