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Simulation of the impact of environmental conditions on selected silicone pressure-sensitive adhesives

Abstract

The influence of environmental conditions on self-adhesive products, such as self-adhesive tapes based on silicone pressure-sensitive adhesives, is a very important issue in the modern world. These conditions affect both the products stored and used. In order to confirm the excellent operational properties of adhesive tapes based on silicone pressure-sensitive adhesives, an experiment was carried out in which the tapes were subjected to the cyclical influence of temperature and humidity changes. Subsequently, they were subjected to basic adhesion, cohesion and tackiness tests, and the results were compared with the references stored in "ideal storage parameters for self-adhesive materials". There are no studies on the impact of environmental of silicone pressure-sensitive adhesives in literature.

Keywords: silicone pressure-sensitive adhesives, kaolin, adhesion, montmorillonite

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Introduction

The adhesives accompany people from the beginning of time. There is an archaeological evidence indicating that adhesives have indeed been found on primitive tools. Although the prospects for the modern man accustomed to modern technology adhesives, primary concepts may seem too simple. With the development of technology, adhesives have been improved more and more to obtain their various forms and structures (e.g. self-adhesive tapes). Along with the development, efforts were made to obtain better and better products, also in terms of resistance to environmental conditions.[1-5] The pressure-sensitive adhesives (PSA) is a class of adhesive material that adheres to a substrate under light pressure and can be removed cleanly, on demand, without leaving residues on the substrate. Thus, PSA should exhibit cohesive strength that is much higher than its adhesion strength to the substrate. In other words PSAs can be described as a special category of adhesive which in dry form are permanently tacky at room temperature. Mechanically, PSA is a soft, sticky substance; consequently, a supporting backing is often required to convert it into commercially useful forms, such as tapes and labels.[5,8-9]

Silicone pressure-sensitive adhesives (Si-PSAs) is a group of PSA (classification by basic polymer) which in the last decade has gained a lot of interest. It is well known that Si-PSAs are materials of high quality destined for special applications. They exhibit unique properties such as high flexibility, chemical resistance and outstanding weathering resistance, low surface tension, excellent thermal stability and high UV transparency, moreover, the adhesives exhibit high cohesion and adhesion (favorably to material with low surface energy). When compared to other PSAs (based on carbon polymers) silicone pressure-sensitive adhesives have been found to be preferred in many applications, especially in the medicine, where the quality is more important than price, and "standard" conventional adhesives are insufficient. For example, Si-PSA due to the fact that they are acceptable for medical use, have found application in transdermal drug delivery which involve the adherence of a drug-containing patch to a patient's skin.[9-12]

The crosslinking process is essential/crucial but difficult step influencing the Si-PSA properties, and thus their potential usage. The crosslinking of Si-PSAs is limited as contain only methyl and phenyl groups. Usually silicone pressure-sensitive adhesives are cross-linked by using organic peroxides at elevated temperature: between 120°C and 150°C. There are also attempts to modify polymers in order to introduce additional functional groups, giving e.g. polymer contain silicon-bonded vinyl (Si-Vi) functional groups.[9,12]

In this paper simulation of the impact of environmental conditions on selected silicone pressure-sensitive adhesives were presented. The adhesive tapes obtained for the tests were characterized by very good useful properties. The type of Si-PSA tapes were selected on the basis of previous tests. The materials thus obtained can be used, e.g. in heat engineering and fireplace installations. The presented research will help to better understand the influence of environmental conditions on adhesive tapes, and thus help to better select the key performance parameters of these materials.

Materials and methods

Materials

Commercial silicone adhesive resin (Q2-7566) a product of Dow Corning (USA) was used as a adhesives. Bentonite from Zębiec (Poland) was used as a natural material to obtain montmorillonite. Kaolin was used as fillers, which was a product of BASF (Germany). 2,4-Dichlorobenzoyl peroxide (DClBPO) supplied by Peroxid-Chemie (Germany) was used as the crosslinking agent.

Preparation of Si-PSA

Two adhesive compositions based on Q2-7566 resin containing respectively 1% wt. of montmorillonite and 5% wt. of kaolin were selected. Base resin and the crosslinking agent (1.5 wt. % 2,4-dichlorobenzoyl (DClBPO) peroxide according to polymer content) were mixed to obtain a homogenous organic composition containing 50 wt. % of polymer. The filler was introduced into the thus prepared composition and mixing was continued until a homogeneous form was obtained. The composition was then left to stand for 24 h for degassing. The adhesive composition prepared in this way was coated on a polyester film with a thickness of 36 µm using an automatic coating machine developed in the Laboratory of Adhesives and Self-Adhesive Materials of the West Pomeranian University of Technology in Szczecin in order to obtain the same thickness of the adhesive layer over the entire surface. The coated film was crosslinked in a drying channel at 110°C by 10 min. The ready-made adhesive tape was protected with polyester film.

Simulation of the impact of environmental conditions

To investigate the impact of environmental conditions samples (tapes and joint tapes with a steel substrate), they were conditioned in a climatic chamber simulating environmental conditions LHU-114 (ESPEC Corporation, Japan) according to the modified simulation of the MMM-A-132B standard. Samples were held in variable conditions in two 24 h cycles simulating negative environmental conditions taking into account temperature and humidity respectively 0 rh moisture, -20°C and 95 rh moisture, 35.5°C. In order to better investigate the impact of environmental conditions, tests were carried out both on the tapes and joint tapes with a steel substrate for adhesion and cohesion measurements which were subjected to moisture and temperature conditions. In the case of tack, simulation was carried out for tape. For all measurements, references were made—samples kept in a climatic chamber to avoid aging processes and the impact of the environment on the tested properties. The simulation was carried out for 20 days (10 days per cycle).[1]

Methods

According to international standards (Association des Fabricants Europeens de Rybans Auto-Adhesifs and Fédération Internationale des Fabricants et Transformateurs d'adhesifs et thermocollants sur papiers et autres support) respectively AFERA 4001, FTM 8 and AFERA 4015 the adhesion, cohesion and tack was measurements shown in Figure (1-3), respectively.

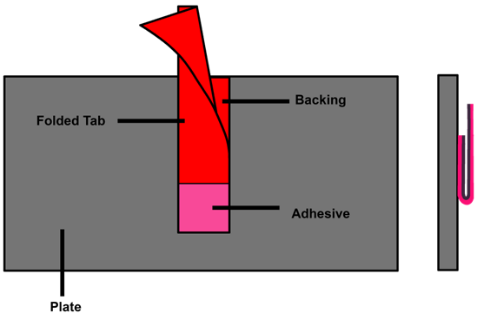

Figure 1 Adhesion test according to international standard AFERA 4001

Figure 2 Cohesion test according to international standard FTM 8.

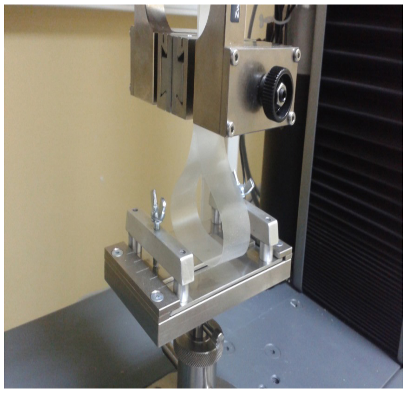

Figure 3 Tack test according to international standard AFERA 4015.

Methods in the studies cited

The value of shrinkage was measured using the well-known cross-method. The PVC or PET film was coated with a sample Si-PSA layer and cross-linked. Then it was applied on a degreased metal plate and two cuts were made at the right angle. The width of the cuts was measured. The measurements were taken at given time intervals, up to 42 days, at a measuring temperature of 70°C. The shrinkage is the percentage value of the ratios of width of the cuts. The shrinkage greater than 0.5% is not allowed.[13,14]

Shear adhesion failure test was measured in accordance with the modifying standard FTM-8 FINAT using test machine designed at the International Laboratory of Adhesives and Self-Adhesive Materials of the West Pomeranian University of Technology in Szczecin. The one-sided adhesive film was attached to a degreased steel plate and pressed with a 2 kg rubber roller. The contact surface area of Si- PSA film sample was 6.25 cm^2 (2.5 cm × 2.5 cm). The plate was then placed in the test machine, and the free end of the test sample was loaded with a 1 kg load, such that the direction of the pulling force was parallel to the surface of the joint (the shear force). The test machine automatically measured the time at which the sample of the adhesive tape would detach from the metal plate. SAFT is presented as expressed temperature (°C) elapsing between the moment burden on the sample until to cohesion/adhesion crack.[13,14]

Results and discussion

The obtained composition exhibit a good useful properties (Table 1). In compared to the sample without fillers the addition of silicone fillers caused a decrease useful value as adhesion, tack and shrinkage increase value of SAFT test about 100 degrees. Modification of silicone pressure-sensitive adhesives does not affect the cohesion of the adhesive film both at room temperature and at elevated temperature (the cohesion value is maintained at a level of >72h).

Table 1 Basic properties of Si-PSA with different filler[13,14]

Selected filler in composition	-	Montmorillonite	kaolin
Tack [N]	12.3	8.1	11
Adhesion [N/25mm]	13.5	8.6	12.2
Cohesion in 20°C [h]	> 72	> 72	> 72
Cohesion in 70°C [h]	> 72	> 72	> 72
SAFT* [°C]	133.2	242	225
Shrinkage after 72 h [%]	0.4	0.2	0.3

SAFT - Shear adhesion failure test

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Cohesion values at room and elevated temperature for the tapes obtained in the conducted simulation showed no deterioration of properties under the influence of changing environmental conditions (Table 2). These results confirm the quality of products based on a composition of silicone adhesives modified with kaolin and montmorillonite.

Table 2 Impact of environmental condition on cohesion in room and elevated temperature of Si-PSA prepared tape

Selected filler in composition	Cohesion			
	in 20°C		in 70°C [h]	
	reference	simulation	reference	simulation
-	> 72	> 72	> 72	> 72
montmorilonite	> 72	> 72	> 72	> 72
kaolin	> 72	> 72	> 72	> 72

All reference samples were characterized by a relatively high adhesion and tack for (stored under storage conditions, at the same time as the samples subjected to stimulation). In the case of materials stored in the climatic chamber, the tack was slightly higher compared to reference samples, but lower to compared freshly received tapes. This effect was very positive and demonstrated well the resistance of tapes to environmental conditions. In the case of adhesion, these changes are also visible (Table 3). In the case of self-adhesive tapes modified with fillers exhibit better condition compared to samples without modification.

Table 3 Impact of environmental condition on adhesion and tack of Si-PSA prepared tape

Selected filler in composition	Adhesion [N/25mm]		Tack [N]	
	reference	simulation	reference	simulation
-	9.1	10.4	8.1	4.5
montmorilonitea	6.5	7.6	7.8	8.8
kaolin	10.5	11.5	10.3	11.1

Conclusion

Simulation of the impact of environmental conditions on selected silicone pressure-sensitive adhesives was improve. The tested composition based on a commercial silicone pressure-sensitive adhesive exhibit decreased of useful properties such as adhesion, tack. Properties like cohesion in room temperature and elevated temperature have been kept to a high standard.

Appropriate selection of adhesive compositions allowed to notice the difference in the environmental conditions resistance of samples containing silicone fillers. These compositions show relatively higher resistance to environmental conditions compared to compositions without fillers. This is most likely due to the tighter structure of the polymer matrix, and thus higher resistance to external factors.

The accumulation presented in the paper showed the influence of the daily variable temperature and the change of the air humidity parameter on the storage of self-adhesive tapes. The experiment simulated extreme conditions, which determined the resistance of samples stored in good and inadequate storage conditions, respectively. Self-adhesive tapes have proven their high resistance to environmental conditions.

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None.

Conflicts of interest

The author declares there is no conflict of interest.

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