High Performance Double-sided PSA Tape Produced by UV Irradiation

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1. Introduction

This paper describes the recent development in our research of acrylic syrup UV polymerization pressure sensitive adhesive and its application in double-sided tapes for construction. This technology provides solutions of environment problems such as residual toluene emissions from adhesive products, one of the sick house syndrome causes, or toluene-free manufacturing process that reduce emission of volatile organic compound (VOC) and energy from factories.

The features of UV irradiation polymerization and the double-sided tapes product characteristics and properties are discussed in detail.

2. Overview of Acrylic PSA Tape

Acrylic Pressure Sensitive Adhesive(Acrylic PSA) is separated into two distinct groups, solvent based and non-solvent. Solvent based PSA is superior in molecular weight adjustment and thin coating technology. However, elimination of organic solvent such as toluene is necessary because acryl monomers are dissolved in it.

Non-solvent acrylic PSA consists of emulsion PSA, hot-melt PSA and radiation curable/polymerization PSA. Emulsion PSA, due to its emulsifying agent content, has inferior water resistance. And another disadvantage is they need to consume huge amount of drying energy. Manufacturing of hot-melt type PSA tape is favorable than using emulsion PSA, however its heat resistance is inferior to emulsion PSA because it can not have sufficient degree of molecular weight by the nature of hot melt polymerization.

In several types of radiation curable/polymerization PSA, this paper focuses on acryl syrup UV polymerization PSA (Syrup PSA) and tape using Syrup PSA. Syrup PSA has no polymer molecular weight restriction as solvent based PSA, so its polymer can be designed flexibly Syrup PSA mainly consists of acryl polymers dissolved in acryl monomers. Various methods of Syrup PSA manufacturing are known. [1) 2) 3)] Manufacturing of Syrup PSA tape starts by mixing Syrup PSA and photoinitiator, then coat the mixed liquid onto a substrate and irradiate UV light to polymerize all acryl monomers. There are some disadvantages of Syrup PSA tape that hazardous property of monomers during tape manufacturing process, narrow range of tackifier choice, inhibition of polymerization due to oxidation, and possible shrinkage of film substrate due to heat generation during polymerization.

3. Photoinitiator for the Polymerization

Benzophenone initiators and acetophenone initiators are readily available as photoinitiator and can be employed to initiate radical polymerization of the acryl monomers in Syrup PSA by UV irradiation. Its polymerization rate depends on the kinetic rate constant of the propagation reaction and termination reaction. However, it is significantly influenced by the concentration of photoinitiator, optical-absorption coefficient. UV irradiation intensity, monomers concentration and composition of monomers.

Addition of UV initiator and polymerization behavior at the time of UV irradiation correlate during polymerization process in Syrup PSA tape, Figure 1 shows correlation of conversion ratio and number of UV irradiation passes when amount of photoinitiator is adjusted to produce polymers with the same weight-average molecular weight (750,000) by different UV irradiation intensities (40 mW/cm^2 and 200mW/ cm^2). The results show that Syrup PSAs designed to have same molecular weight yields the same conversion ratio regardless of the UV irradiation intensity. In order to achieve the desired molecular weight, at constant conversion rate, adjustment of irradiation condition and initiator concentration is needed. The conversion ratio can be adjusted by selection of the optical-absorption coefficient of the UV initiator and UV polymerization at near-UV region by black light is widely known.[4) 5) 6)]

Figure 2 shows the correlation between the number of UV irradiation and conversion ratio. The conversion ratio is proportional to the number of UV irradiation intensity. However, the polymer molecular weight decreases at the elevated intensity. In order to highly polymerize the polymer, relatively low intensity and longer time of irradiation are needed.

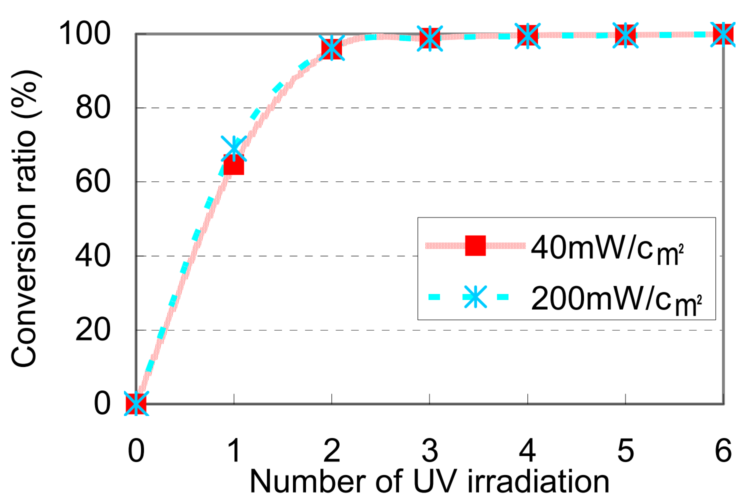

Figure1. Conversion ratio change at polymerization where Mw is fixed at 750,000

PSA : 2EHA/AA syrup, Heating residue 25%
Coating thickness : 57μm
UV lamp : H-bulb made by Fusion UV System,Inc
(PET film laminated during irradiation)

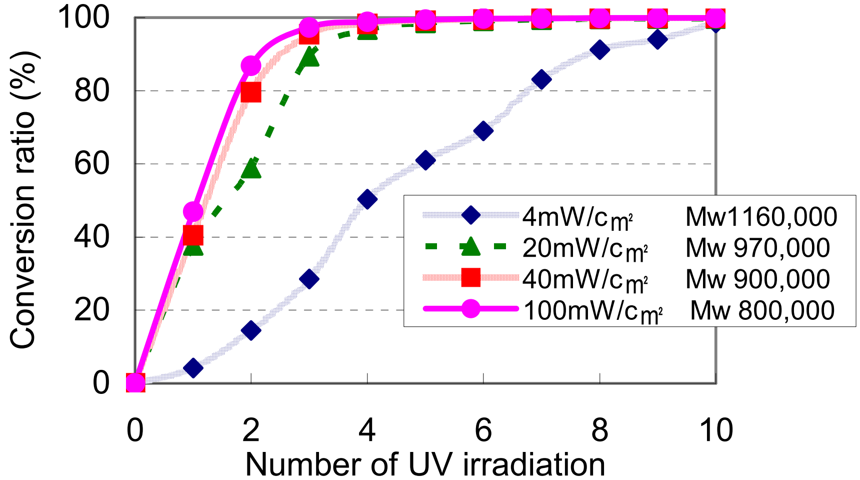

Figure2. Correlation between number of UV irradiation and conversion ratio at constant addition of photoinitiator

PSA : 2EHA/AA syrup, heating residue 25%
Coating thickness : 57μm
Photoinitiator : 0.3wt%

4. Inhibition factor of polymerization

Inhibition of polymerization by oxygen occurred in the radical polymerization initiated by photoinitiator. Figure 3 shows the correlation between the number of UV irradiation passes and the conversion ratio under various conditions. At 5% oxygen concentration, the conversion rate and the molecular weight of the generated polymer significantly decrease in comparison to the method of laminating the coating surface with a film liner. The lamination coating process scheme is shown in Figure 4. Other methods are also being developed in order to prevent inhibition of polymerization by oxygen. [7) 8)]

Acryl polymers with highly polar acryl monomer due to its ester group results a weak bonding strength to non-polar materials such as polypropylene. For this reason, in many cases it is difficult to obtain a sufficient adhesive performance only with acrylic components. The adhesion performances could be improved by adding tackifiers to improve the adhesion properties. Figure 5 shows correlation between the number of UV irradiation passes and conversion ratio of acrylic syrup with addition of various tackifiers. Inhibition of polymerization and decrease in the molecular weight are observed when tackifier is added in conventionally used Syrup PSA. Addition of tackifier with methacrylate acid ester as the main component in the acrylic syrup does not show the inhibition of polymerization.[9)]

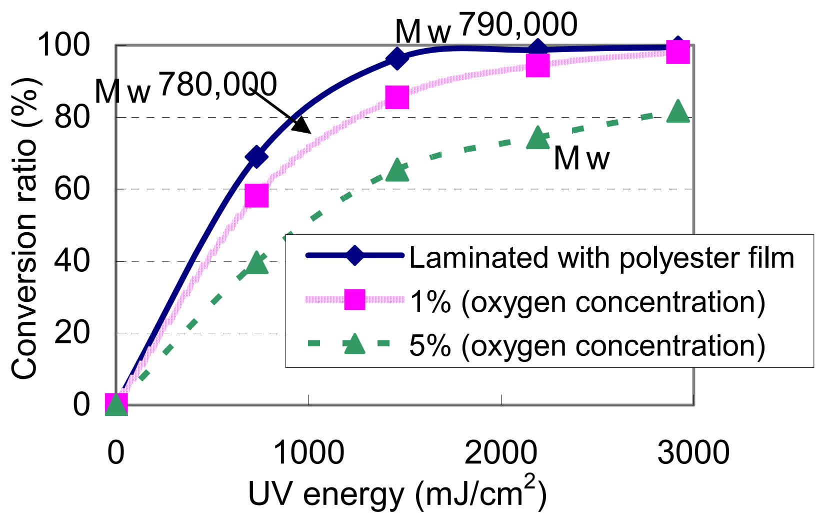

Figure3. Influence of oxygen on polymerization behavior

PSA : 2EHA/AA syrup type, heating residue 25%
Irradiation intensity : 200mW/cm^2

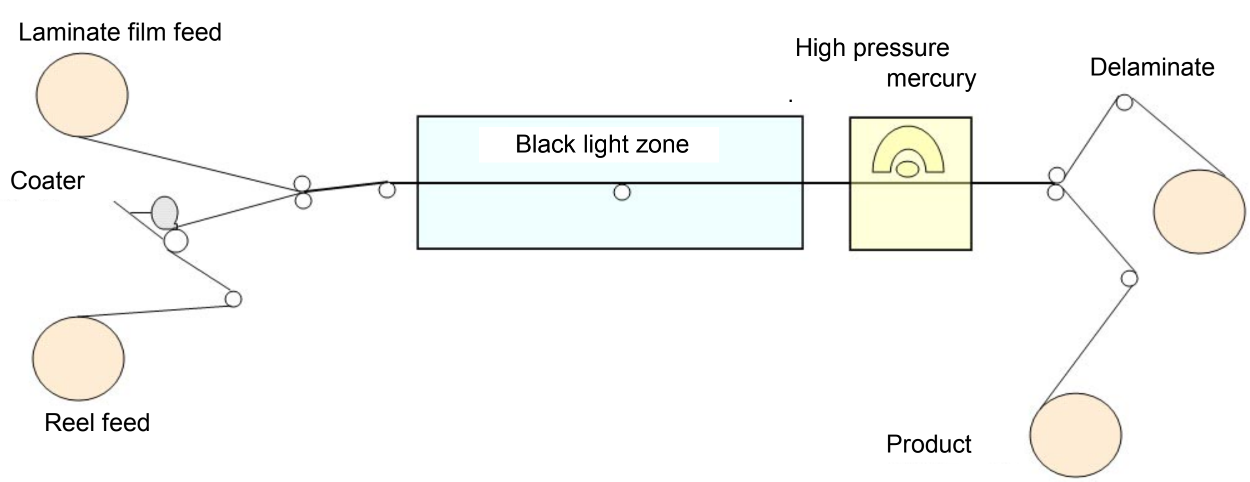

Figure4. Coating process scheme

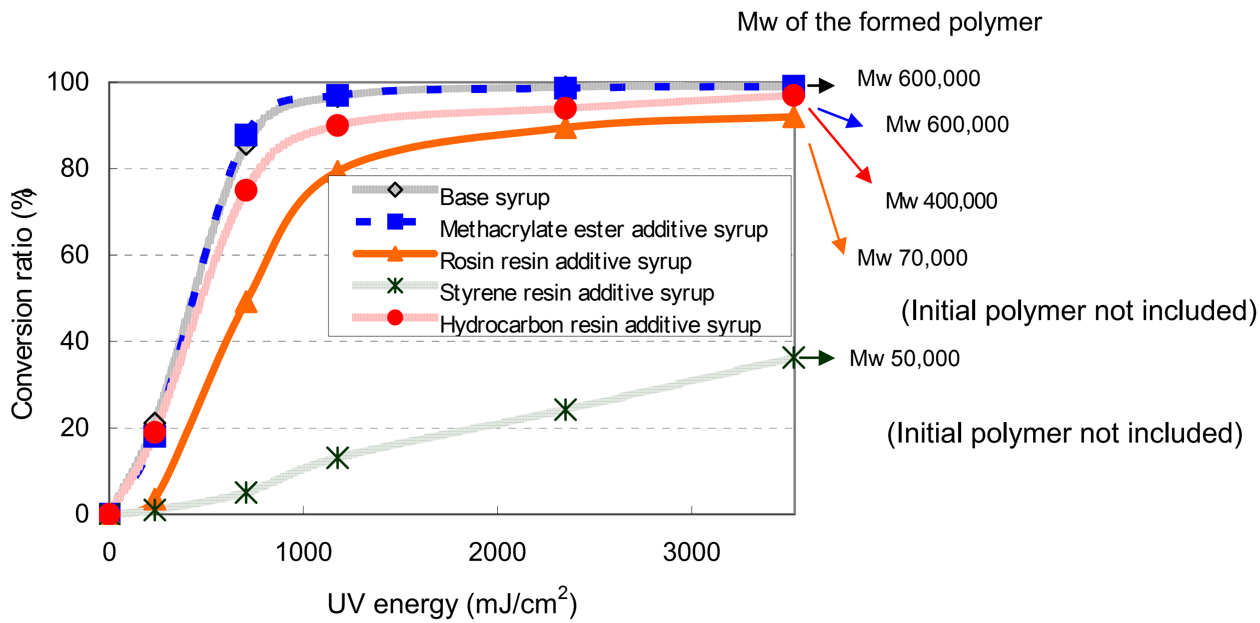

Figure5. Polymerization behavior at different tackifier condition

Base syrup : heating residue 20%
Irradiation intensity : 200mW/cm^2
Tackifier addition quantity : 20wt%

5. Heat generation at polymerization

The state of polymerization can be observed indirectly from the heat generation of the laminating liner during the polymerization in the manufacturing process of Syrup PSA tape. Figure 6 shows the correlation of irradiation time of the polymerization with different optical-absorption coefficient initiators and the laminating liner surface temperature.

Figure 7 also shows the correlation between the irradiation time of the acrylic syrup with different heat residue and the laminating liner surface temperature. Despite of these advantages, some heat shrinkage of the substrate might occur due to the heat generation. To stabilize the coating thickness and minimize the substrate shrinkage, adjustment of the conversion ratio, heat residue and installation of the cooling system at the polymerization process are necessary.

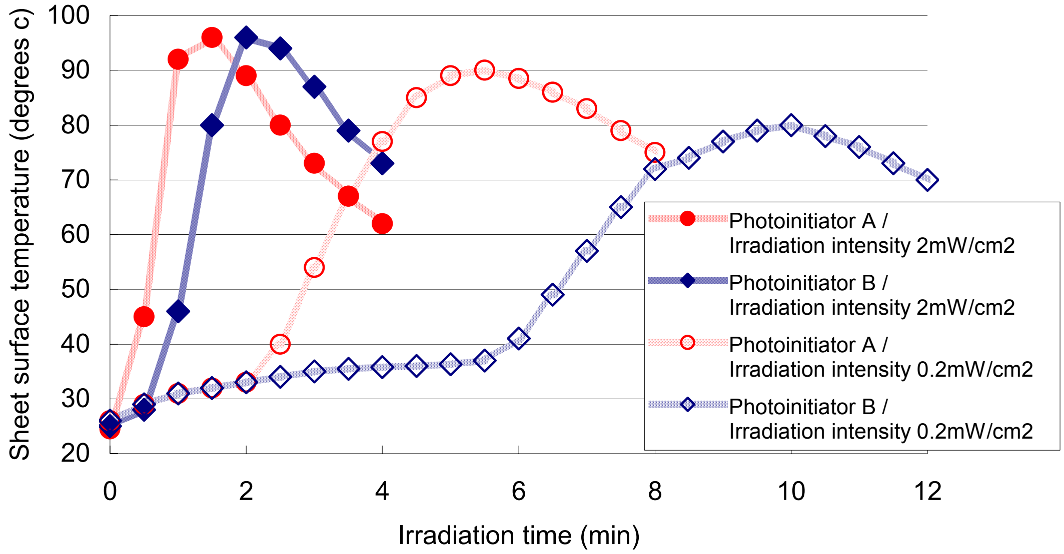

Figure6. Polymerization behavior at different absorption coefficient of photoinitiator

PSA : BA syrup
Coating thickness : 1mm
Photoinitiator : 0.3wt%
Lamp : black light

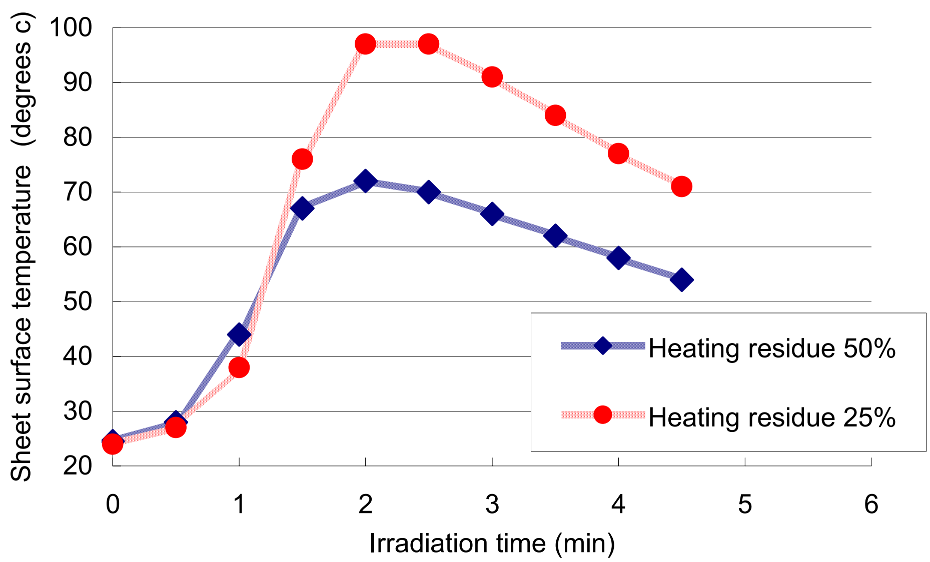

Figure7. Heat generation behavior of syrup polymerization at different heating residue

PSA : BA syrup
Coating thickness : 1mm
Photoinitiator : 0.3wt%
Lamp : black light 3mW/cm^2

6. Acrylic Syrup UV PSA Double-Sided Tape

The main feature of the Syrup PSA tape manufacturing process is the elimination of the need of organic solvent. The tape thickness of Syrup PSA tape could be adjusted independently from the production rate, as there is no need for the drying process to eliminate the organic solvent that is required for manufacturing solvent based PSA tape. Up to 2 mm adhesive layer thickness has been accomplished on our trial production. Syrup PSA enables production of a thicker PSA tape that is more elastic and superior to stress relaxation, and it achieves more conformability on rough surface. Figure 8 shows the correlation between the tape thickness and adhesive strength at different adherent materials. Figure 9 shows the correlation between the 1mm thick acrylic UV foam acrylic syrup UV PSA double-sided tape with addition of methacrylate ester tackifier, and the adhesive strength.

The Syrup PSA double-sided tape is constructed from the acrylic foam core material with layers of acryl Syrup PSA on both sides and backing liners. The core material consists of mixture of acryl monomer and polymer, fillers, crosslinking agent, photoinitiator, pigments and other additive agents. Syrup PSA is also being manufactured commercially. The Syrup PSA double-sided tape for construction use passed heat resistance properties testing analysis based on Japan Industrial Standard testing method, (JIS Z1541 - High potential pressure sensitive adhesive double coated tapes).

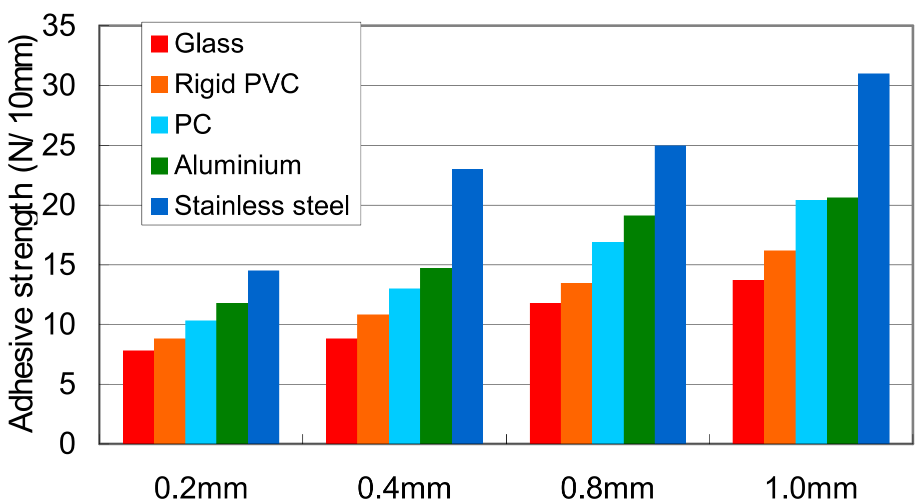

Figure8. Adhesive strength of different thickness PSA tape on various adherent materials

Adhesive strength after 24 hours
90 degrees peel. 300mm/ min

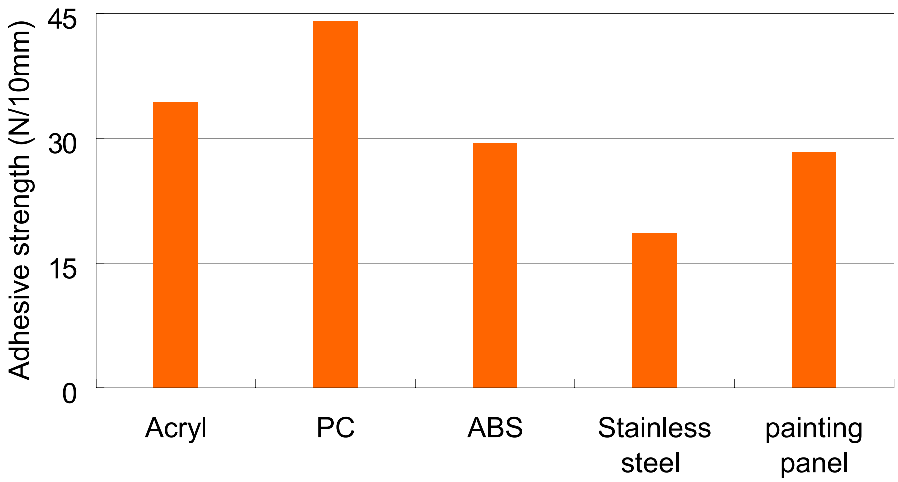

Figure9. Adhesive strength of acryl foam double-sided tape

Adhesive strength after 24 hours
90 degrees peel, 300mm/min

7. Conclusions

Syrup PSA double-sided tape for construction use and Syrup PSA non-woven double-sided tape have been produced using the acrylic syrup and UV polymerization technology. In the coming future, adhesives and PSA markets are expected to shift to the more environmentally-friendly products and also expansion of the application of recycled and hybrid materials are expected. End-users are requiring higher and more various performance on tape products. In order to manufacture tapes that meet those market demands, higher performance tackifier resins and more developed acrylic syrup technology are deemed necessary as well as development of equipments for UV polymerization tape manufacturing.

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