Application of primer and ultraviolet radiation in pressure sensitive adhesive tape

Bangyu Li\textsuperscript{1,}\textsuperscript{a} and Yangyang Huang\textsuperscript{2}

\textsuperscript{1}Institute of Applied Chemistry, 106 Zhineng Road, International Education Park, Suzhou Vocational University, Suzhou, China 215104
\textsuperscript{2}Research Institute of Silk Applied Technology, Suzhou Vocational University, Suzhou, China 215104
\textsuperscript{a}Email: lby@jssvc.edu.cn.

Abstract. Primer helps to enhance the adhesive force of the tape and the substrate. Different reinforcements on different substrates have different amplitudes. The order of increase in initial bond strength is PC > PVC > PP > PET > PE. The order of increasing holding power after 7 days is PP > PVC > PC > PET > PE. The primer has better adhesion on the modified tape than on the unmodified tape. High temperature and humidity are not conducive to the enhancement of the primer. The polar substrate has a more pronounced reinforcing effect. Ultraviolet (UV) irradiation can initiate group polymerization cross-linking to increase the tackiness. With the increase of irradiation power, the adhesive strength of the adhesive layer gradually increased and reached stability at around 3000mJ. The effect of ultraviolet irradiation on the shearing force of the adhesive tape on the glass substrate is significant, the decrease is greater than 60%. With the increase of the irradiation power, the maximum deformation of the tape decreased, and the rebound rate remarkably increased from 10.7% to 62.5%.

1. Introduction
Pressure sensitive adhesive (PSA) tapes are widely used in omestic, industrial and medical applications [1-4]. Prior to bonding, the surface to be bonded is pre-treated, and the primer is the simplest and most straightforward method to use on the board. The primer is a coating agent that firmly binds different kinds of substances and is essentially an adhesive that can enhance the adhesion between the adhesive and the plate[5]. UV radiation technology has achieved rapid development in adhesives. UV-curable UV adhesives are widely used in glass products and jewellery industries, furniture, instruments and other fields. During radiation, chemical reactions such as radiation initiation, polymerization and cross-linking of polymerizable monomers and functional oligomers mainly occur, and the bonding strength is enhanced. This article focuses on the effect of primer and UV radiation on acrylic tape.

2. Experimental Materials and Equipments

2.1. Experimental Materials
Pure Acrylic Foam Tape, Modified Acrylic Foam Tape (provided by Dow Corning, USA), Same uv-curing tape with different thickness number; substrates, Polycarbonate, PET, PP, PE, PMMA, Glass (Jinan languan, CHN), Universal halogen-free primer (Suzhou New Electronic Material Co., Ltd.)
2.2. Experimental Equipments
Zwick Universal testing machine (BT1-FR2.5TH. 140 Fnom 2.5kN), Weiss simulation sanlagenmess technik Oven (WK-340/40 22604900), Roller press (HOWE Elektrotechnik RDD20050), UVACUBE2000 (Hoenle, Germany). Mirco Shear Tester AS250M (Italy OEMME)

2.3. Experimental Methods
The peel adhesion of pressure-sensitive adhesives was tested using a Zwick-Roell machine according to the international standard ASTM D3330 procedures. A sample of PSA-coated material (20mm wide and about 150mm long) was bonded to a horizontal target substrate surface consisting of a clean steel test plate providing at least 15 cm² firm contact. A 4Kg hard rubber roller was used to apply the strip. The free end of the coated strip was doubled back nearly touching itself, so that the angle of removal would be 90° or 180°. The steel test plate was clamped in the jaws of a tensile testing machine, which was capable of moving the plate away from the scale at a constant rate of 300mm/min. The scale reading in Newton [N] was recorded as the tape was peeled from the steel surface. The data were reported as the average of the range of numbers observed during the test. The given result was an arithmetic average of three specimens [6].

The influence of primer on PSA measurements was carried out after 15 seconds (instant) and 7 days. The temperature and humidity conditions were as follows: constant temperature (23±0.5°C), constant humidity (50±5%RH) (RH: relative humidity), high temperature (85°C) and high humidity (85%RH). And the primer was evenly coated with a primer. Bonding surface, the general coating thickness is 2 ~ 4µm.

The influence of UV irradiation on PSA measurements was carried out after UV irradiation for 30 minutes in UV irradiator.

3. Results and Discussion

3.1. Effect of Primer on Tape Peel Strength
The initial adhesiveness of the adhesive tape is affected by the molecular chain segments and the polarity of the substrate. The following results from Table 1 can be summarized. 1) The initial adhesive strength (immediately tested) on the different substrates in the absence of the primer is in the order of PET > PVC > PC > PP > PE. The initial viscosity of PET, PVC, PC and PP is greatly enhanced, but PE does not rise slightly. The order of adhesion force increase rate is PC>PVC>PP>PE. 2) The sticking force of the adhesive tape is related to the cohesive strength of the adhesive layer. After 7 days of infiltration, the adhesion force generally increased, but the absolute value of the adhesion force without the primer was still small and no cohesive failure occurred. The order of peel strength on different substrates was PET>PVC>PE>PP>PC (unmodified), PVC>PC>PET>PP>PE (modified). After the primer is added, the adhesive strength continued to increase to reach the cohesive failure mode, in which the PET adhesive strength increased 3-4 times, while the PE does not change substantially. The order of increasing peel strength is PP>PVC>PC>PE. 3) In the high-temperature and high-humidity environment for 7 days, the non-polar substrates of PP, PE adhesion decrease, while the polar substrates of PET, PVC adhesive layer adhesion continues to increase. The order of peeling strength of the tapes on different substrates is PVC>PET>PC>PP>PE (no primer), PC>PET>PVC>PP>PE (primer). The order of increase in peel strength is PC>PP>PET>PVC>PE. 4) Under high-temperature and high-humidity conditions, the adhesive force is reduced to varying degrees for pure acrylic tapes, whether or not a primer is added. The tape stripping strength reduction order is: PVC>PET>PP=PE (primer), PC>PE>PET>PVC>PP (No primer). Under high-temperature and high-humidity conditions, with or without a primer, the adhesion of modified PP and PE tapes is reduced by 20-67%, while PC, PET, and PVC is increased by 70-400% on the substrate without primer, the change is very small on the substrate with the primer.
Table 1. Effect of primer on tape peel strength on different substrates$^a$

| Primer     | Pure Acrylic Foam Tape(N/cm) | Modified Acrylic Foam Tape(N/cm) |
|------------|------------------------------|----------------------------------|
|            | No  | Yes | Increase (%) | No  | Yes | Increase (%) |
| PP 23±0.5° C, 50±5%RH  | 2.05 | 8.11 | 295.61       | 1.02 | 7.60  | 645.10 |
| 7d         | 2.24 | 7.95 | 254.91       | 1.06 | 9.74  | 818.87 |
| 85° C,85%RH | 1.99 | 5.18 | 160.30       | 0.84 | 3.20  | 280.95 |
| PE 23±0.5° C, 50±5%RH  | 1.75 | 1.66 | -5.14        | 0.84 | 0.61  | -27.38 |
| 15s        | 1.62 | 0.88 | -45.68       | 0.85 | 0.59  | -30.59 |
| 85° C,85%RH | 1.17 | 0.87 | -25.64       | 0.51 | 0.46  | -9.80  |
| PVC 23±0.5° C, 50±5%RH | 7d | 30.95 | 61.50 | 98.71 | 4.38 | 51.20 | 1068.95 |
| 7d         | 5.27 | 60.55 | 1048.96     | 7.22 | 60.80 | 742.11 |
| 85° C,85%RH | 11.15 | 21.20 | 90.13        | 6.10 | 11.81 | 93.61  |
| PET 23±0.5° C, 50±5%RH | 32.30 | 61.05 | 89.01        | 4.01 | 49.05 | 1123.19 |
| 7d         | 21.90 | 38.85 | 77.40        | 19.90 | 46.20 | 132.16 |
| 85° C,85%RH | 7.68 | 52.65 | 585.55       | 4.94 | 50.55 | 923.28 |
| PVC 23±0.5° C, 50±5%RH | 30.60 | 63.65 | 108.01       | 9.87 | 50.25 | 409.12 |
| 7d         | 22.55 | 32.85 | 45.68        | 20.50 | 46.30 | 125.85 |
| 85° C,85%RH | 12.0 | 12.2 | 12.5         | 10.5 | 11.2 | 12.5 |
|            | 15.1 | 15.9 | 18.6         | 12.2 | 13.8 | 16.5 |
| No         | 25.8 | 30.3 | 48.8         | 16.2 | 23.2 | 32.0 |
| Increase (%) | 19.0 | 16.5 | 6.9          | 17.9 | 21.6 | 46.7 |

$^a$90 degree peel test.$^b$RH: relative humidity

3.2. Effect of UV Radiation on Peel Strength of Tape

Table 2. Effect of UV radiation on peel strength of tapes on different thickness substrates$^a$.

| Substrate | Thickness(μm) | PC | Glass | PET | PMMA |
|-----------|--------------|----|-------|-----|------|
| No        | 12.0         | 10.5 | 12.2 | 11.2 | 11.6 |
| Yes       | 15.1         | 12.2 | 13.8 | 9.4  | 9.9  |
| Increase (%) | 25.8 | 16.2 | 23.2 | 19.0 | 17.9 |

$^a$180 degree peel test.

As can be seen from Table 2, the following two results can be obtained under irradiation of 1000mJ ultraviolet light. 1) The peel strengths on the different substrates are significantly increased, and in the range of 50-200μm thickness, the increasing order is: PC>PMMA>Glass>PET. The order is related to the polarity of the substrate, the greater the polarity of the substrate, the greater the peel strength of the tape. 2) For the same tape, the peel strength increases as the thickness increases [7]. In the range of tape thickness under test, all plastic tapes can undergo obvious plastic deformation, the greater the energy is consumed by plastic deformation of thicker tapes, the greater the contribution is to the peel strength and the higher the peel strength.

3.3. Effect of Different Power UV Light on Peel Strength and Shear Force of Tape

Analysis of the data in Table 3, the following conclusions can be obtained. 1) The peel strength of the adhesive layer on the glass substrate is gradually increased with the increase of the irradiation power in the range of 1000-10000mJ power. In the thickness range of 50-200μm, the strength peaks at 3000mJ. After achieving stability, as the UV power continues to increase, the bond of the adhesive layer decreases. There is little relationship between the increase in adhesion and thickness. 2) In the range of 1000-10000mJ power, the shear strength on the 50μm thickness glass substrate has a significant effect and the reduction is greater than 60%. And with the irradiation power increased, the maximum shape variable decreased; meanwhile, the drop rate of the tape rebound rate is also significant, and the decrease rate increased from 10.7% to 62.5%.
4. Conclusion
The primer has better adhesion on the modified tape than on the unmodified tape. High temperature and humidity are not conducive to the enhancement of the primer. The polar substrate has a more pronounced reinforcing effect. With the increase of irradiation power, the adhesive strength of the adhesive layer gradually increased and reached stability at around 3000mJ. The effect of UV irradiation on the tape shearing force on the glass substrate is significant. With the increase of the irradiation power, the maximum deformation of the tape decreased, and the rebound rate remarkably increased.

Acknowledgement
The financial support from the Technology Plan Project Foundation of Suzhou Science and Technology Bureau (Grants SS201742)

References
[1] Valentin L. POPOV, Roman POHRT .Qiang Li. Strength of adhesive contacts: Influence of contact geometry and material gradients [J]. Friction, 2017, 5(3): 308 – 325
[2] Sha Yang, Shuhua Qi, Bo Cheng, Lina Ma. Research progress of pressure-sensitive adhesives [J]. Adhesion, 2014, 3: 83 - 86
[3] Peng Zhang, Ying Li, Junbin Li, Xiaolong Yao, Zongshan Chen. Discussion on influence factors of aging-resistance of protective film for aluminum oxide profile [J]. Adhesion. 2017, 1: 52 -54
[4] Afferrante L, Carbone G. The ultratough peeling of elastic tapes from viscoelastic substrates [J]. Journal of the Mechanics and Physics of Solids. 2016, 96: 223 – 234
[5] Ruijing Chen. Research status of the overseas primers for pressure sensitive adhesive tapes [J]. Guangzhou Chemical Industry.1999, 2: 4 - 6
[6] Wilpiszewska K, Czech Z., Citric acid modified potato starch films containing microcrystalline cellulose reinforcement — properties and application [J]. Starch. 2014, 66 (7-8): 660 - 667
[7] Qilin Liu, Yingyu Huang, Weiwen Deng, Qian Huang. Influencing factors of double-sided tape peel strength test [J]. Bonding. 2017, 48 - 53