Enhancement of Optical Performance by Light Diffusion Films

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Abstract

To increase the performance of the light diffusion films, we controlled the three dimensional microstructure of the organic fillers(beads). The refractive index, the size distribution and the three dimensional distribution of beads play an important role to determine the performance of light diffusion films for the backlight unit of TFT-LCD.

Introduction

The light diffusion films(LDF) are used to make a uniform light distribution across the surface and to condensate the light to enhance the luminance of backlight unit[1]. As shown in Figure 1 it shields the patterns of light guide panel(LGP) and concentrate the light which is emitted from the LGP. As shown in Figure 2, the LDF consisted of organic or/and inorganic globular shape fillers(beads) and polymeric resin which fix the fillers onto the plastic substrate. Typically high transparent PET(Poly-ethylene-theraphthalate) films are widely used as a substrate films for their relatively good optical and mechanical properties, however in some cases PC(Polycarbonate) films are used to eliminate optical disturbance which might be aroused by the crystalline orientation of the substrate. Generally in the case of 100 ㎛ thick PET, the high transparent substrate should have the haze below 2.0% and the transmittance of higher than 88%. We developed high performance light diffusion film to enhance the brightness(Figure 4). To make the enhanced LDF we controlled beads distribution by three-dimensional approach. In this approach we simultaneously design the composition of beads solution and operating condition of coating and drying. By doing this we enhanced luminance of normal direction to the LGP by 5%(Double pieces of LDF).

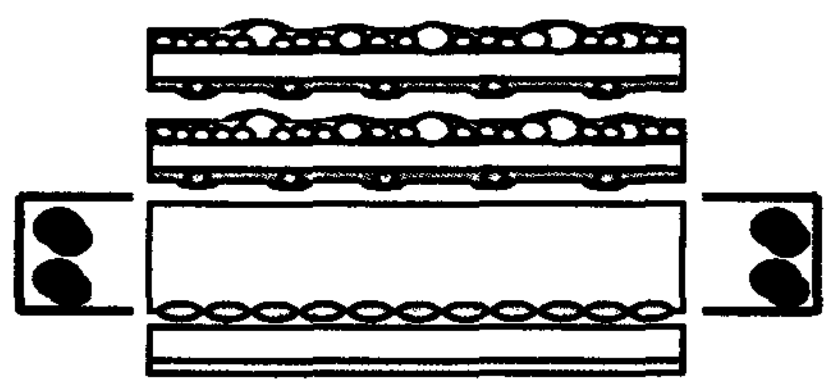

Figure 1. Schematic structure of Back light unit

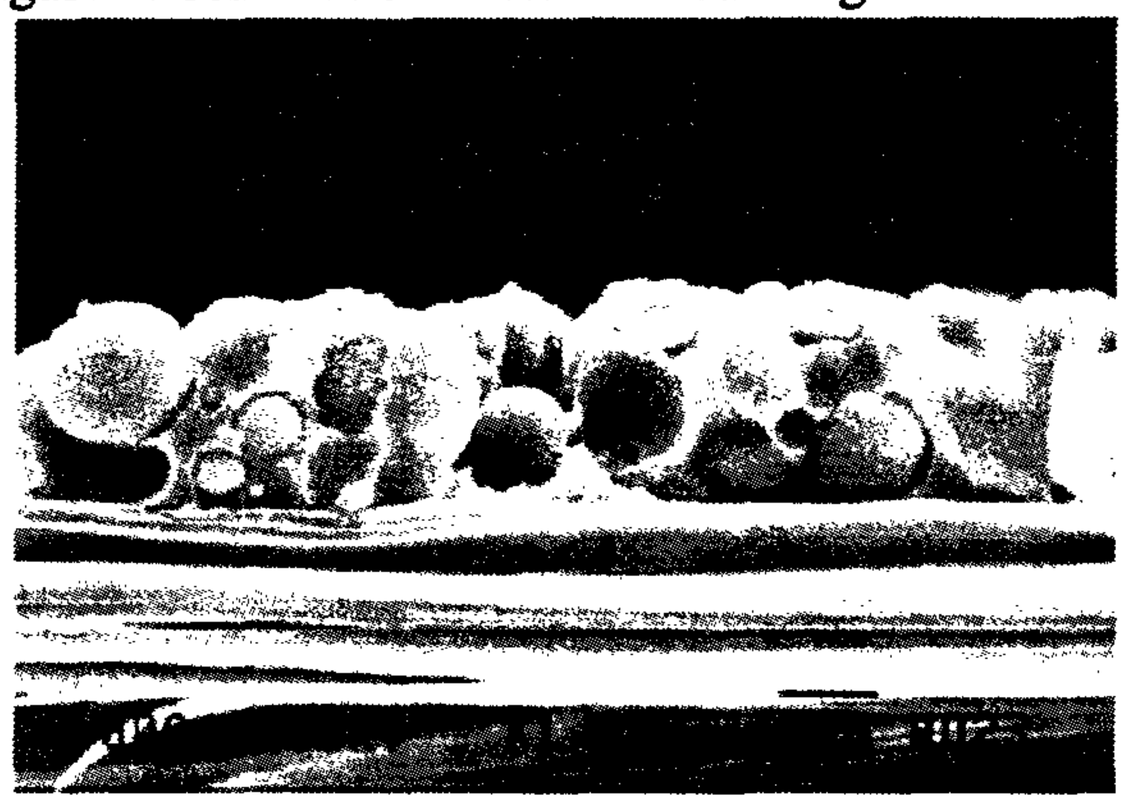

Figure 2. The cross sectional view of light diffuser films

Enforcement of Optical Performance

As shown in Figure 1. the light which comes from the LGP does not consist fully two dimensional light source, moreover it has the highest luminance around the angle of 60°. As shown in Figure 3, LDF enhance the normal direction luminance by refracting and diffusing light. Generally the luminance of normal direction to the LGP increases according to increasing of the number of diffuser films used. However above the 4 pieces of diffusion films the light loss through the LDF becomes larger than the effectiveness of the light concentration performance of LDF, thus the luminance of normal direction becomes to decrease.

Therefore to obtain higher luminance it should be preceded to enhance the performance of LDF itself.

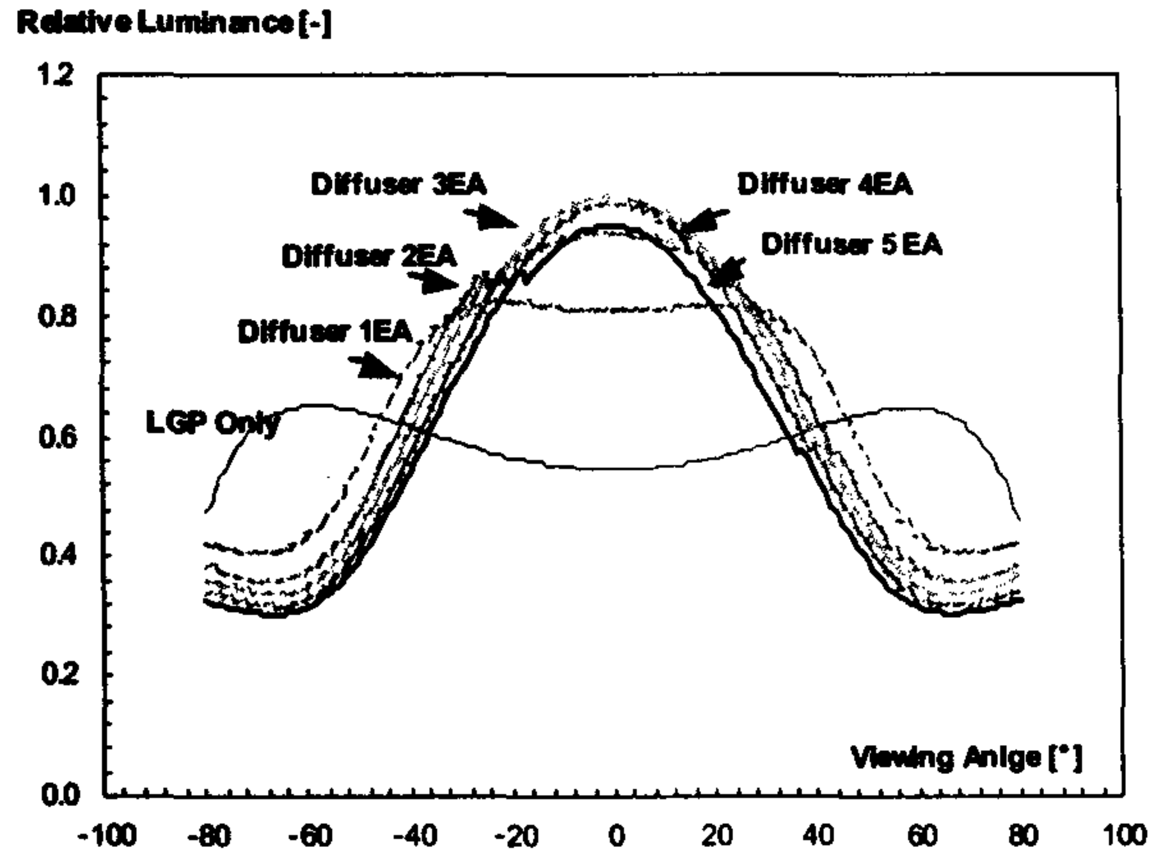

Figure 3. Luminance profile according to viewing angle with various optical film structure.

We could observe the optical properties enhancement by optimizing the size distribution and refraction index of organic fillers. Figure 4 shows the enhancement of brightness, especially the luminance of normal direction to the LGP. Considering the conventional diffuser gain is around 1.71, the luminance of enhanced LDF of normal direction to the LGP increases about 5% than the conventional one.

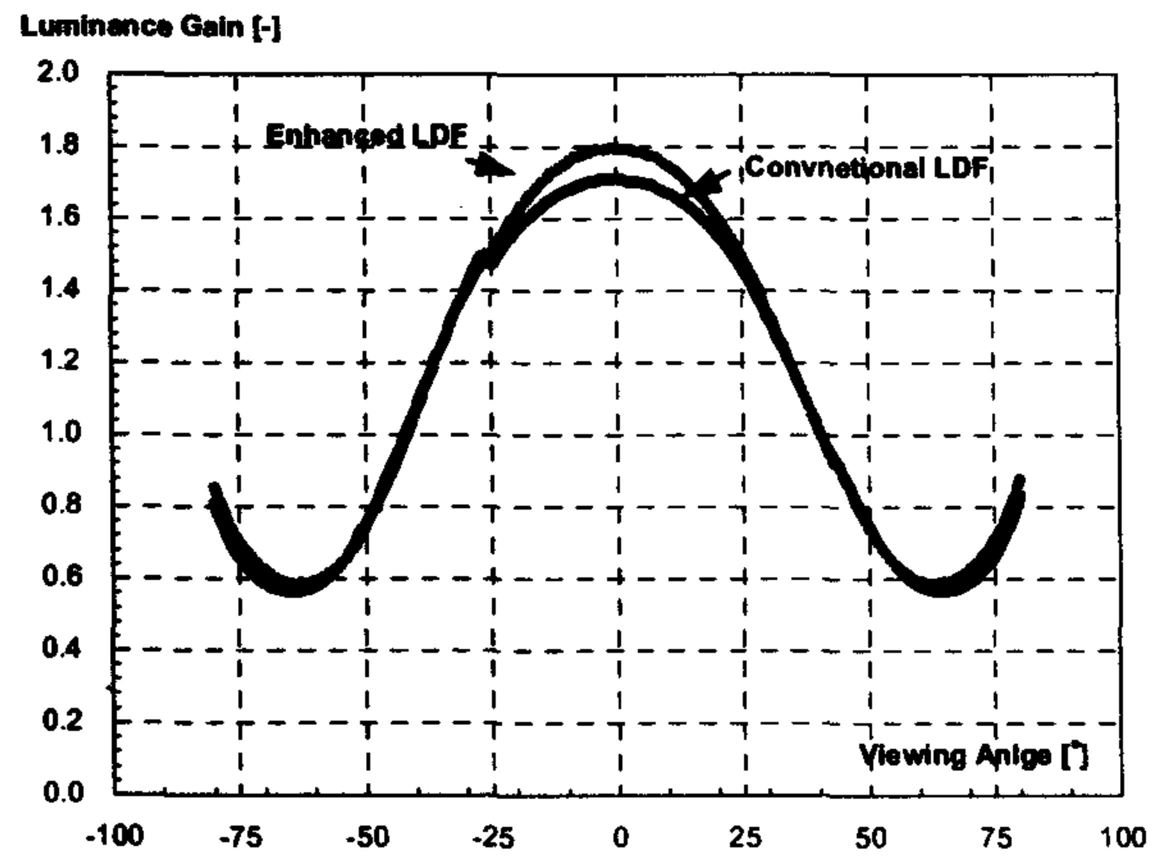

Figure 4. Comparison of luminance gain(reference to luminance which comes from light guide panel only) between conventional diffusion films and enhanced diffusion films according to the viewing angle.

Figure 5 and 6 show the refracted ray of light of conventional and enhanced light diffuser film. Considering the normal direction to the LGP as 0° then the angle of light which is emitted from LGP is around 60°. The conventional diffuser film refracts this ray of light about 18°, however the enhanced diffuser film refracts the ray of light as much as 24°. It increases the ray of light that is normal to the LGP, and increases the utilization of light

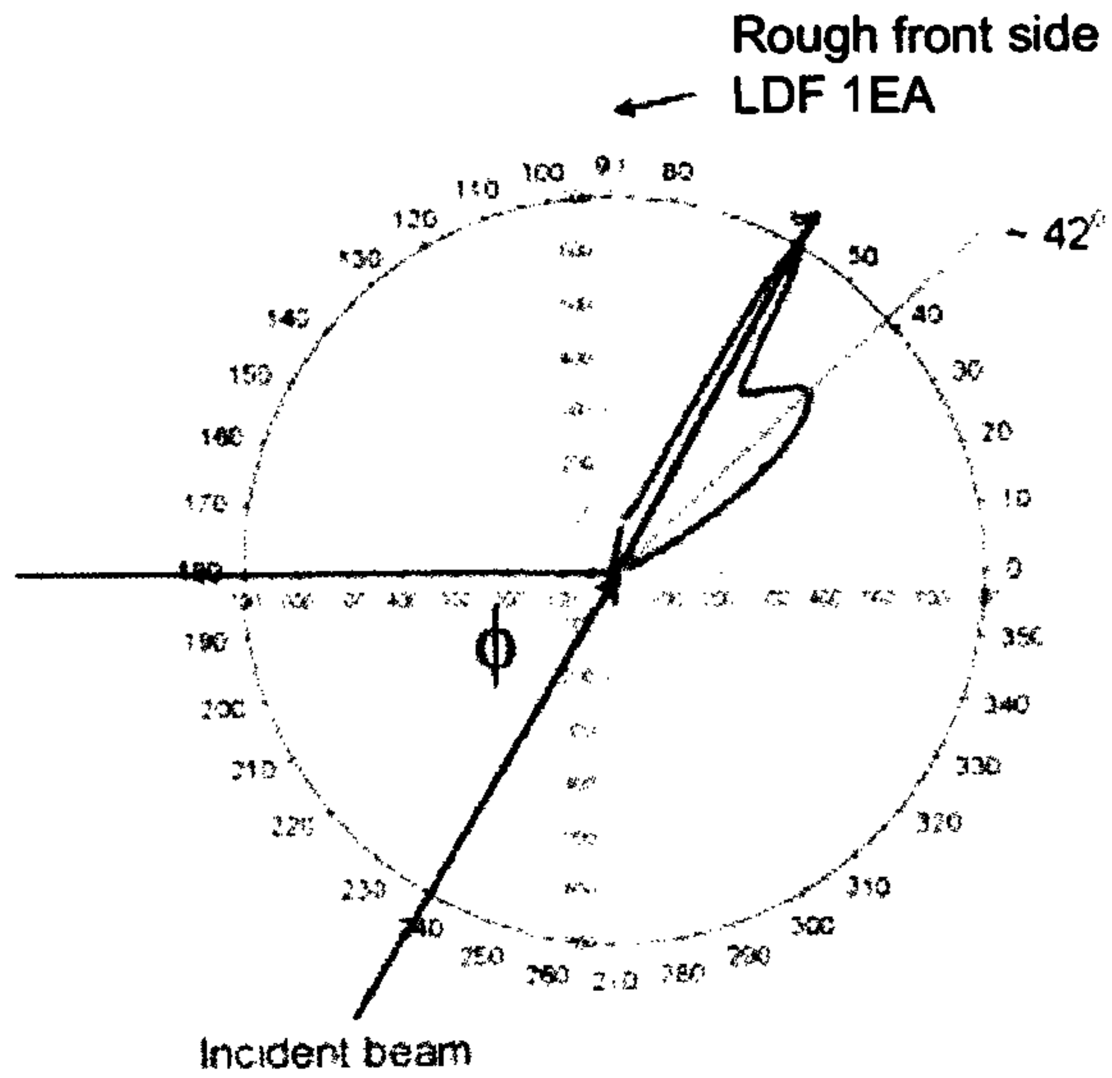

Figure 5. Optical properties of conventional LDF.

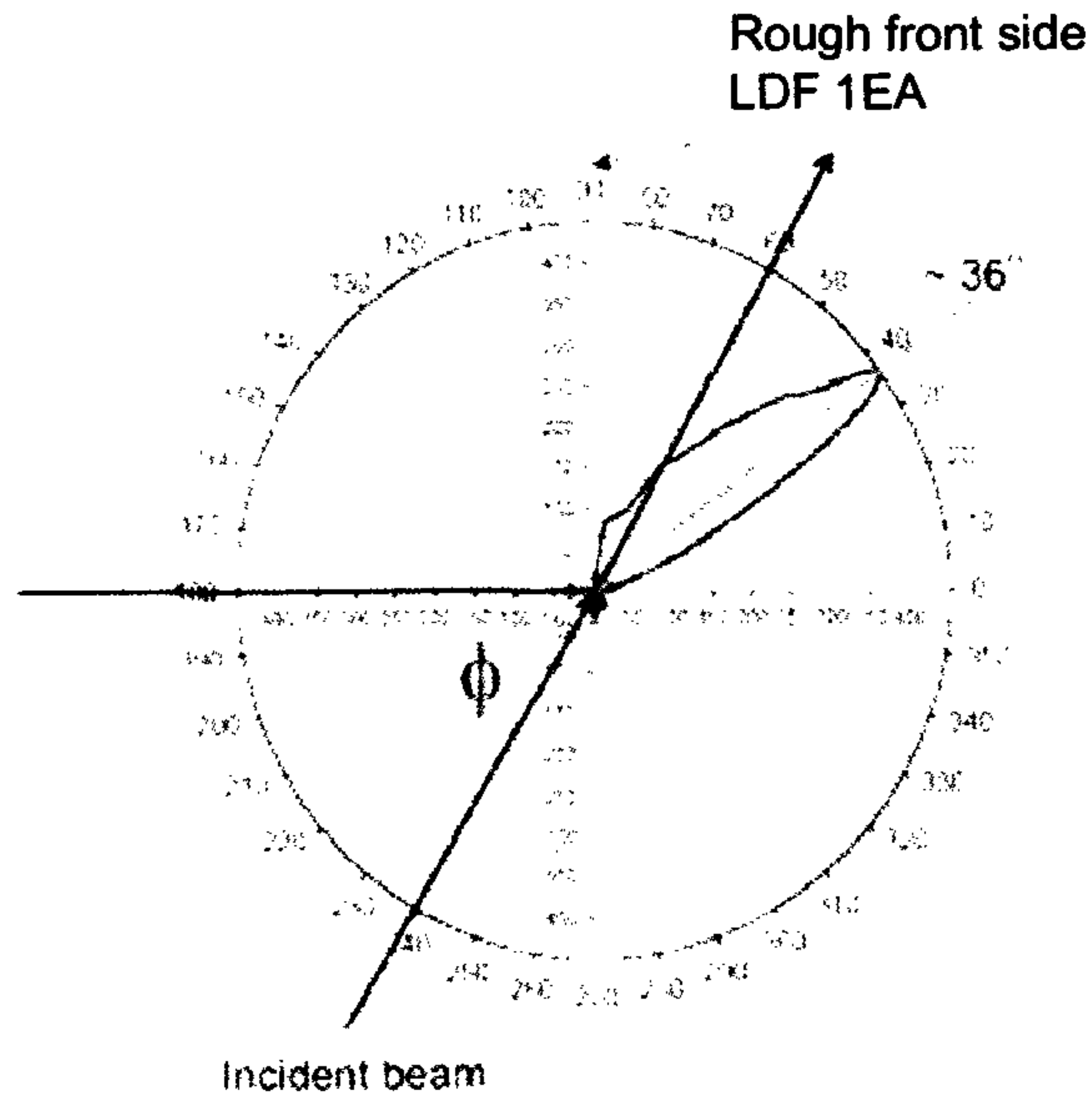

Figure 6. Optical properties of enhanced LDF.

As shown in Figure 2 the conventional diffuser film consisted of different sizes of piled up beads.

However as shown in Figure 7 and 8 the enhanced diffuser film consisted of uniform size of beads with single layer. It decreases the loss of light due to the scattering and absorption of light by the piled beads and at the same time it maximizes the utilization of the refractive characteristic of the beads.

Optimum Sets of Process Condition

To embody the designed beads layer onto the substrate we made the sets of optimum process conditions. Generally the whole process involves three continuous operations – (1) dispersion of beads to make uniform solution, (2) coating of solution to make uniform layer and (3) drying of solution coated film to obtain the final dried product.

First of all the beads should be dispersed uniformly, typically the size of beads ranges from sub micrometers to tens of micrometers. Therefore there exist spontaneous agglomeration forces among the beads. Carefully designed dispersion facilities enforce the appropriate shear and impact stress on the beads to stabilize the high concentrate beads solution.

To coat the high concentrate beads solution onto the substrate we used gravure coating method [3,4]. The depth, angles and pitches of cell of gravure roll were investigated and simulated by numerical and experimental method to coat the high concentrate solution uniformly across the substrate [3, 4].

As shown in Figure 9 the solution coated film is fed to the drying ovens – the temperature and velocity of the air could be adjusted independently among the ovens.

The microstructure of coated layer is determined during the drying process in which solvent is removed and the solution becomes to be concentrated. To make the single layer across the coating thickness we simulate the drying process with various drying conditions by numerical and experimental method [2]. The temperature and velocity of air in the first zone of the dryer made the critical difference for the final structure of beads layer. To make the single layer, the beads should have enough time to be landed onto the substrate. We suppressed the vaporization pressure of the solution during the constant drying rate period.

As a result we could obtain uniformly distributed single layer of beads(Figure 7 and 8).

Conclusions

To enhance the brightness of backlight unit of TFT-LCD, we developed high performance light diffusion films by designing optical beads layer. The refractive index and the three dimensional structure of beads play an important role for the improvement of performance of LDF. The uniformly distributed single layer increases luminance of backlight unit in normal direction to the LGP.

The uniformly distributed single layer could be obtained by careful design of whole process of coating[2, 3, 4].

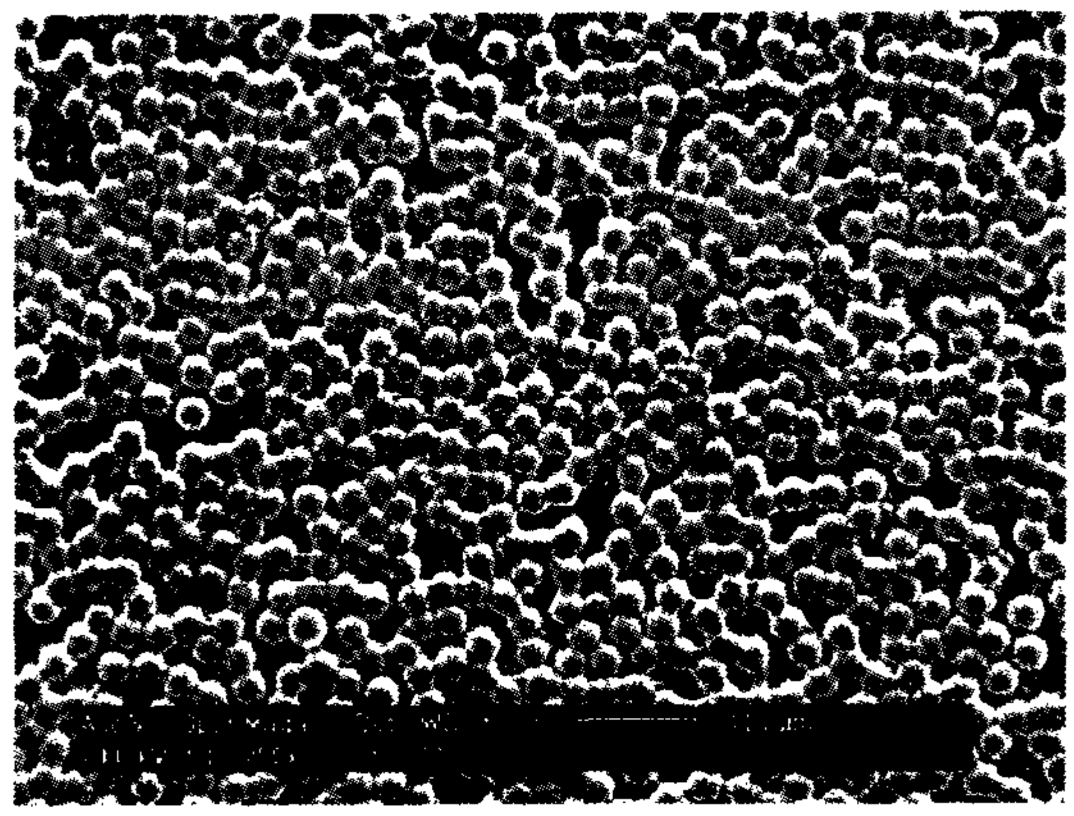

Figure 7. Front view of enhanced LDF

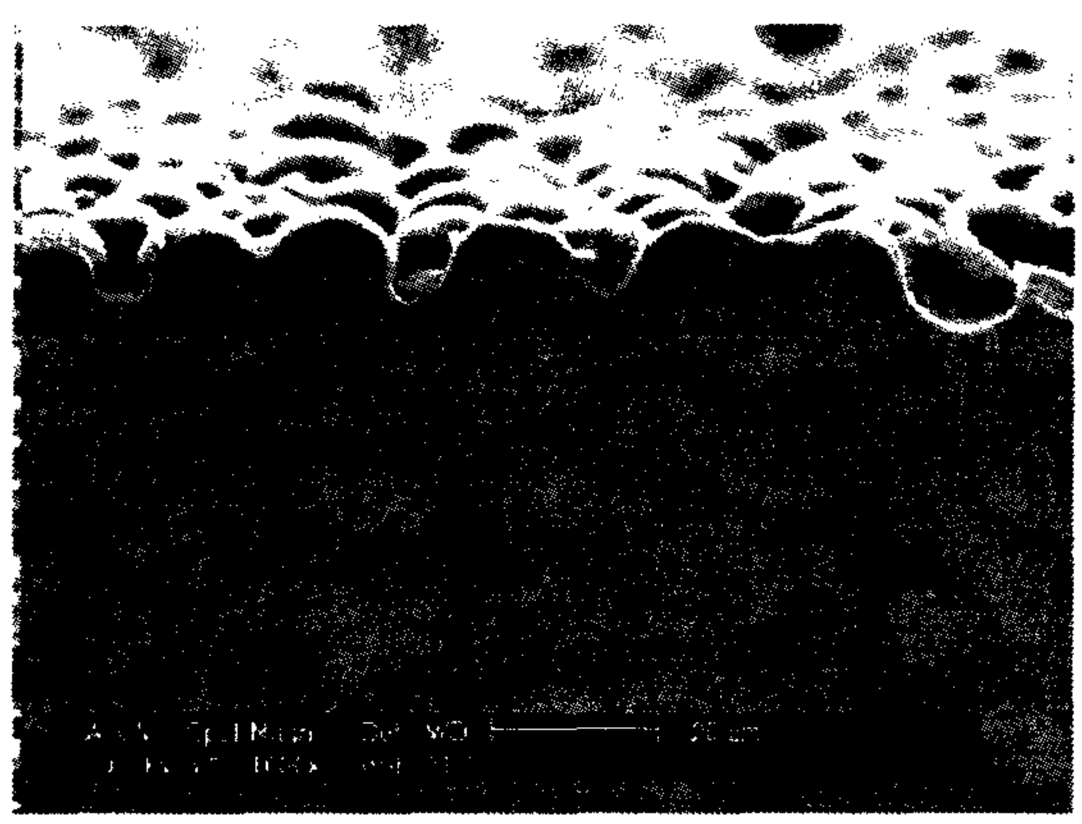

Figure 8. Cross sectional view of enhanced LDF

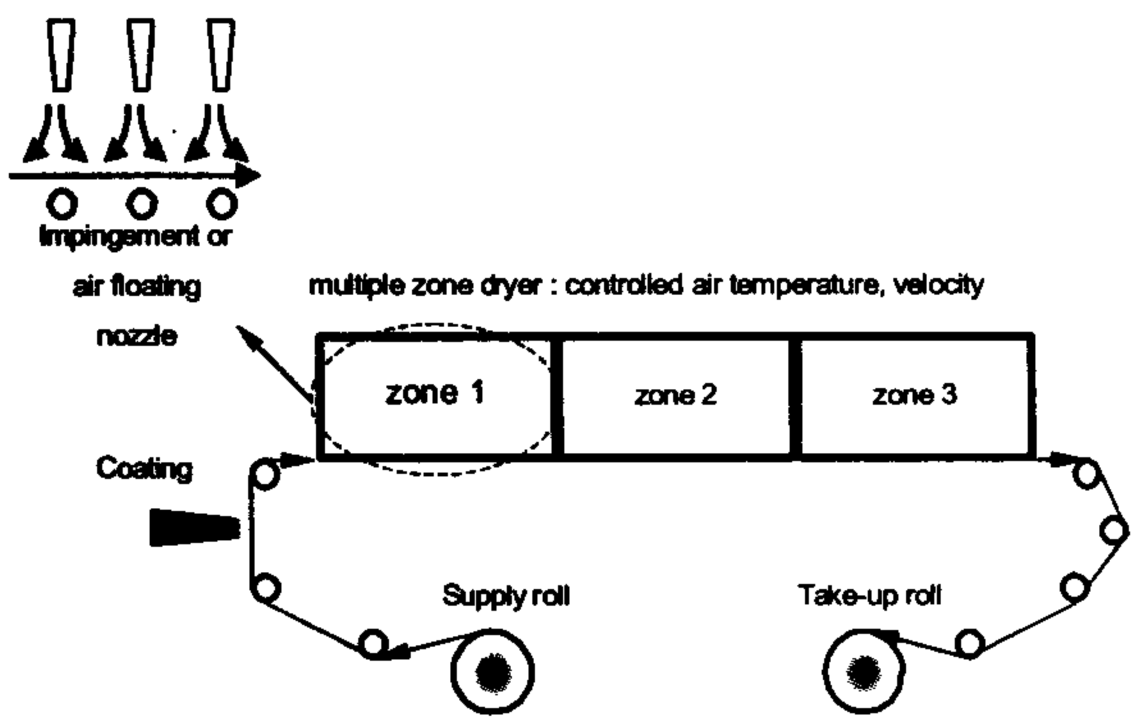

Figure 9. Schematic drawing of the facility for the LDF coating process [2]

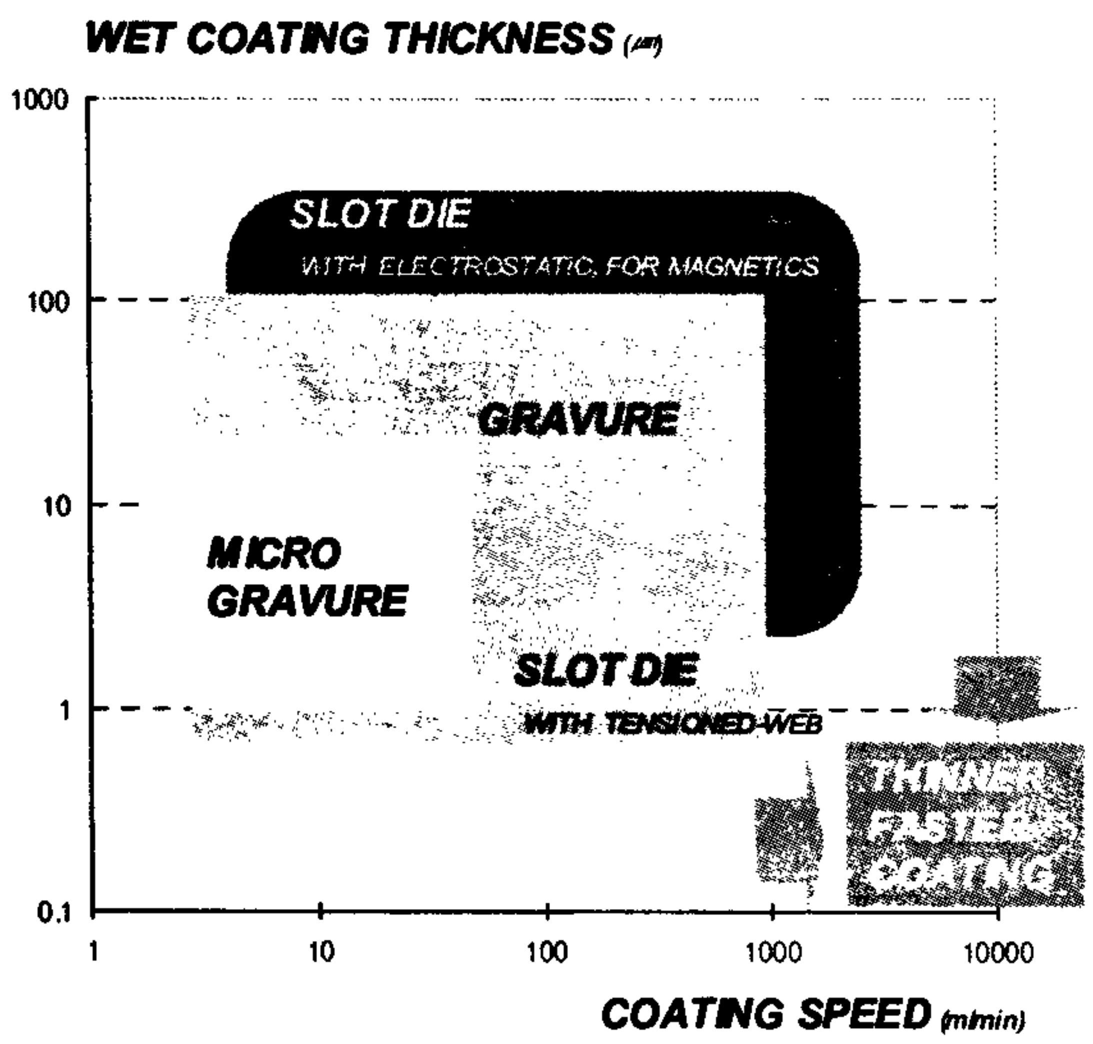

Figure 10. Coating window for the various kinds of coating method [4]

Reference

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