Chapter 5

Discussion

Effects of Production History of Glass on Bloom Formation

1. Effect of type of annealing furnace

The result from table 4.2 and especially from the extraction test from table 4.4 indicate that the amount of Na_2O in the surface of samples from the direct lehr, B1408A, were less than the others. This is because the atmosphere in the lehr contains SO_2 which reacts with the alkali at ~ 650 °C and leads to its evaporation.

2. Effect of forming process

As mentioned before, that samples from both press-press and press-blow forming were investigated. The results were distinctly different. The surfaces of press-press samples were very weak, the highest dissolution depth seen from table 4.1 and the amount of Na_2O on surface layers including the extraction test in table 4.4, support this conclusion. After annealing, the amount of Na_2O in the surface became very low, indicating that there is no condensation of Si-OH groups in the glass surface. The observations can be explained as follows: while moulds are contacting with hot glass melts, stress is built up and cannot dissipate well in the case of press-press forming.

From figures 4.2-4.5, profiles show that the amount of Na_2O in the surface of all samples exceeded the Na_2O contained in the glass composition (14.30 wt. %). Therefore, the tendency for bloom formation is high. Figures 5.1 and 5.2 show the comparison of the distribution of Na_2O relating with dissolution depths among the non-annealed and annealed groups, respectively. In the non-annealed group, the amount of Na_2O in the surfaces of P0340 and B1408 are high and increasing with the dissolution depth, while B1213 and BG show nearly constant concentration. Comparing B1213 and B1408, both from press-blow forming, the efficiency of stress releasing in the surface of B1213 is better.

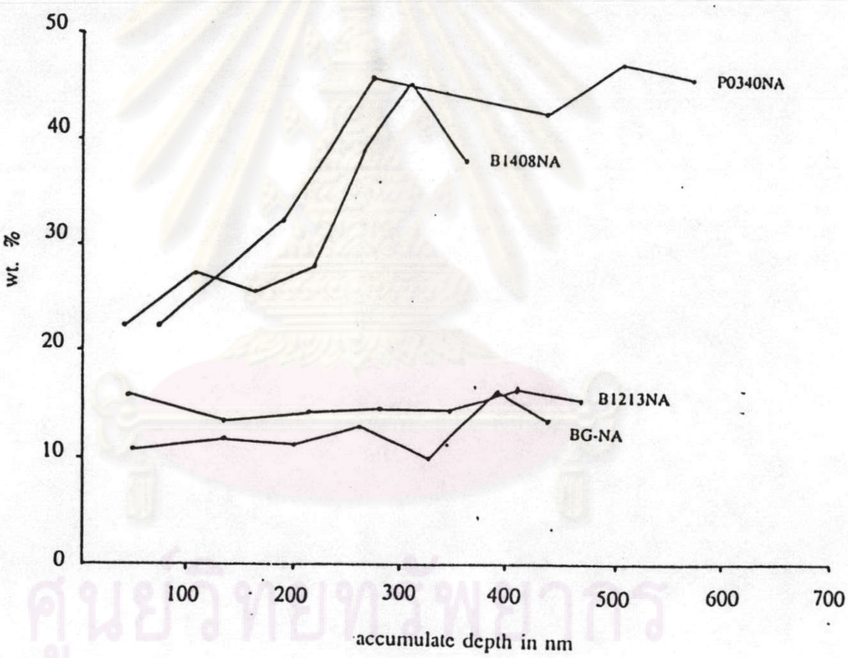


Fig. 5.1 Profiles of Na_2O distribution in the surfaces of non-annealed samples.

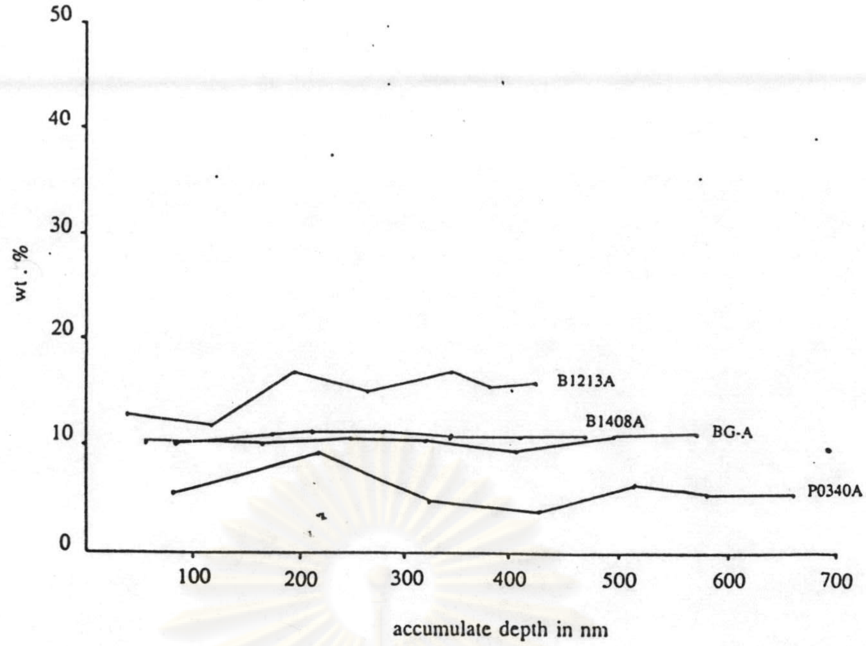


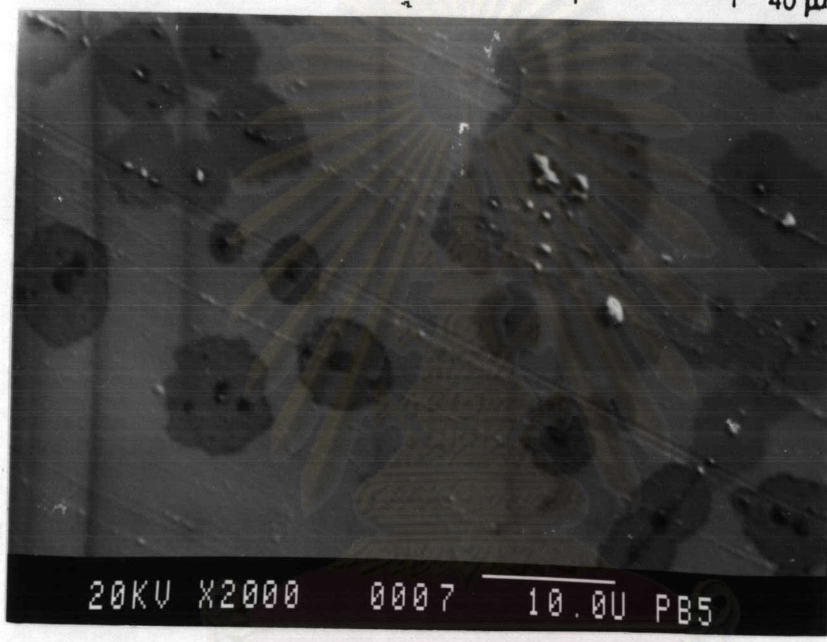
Fig. 5.2 Profiles of Na_2O distribution in the surfaces of annealed samples.

After annealing, B1213 and BG have no significant change, but B1408 and P0340 are dramatically reduced in sodium.

Characterization of Existing Bloom

The dark phases shown in figure 4.10 are not bloom, but it is believed that causing by contact behavior of hot glass melts towards mould materials. This sticking influences the surface durability and let surface defect like bloom occur easily. Figure 5.3 shows the metallographic section of mould after 76 h of cyclic contact of the glass melt at 1050 °C presented by Manns, Doll and Kleer (1995).

(mould)



PB5

Fig. 5.3 Corrosion of mould and PB5 surface.

The defect is similar to the micrograph of PB5. That leads to the assumption that the dark phases in the surfaces are caused by mould sticking. The composition of bloom occurring in the center of phases is close to the mineral composition of comentic and feldspartic groups.

Effect of Glass Composition and Reformulation

Generally, the rate of alkali extraction from glass by aqueous solutions is largely determined by the composition of glass. The rate decreases with decreasing alkali content of glass, with decreasing ionic radius of the alkali ion. In this test, the maximum reduction of Na_2O was approximately 2 wt. % (sample called N12.5). Figure 5.4 shows profile of Na_2O concentration compared to the original formula.

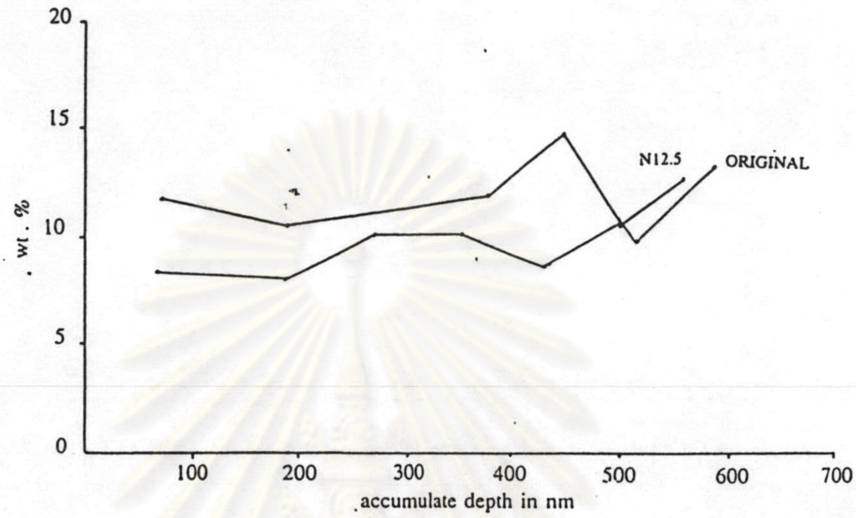


Fig. 5.4 Profiles of Na_2O distribution in the surfaces of the original and reformulated formula (N12.5).

The concentration of Na_2O in the surface is reduced after the reformulation. So it can be expected that bloom formation is reduced too, the extraction test in table 4.8 supports this. However, the results of HF etching depths from table 4.6 show that the bonding of silica in the glass surface is not improved by the reformulation.

After the investigation was finished, the factors influencing the bloom formation are categorized as follows:

Factors Influencing the Bloom Occurrence in the Factory

1. Contact behavior of hot glass melts towards mould materials,
2. Atmospheric conditions in the warehouses,
3. Overall Na_2O in the glass formula,
4. Forming process,
5. Type of annealing furnace.

Suggestions

In accordance with the factors influencing bloom occurrence, the following options for bloom prevention are summarized below:

1. Based on the similar surface appearances seen by SEM in figure 5.3, mould sticking is believed to be the primary cause of bloom. Although bloom formation may occur anywhere at the glass surface, the driving force of bloom formation is high especially in the damaged areas. In other words, such areas are weak. If the sticking problem is overcome, bloom formation is expected to decreased significantly. Within the scope of this thesis, a ready-made solution to the problem cannot be offered. The entire time-temperature schedule of forming needs to be optimized.

2. Changing the atmospheric conditions in the warehouses is an option which seems to be more practical and convenient than option 1. The humidity in most of the warehouses is high, so that dew condensed from the atmosphere, especially in warehouse no. 8. The way to solve this problem is to heat the atmosphere by a few centigrades only. This will make the relative humidity fall down, therefore the dew point will not be reached.

In this case, there must be some investment for piping, blowers conveying hot air to the warehouse. The best source of hot air is the hall hosting the tank furnace.

3. The reformulation of the glass formula was also studied. It was concluded that the concentration of Na_2O in the glass surface can be decreased by decreasing Na_2O in the formula. This can be achieved under the boundary condition of constant workability of the glass melt. The resulting glass has a better hydrolytic stability. However, like option no. 1, this option is a very demanding task.

4. The sulfur content in the packing material did not seem to have any influence on the bloom formation, as sulfur was not identified as a constituent of the bloom.