Technique for evaluating the mechanical properties of barrier ribs in PDP

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Abstract

To prevent deformation and fracture of barrier ribs we suggest how to evaluate the mechanical properties of barrier ribs which depend on porosity and components by indentation technology. Our experimental results show that the mechanical properties of barrier ribs are strongly correlated to porosity and components.

1. Introduction

In display industry, mechanical properties of the barrier ribs of PDP (Plasma Display Panel) are very crucial for the improvement in reliability of the panel because barrier ribs (cross section area: 80 x 120-150um) might fracture during the fabrication process, assembly [1]. The functions of barrier ribs are to prevent the mixing of phosphors (RGB), to make a small space for discharge, and to sustain the front plate in PDP [2-3]. Therefore, it is important to evaluate the mechanical properties of barrier ribs such as strength, hardness, stiffness, and ductility, which are correlated to the deformation and fracture. The materials used for the formation of barrier ribs are mostly glass composites such as glass-ceramic matrix composite, glass matrix composite reinforced with fillers, and the barrier ribs are manufactured by a sintering process [4]. However, composite materials are difficult to evaluate their mechanical properties because of many factors such as size and quantity of pores and crystallinity and size of crystalline phases in the matrix [4].

The processes of barrier ribs have been transited for forming a minute pattern by using screen printing, sand blasting and dry film for etching and photosensitivity. Generally, in display industry, the processes for forming barrier ribs prefer the formation of minute patterns. As a result, the most popular dry film method is one that is capable of forming micro pitches for etching and photosensitivity. The sintering process consolidates powder and evaporates gases from additives. Consequently, various shapes and sizes of pores are formed in the barrier ribs with sintering parameters, and porosity significantly affects the thermal, electrical, and mechanical properties of materials [5]. In view of porosity, the barrier ribs are classified as dense and porous, which are manufactured according to microstructural parameters.

In this work, we evaluate and compare two types of barrier ribs (dense and porous) in PDP, which are composite materials with barrier ribs, based on the mechanical properties (elastic modulus and hardness) versus porosity. Our experimental results suggest that the mechanical properties are strongly correlated to porosity, and that the reliability of barrier ribs can be measured by indentation technology.

2. Experimental procedure

The hardness and elastic modulus of the barrier rib were measured by nanoindentation (Nano Indenter XP, MTS, USA) [6]. The indenter of the nanoindentation was Berkovich, which is of a pyramid shape and made of diamond (XPb1683, MTS, USA). When the tip was indented into the barrier rib in a sample, the optical microscopy was observed at the nanodindentation. The indentation for the barrier ribs was tested at least 5 times. The microstructure of the barrier rib was detected by FEG-SEM (Field Emission Gun-Scanning Electron Microscopy, S-4300SE, HIACHI, Japan) and EDX (Energy Dispersive X-Ray Micro-analysis System, Phoenix60, EDAX).

3. Results and Discussion

The bulk samples used in this work are dense (D) and pores (P) type in terms of porosity in Table 1. The P, a glass-composite material, is composed of PbO system of composition for matrix and TiO_2, Al_2O_3 as a filler. On the other hand, the D composition for matrix is Pb-free glass system that consists of various oxides such as Na_2O_3, SiO_2, Al_2O_3 and MgO for additive.

Table 1. Properties of barrier ribs

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Samples	Type	Porosity	Contents
D	Dense	<2%	Non-Pb based glass
P	Porous	10%	Pb based glass $+Al_2O_3+TiO_2$

When the D barrier rib was indented with an increasing load (50-250gf), the cracks around the indent were found at 150gf. As shown in Fig. 1, the crack was accompanied with a sudden change in displacement. It suggests that the formation of cracks could be predicted with the curves of load and displacement. As the result, the formation of cracks appeared at a load smaller than 150gf (1500mN).

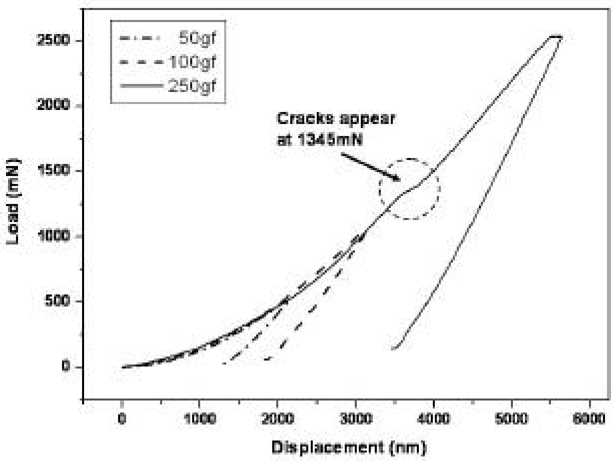


Fig. 1. Comparison of the curves of load and displacement of D under different loads applied.

In Fig. 2 the mechanical properties of D barrier rib decreased (from 89 to 58GPa in elastic modulus and from 8 to 6GPa in hardness) when an increasing load was applied. Before the cracks occurred around the indent, the hardness and elastic modulus decreased because of the indentation size effect (ISE) that the hardness decreases with an increasing indentation depth. In other words, hardness is dependent on the applied load [7]. Thus, the true hardness of D is around 8GPa. Moreover, the mechanical properties should be considered before the appearance of cracks.

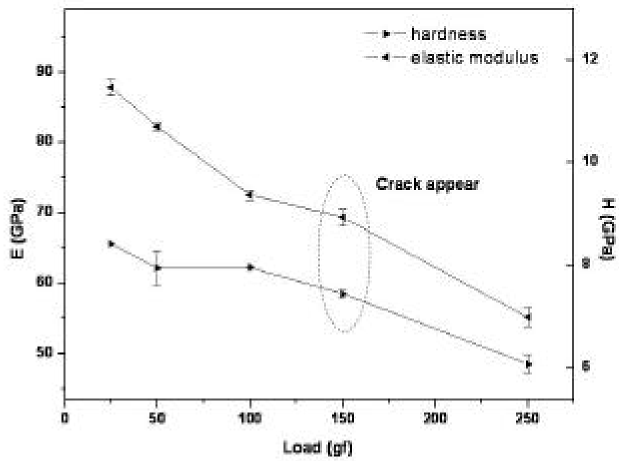


Fig. 2. Mechanical properties (elastic modulus and hardness) of D.

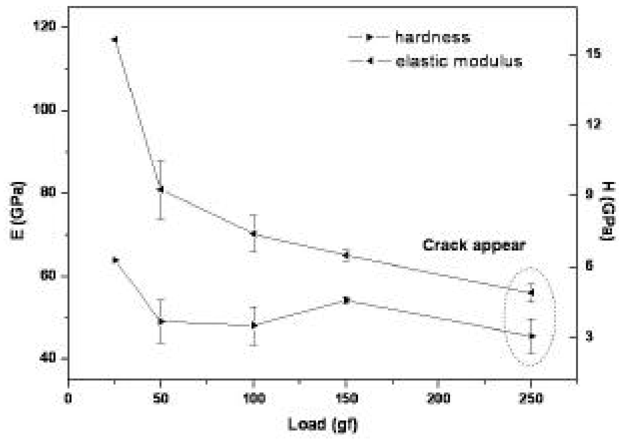


Fig. 3. Mechanical properties (elastic modulus and hardness) of P barrier rib.

The P is significantly similar to the mechanical properties of D except for its hardness (Fig. 2-3). The elastic modulus of P decreases with the increasing loads (Fig. 3). Although, the hardness of P is less than D at a load greater than 100gf, the cracks appeared at a load greater than 150gf in P barrier rib. In addition, the mechanical properties of P have larger error bars than D because of two factors: the small size indenter (tip edge radius: <0.1um) and the complex microstructure, which are composed of distributed pores (>5um) and alumina powders (3-4um) in the matrix. In the load and displacement of P barrier rib (Fig. 4), the cracks are confirmed at the load of 2427mN. Furthermore, we observed the cracks by SEM (Fig. 5).

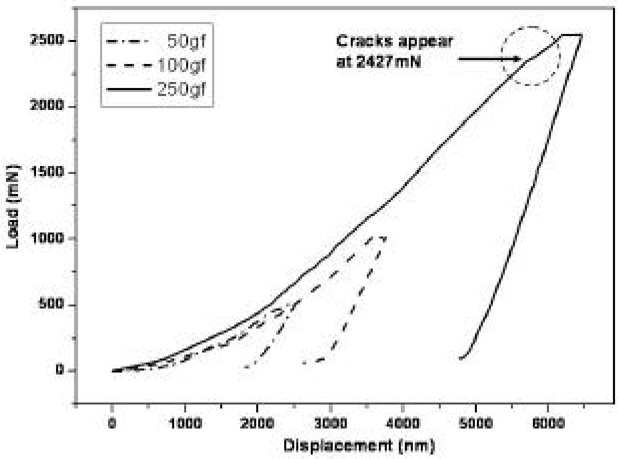
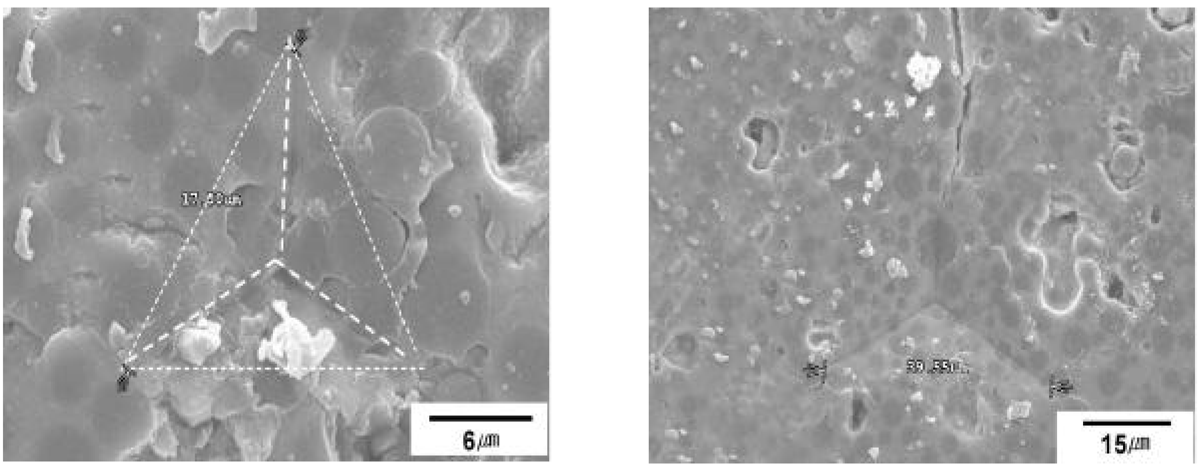


Fig. 4. The curves of load and displacement of P barrier rib under different loads applied.

In terms of the occurrence of cracks, the application of elastic and plastic deformation between D and P barrier ribs is significantly different. In the case of P barrier rib, the displacement is longer than D while the recovering displacement is lower because the plastic deformation is more dominant than elastic deformation. It is supposed to be the reason of low hardness of P at the load of 50-100gf compared with the hardness of D.

The barrier ribs, which are composite materials, are mechanical properties of ceramic tiles should be governed with the relationship between hardness (elastic modulus and strength) and porosity. It has also been reported that the constants (K_i and b) for elastic modulus and hardness are 69.1, 6.64 and 4.38, 6.27, respectively, in the empirical equation (H, S, $E=K_i\exp(-bP)$ where, H, S and E is hardness, strength and elastic modulus and P is volume fraction of porosity).[8] Using this formula, the elastic modulus of the D and P is predicted to be 64.7GPa and 35.6GPa, respectively. However, the elastic modulus of D and P was measured in the range of 72.5-87.8GPa and 65.1-117.0 in our experiment.

Based on the empirical relation of Kim *et al.* [8], i.e. E/H=18, H/MOR=100 for dense ceramic, E/H=12, H/MOR=85 for tiles ceramic (porosity <20%), the strength of D and P calculated around 36.25MPa and 24.84MPa, respectively. The difference of values between the prediction and our experiment can be explained in two paths based on our result and results of Kim *et al.*. In the one path, the components of the composites are significantly different.



(a) (b)

Fig. 5. Indent images and crack propagation in P under different load: (a) 50gf and (b) 250gf.

similar to that discussed in the work of Kim *et al* [8]. They showed the porosity dependence of hardness and elastic modulus of ceramic tiles, which are composite materials. They suggest that the

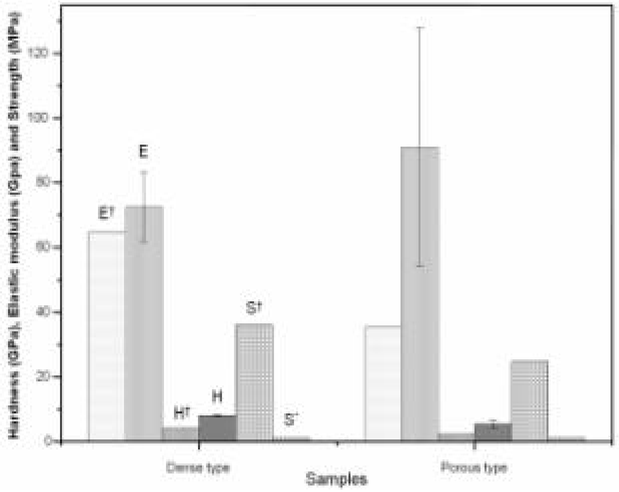


Fig. 6. Comparison of predicted and experimental mechanical properties.

※ H†, E†, and S†: Hardness, elastic modulus and strength of prediction calculated using the empirical formula with constants which reported by Kim *et al.* [8].

※ H, E: Hardness, elastic modulus and strength of experiment. S*: no measured because of sample condition.

In the other path, in view of the microstructure, the effects of components size, grain boundary, and shape of pores should be considered. The hardness of the D and P barrier ribs was similar to the elastic modulus. Figure 6 shows in detail the hardness of the D and P barrier ribs for mechanical properties based on the results reported by Kim *et al.* [8] and ours. However, the mechanical properties revealed by our experiment were insufficient for evaluation data under porosity because we only examined two materials (D and P barrier rib).

We suggest that porosity is correlated to the mechanical properties, and that the mechanical properties of a composite depending on porosity call for further research. The barrier ribs in PDP are useful for evaluating physical and mechanical properties using a nanoindenter although the result might have a low reliability since they have to deal with a nano scale.

4. Conclusion

Nanoindentation gave reliable values for mechanical properties of barrier ribs in PDP. The dense and porous types of barrier ribs showed characteristics of the sudden non-smooth section in displacement and load obtained by nano indentation. It suggests an indication of crack initiation in the matrix. The hardness and elastic modulus of samples are totally dependent on applied loads. An empirical equation to give strength, hardness, and elastic modulus shows slightly different values compared with our experiment because of the complex microstructure. However, porosity dependence of elastic modulus and hardness is a key factor in predicting the values. Therefore, we suggest that the mechanical properties of barrier ribs in PDP should be evaluated for reliability of barrier ribs in PDP by indentation technology.

5. References

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