

Elvax® and Wax: A Good Fit

Overview

DuPont™ Elvax® ethylene vinyl acetate (EVA) and wax complement each other in a variety of uses including hot-melt adhesives and curtain coatings for paper. Each component has a certain set of properties that makes the blend perform well. The wax is relatively low-priced and has low viscosity, good barrier properties to water vapor, and very fast set time. DuPont™ Elvax® has high cohesive strength and good adhesion to paper, and allows the wax to maintain its water barrier properties in creases and folds. In most cases, both wax and Elvax® meet FDA packaging guidelines for direct food contact.

Of the three major hydrocarbon waxes, paraffin wax is most often used with Elvax®. Paraffin wax is similar in chemical composition to polyethylene (PE), but has surprisingly poor compatibility with PE. Elvax® resins with 18 to 28 percent vinyl acetate (VA) have the best compatibility with paraffin wax.

Applications

The largest commercial use for an EVA/wax blend is in hot-melt adhesives, where Elvax® and wax make up about two-thirds of the formulated adhesive. Hot-melts are used for closing cases and cartons or for binding paperback books and magazines.

Wax and Elvax® are also used in food packaging applications as curtain coatings for corrugated paper boxes. The EVA/wax blend waterproofs the coated paper so that it can be used to ship vegetables or poultry from the farm to the market. There are many other smaller end-uses for EVA/wax blends, ranging from slow-burning candles to glue sticks used by hobbyists and do-it-yourselfers.

Background

Elvax® is a copolymer of ethylene and vinyl acetate. The two key parameters that determine their properties are weight percent vinyl acetate in the copolymer and melt index (MI). Elvax® is made in basically the same process used to make low-density polyethylene (LDPE), and many of the properties of Elvax® can be understood by comparing Elvax® to LDPE. As more vinyl acetate is added to the polymer, it disrupts the polyethylene crystallinity, which in turn lowers the melting point, modulus, and hardness. The VA makes the polymer more polar, which improves adhesion to polar substrates and aids in solubility.

Melt index is a measure of how many grams of polymer flow through a narrow orifice held at 190°C (374°F) for ten minutes. MI is an indication of viscosity and molecular weight (MW). If the MI is low, the viscosity and MW are high. If the MI is high, the viscosity and MW are low.

Types of Waxes

The waxes most often used with Elvax® are the low-MW hydrocarbon resins listed below:

- **Paraffin wax**
- **Microcrystalline wax**
- **Synthetic wax**

The paraffin and microcrystalline waxes are present in crude oil and are separated from the crude in a refinery.



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The paraffin leaves the refinery with lube oil and is separated in a lube oil plant. The paraffin is a straight chain hydrocarbon having a melt point (MP) of about 49° to 71°C (120° to 160°F). The microcrystalline wax is separated from the asphalts and is higher in molecular weight and more branched than the paraffin. It has a higher MP (60° to 89°C [150° to 190°F]), which gives it better heat resistance than the paraffin.

Synthetic waxes are either low MW polyethylenes or polymethylenes. The polymethylenes are produced from syngas plants using the Fischer-Tropsch process. Synthetic waxes melt at relatively high temperatures, and provide good heat resistance and fast set times. They are significantly higher in price than petroleum waxes.

Compatibility of Elvax® and Paraffins -- 18 Percent and Lower VA

Why is polyethylene incompatible with paraffin wax when Elvax® is compatible? Polyethylene is a straight chain hydrocarbon resin with a chemical composition almost exactly the same as that of paraffin. Elvax® is a copolymer of ethylene and vinyl acetate, and the VA makes the EVA polymer more polar than wax.

Figure 1 shows a graph of cloud point in a 66°C (150°F) melt point paraffin wax versus percent VA in an Elvax® copolymer. This graph shows why Elvax® resins are used in wax blends. To measure cloud point, a blend of 10 percent polymer in wax is heated until the blend becomes clear; then it is allowed to cool. The cloud point is the temperature at which the solution starts to cloud up, usually by forming white droplets. Figure 1 shows that Elvax® resins with 18 to 28 percent VA have the best compatibility with paraffin wax.

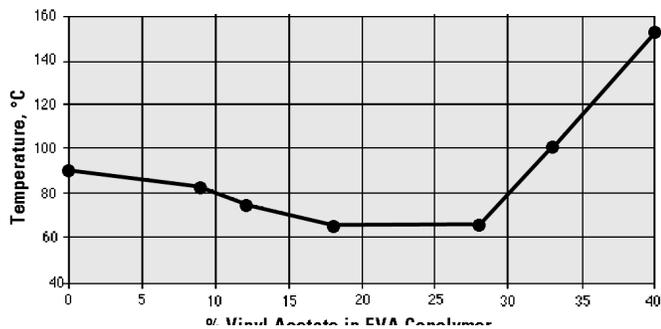


Figure 1. Cloud Point for Elvax® Polymers in a 150 MP Paraffin Wax (66°C)

The compatibility of Elvax® with the wax seems to be related to the freezing points of Elvax®. **Figure 2** shows the freezing point and cloud point versus percent VA. We measured the melting and freezing points by differential scanning calorimeter (DSC). Low-density polyethylene melts at 110°C (230°F), and freezes at about 89°C (192°F). Its cloud point in paraffin wax is about 90°C (194°F). The cloud point measurement is actually the temperature at which the LDPE crystallizes. It crystallizes before the wax does; then, at a lower temperature, the wax freezes around the polyethylene. The polyethylene acts as a filler and does not improve the properties of the wax.

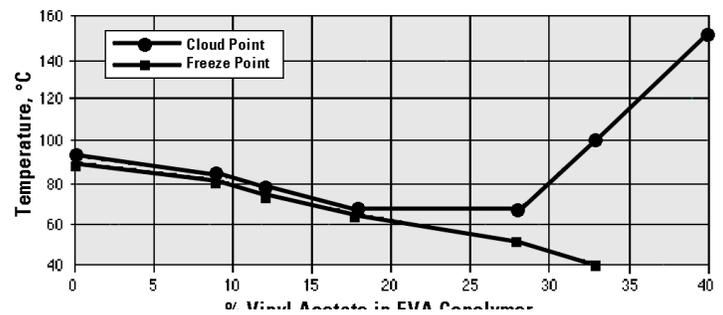


Figure 2. Cloud and Freeze Points in 150 MP Paraffin Wax (66°C)

Elvax® 460, an 18 percent VA copolymer, melts at 87°C (189°F), and freezes at 66°C (150°F). The freezing point of the polymer ranges from 40° to 80°C (104° to 176°F), with most of the freezing occurring at 66°C (150°F). The polymer freezes at the same temperature as wax. This co-crystallization process allows the EVA resin to reinforce the wax.

Elvax® with 28 Percent and Higher VA

At vinyl acetate levels greater than 28 percent, the relationship between the EVA and wax changes. To study this, we used a model from polymer-polymer blend theory. **Figure 3** shows a typical phase diagram for a two-component mixture.

At low levels of each component, the two polymers are compatible, but in the midpoint region they are incompatible. Blends in the midpoint region will become compatible if the temperature is raised to the critical temperature (Tc). We chose the cloud point as a measure of compatibility. Typically, the cloud point is measured at 10 percent polymer in wax, but we chose to vary the polymer content from 1 to 30 percent.

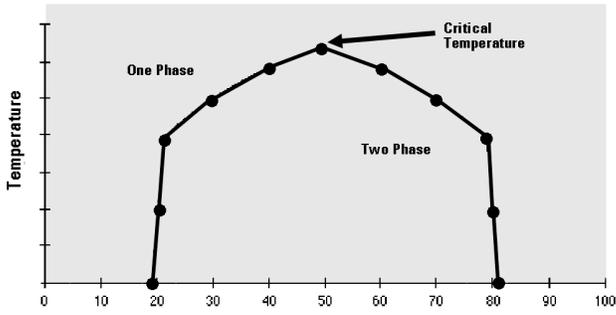


Figure 3. Generalized Phase Diagram for Two-Component Blend

Figure 4 shows the cloud point for a 28 percent VA copolymer (Elvax® 240) as the percent polymer in the wax is changed. For a 28 percent VA copolymer, the cloud point does not change very much as the polymer concentration is changed.

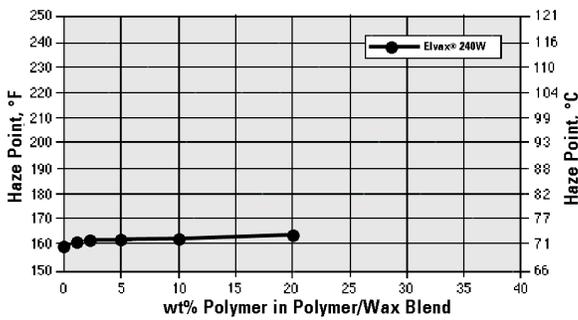


Figure 4. Haze Point of Elvax® in Paraffin Wax

Figure 5 shows the cloud point for an experimental 30 percent VA copolymer as the percent polymer in the wax is changed. The maximum incompatibility is seen at 10 percent polymer. For this work, we used the term “haze point.” Typically, the cloud point is measured at the bottom of a test tube and is seen when the first white droplet is formed. At the high VA levels, the solution starts to become opaque long before the first drops are seen at the bottom of the test tube.

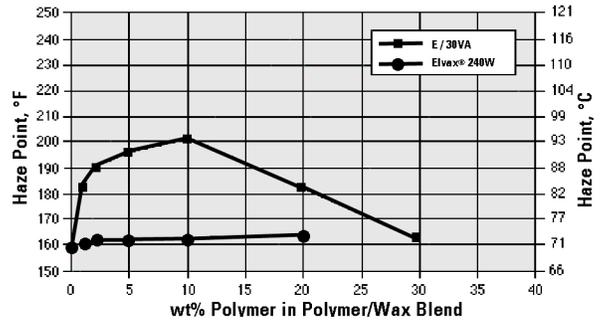


Figure 5. Haze Point of Elvax® in Paraffin Wax

Figure 6 is the same as Figure 5 except that the VA level is now up to 33 percent VA (Elvax® 150). The compatibility is worse at the higher VA levels.

As the vinyl acetate content is raised above 28 percent, the polymer starts to become incompatible with paraffin wax. The worst incompatibility occurs when the polymer concentration is about 5 to 10 percent. A 33 percent VA resin is compatible with wax under conditions where the concentration of Elvax® is greater than 30 percent. A 40 percent VA resin is also compatible with wax, but the conditions are more restricted.

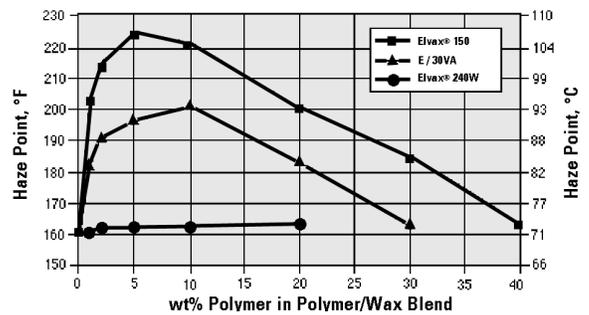


Figure 6. Haze Point of Elvax® in Paraffin Wax

Microcrystalline Wax -- Low VA Resins

Microcrystalline wax is priced a little higher than paraffin. It has a higher softening point than paraffin and is also more branched. We studied the compatibility of different EVAs with microcrystalline wax. We used a filtered microcrystalline wax from Conoco, Microwax 783, which had a melt point of 79°C (175°F). As before, we used cloud point and haze point as an indication of compatibility.

We measured the compatibility of EVA resins with the microcrystalline wax. **Figure 7** shows the cloud point at 10 percent polymer for EVA copolymers with different VA levels. Once again, the freezing point of the polymer is the key parameter in determining compatibility. The melting point of a 9 percent VA Elvax® is about 100°C (212°F), and its freezing point is about 80°C (176°F).

A major difference between the micro and paraffin wax is that low VA resins (9 to 15 percent VA) are compatible with the micro waxes, but not the paraffin waxes. This is because the micro waxes have a higher freezing point than the paraffins.

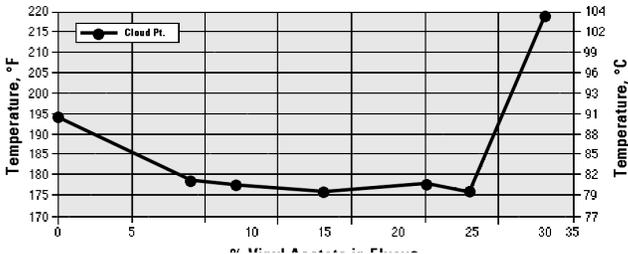


Figure 7. Cloud Point for Elvax® in Microcrystalline Wax

Microcrystalline Wax -- High VA Resins

We measured the compatibility of the high VA resins, starting with Elvax® 350 (25 percent VA), with Microwax 783. The results are shown in **Figure 8**. The Elvax® 350 was compatible with the wax between 1 and 30 percent polymer in the wax blend. Elvax® 240 (28 percent VA) was also compatible throughout the range of 1 to 30 percent polymer. When we tested the compatibility of the Elvax® 150 (33 percent VA), there was a dramatic change. At 1 and 2 percent polymer, the Elvax®/wax blend was compatible. Between 5 and 30 percent polymer, the system became more and more incompatible (higher cloud point).

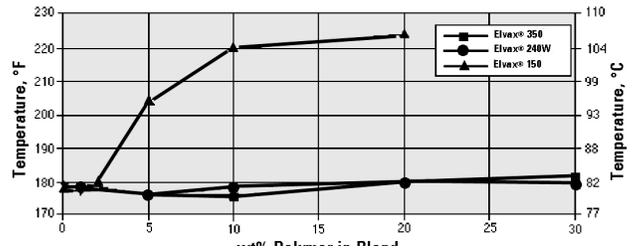


Figure 8. Haze Point for Elvax® in Microcrystalline Wax

Synthetic Wax

Synthetic waxes have high melting temperatures and are used in hot melts to give good heat resistance and fast line speeds (quick setup time). They are significantly higher in cost than the petroleum waxes. For this study, Parafint H-1 was used, which has a softening point of 104°C (220°F). It is a by-product of the syngas plants and is unique because it is based on polymethylene. There are other synthetic waxes based on polyethylene chemistry.

We tested the compatibility of three different Elvax® polymers with Parafint H-1. The results are shown in **Figure 9**. The 25 percent VA resin (Elvax® 350) had a constant cloud point from 0 to 30 percent polymer. The 28 percent VA resin (Elvax® 240) had a maximum haze point of 129°C (265°F). The 30 percent VA resin was incompatible with the Parafint H-1.

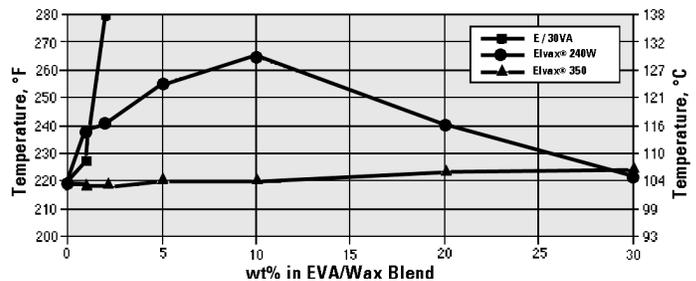


Figure 9. Haze Point for Elvax® in Synthetic Wax

We did not test the low VA resins with the Parafint H-1. Based on its high softening point, however, it should be compatible with LDPE and all of the low VA resins.

Conclusion

DuPont™ Elvax® EVA polymers have been used for many years in combination with hydrocarbon waxes. Each component brings a certain set of properties that complement the other component. By knowing the melt point of the wax and the freezing point of the EVA copolymer, one can predict the compatibility of the blend. This general rule does not hold up for VA levels greater than 28 percent. Above 28 percent VA, the compatibility of the EVA/wax blend is limited.

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