

Silicone Release Coatings for the Pressure Sensitive Industry – Overview and Trends

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Part 3 – Understanding Release Force

Impact of Coating Architecture and Delivery System

Each type of silicone release coating demonstrates unique release behavior. The coating's architecture and delivery system have a great impact on release performance. For example, Figure 1 shows that a hot melt tape has very different release profiles depending on the type of silicone release coating to which it is applied. A particular silicone formulation has no absolute release performance; performance also depends on other factors including the adhesive, peeling parameters, substrate and so on. The selection of a silicone release product is only one of many considerations for release manufacturers in the PSA industry. Silicone formulations have rheological characteristics. Due to their structures, different types of silicone coatings have significantly different influences over release force.

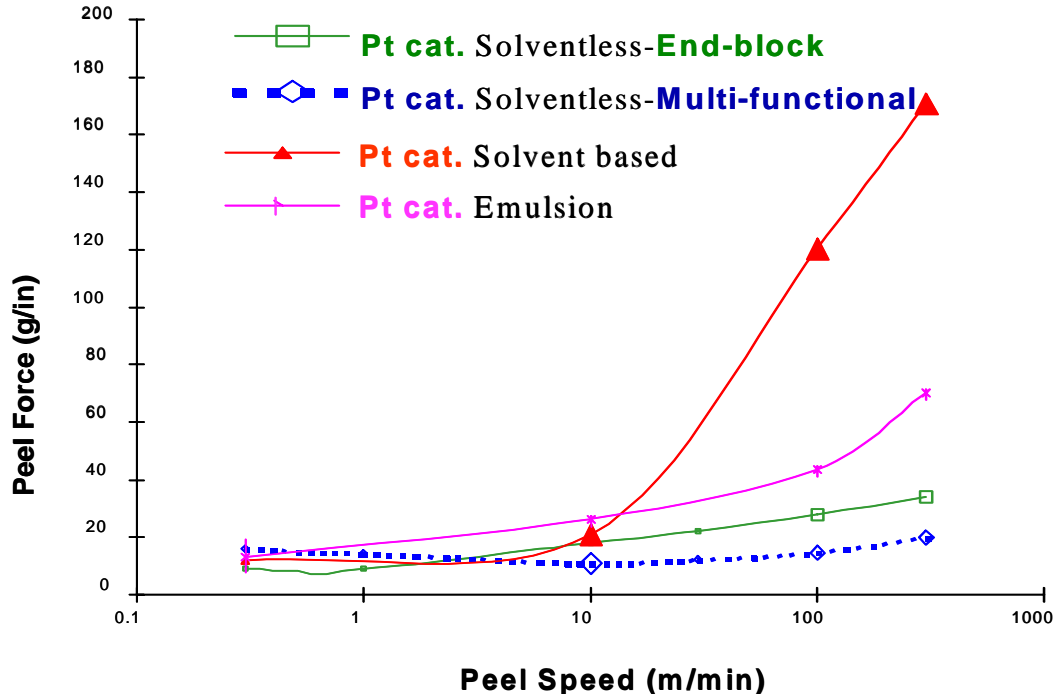


Figure 1 – Release Profile of a Hot-Melt Adhesive Tape from Various Silicone Release Coatings.

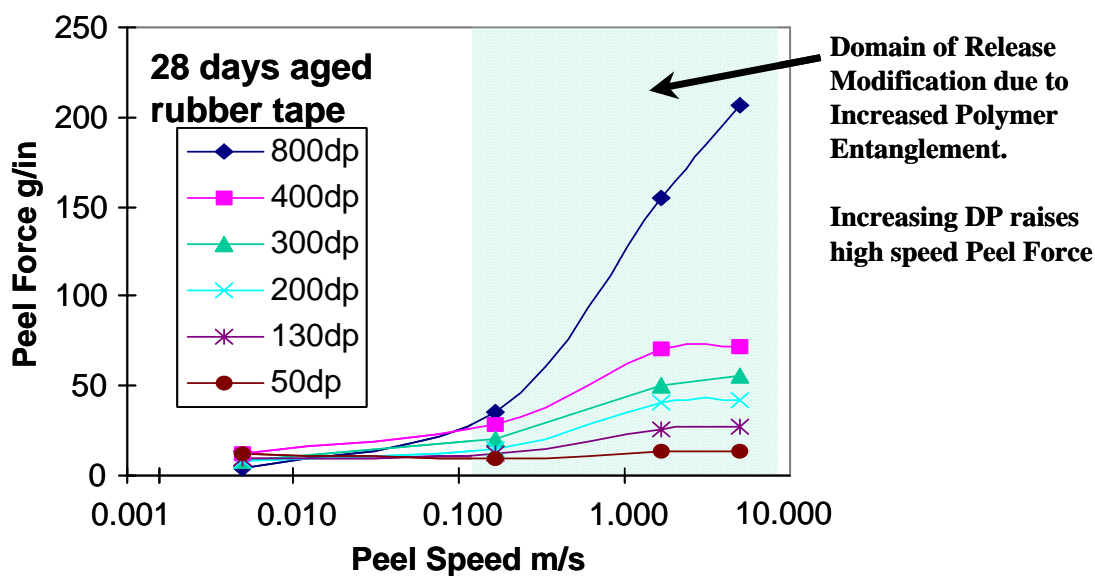
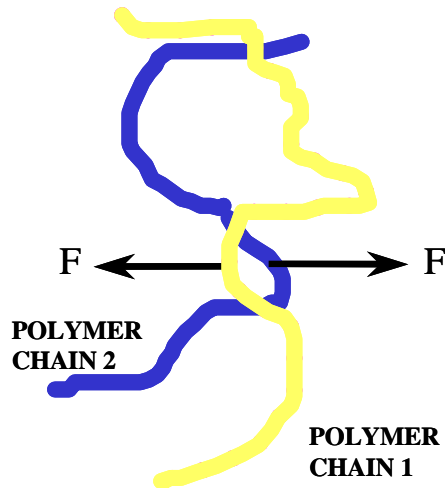


Figure 2 – Effect of Crosslinking Density on the Release Profile of Silicone Release Coatings.

From a silicone architecture viewpoint, the crosslinking density of the polysiloxane is the principal factor affecting release force. Crosslinking density is the number of polymer crosslinks per unit volume. Crosslinking density is a function of the molecular weight of the PDMS and the active crosslinker sites. This is an essential relationship in providing the ability to vary the release force of a silicone coating from easy release to high release. In general, high-crosslinking-density networks yield a rigid hard coating layer, which has a flat release force profile at low to high peeling speeds. In contrast, a low-crosslinking-density network from a higher-molecular-weight polymer has greater flexibility of the polymer chains. It yields a softer, more elastic coating, as shown in Figure 2. The greater flexibility allows more penetration or interaction with the adhesive polymer chains than would occur with a highly crosslinked silicone coating. The resulting release is initiated at low release force but demonstrates high release force at high-speed peeling.

Also, the entanglement is a common effect caused by long-chain polymers (see Figure 3). A long-chain siloxane network has a clear entanglement effect due to its flexible siloxane backbone. This entanglement is able to absorb energy and dissipate energy. During application of the peeling force, release behavior is also affected. Because the silicone layer is located between the adhesive layer and the substrate, the visco-elastic effect of crosslinking density combines with entanglement to affect release behavior as well as the anchorage of the silicone coating.



Above a certain degree of polymerization (DP), polymer chains become entangled.

There is usually marked change in physical properties at this point i.e., a fast rise in viscosity

Pulling against the entangled polymers is a energy dissipating process.

Figure 3 – Polymer Entanglement Effect.

Use of Release Additives to Modify Release

The release additive, or controlled release additive (CRA), is the other factor affecting the release profile of the silicone formulation. The most widely used high-release additives (HRAs) are based on MQ-type silicone resins, shown in Figure 4. HRAs have high melting points, high T_g transition and, when incorporated into the silicone crosslinking network during cure, they provide a consistent modification to the release coating. This effect is particularly pronounced at initial and low peeling speeds. The resin additive changes the siloxane network structure and physical properties. This is able to disrupt the network polymer-polymer interaction and also reduce siloxane segment mobility. The function of energy dissipation is the key factor in modifying the release force applied to separate the coating from an adhesive layer.

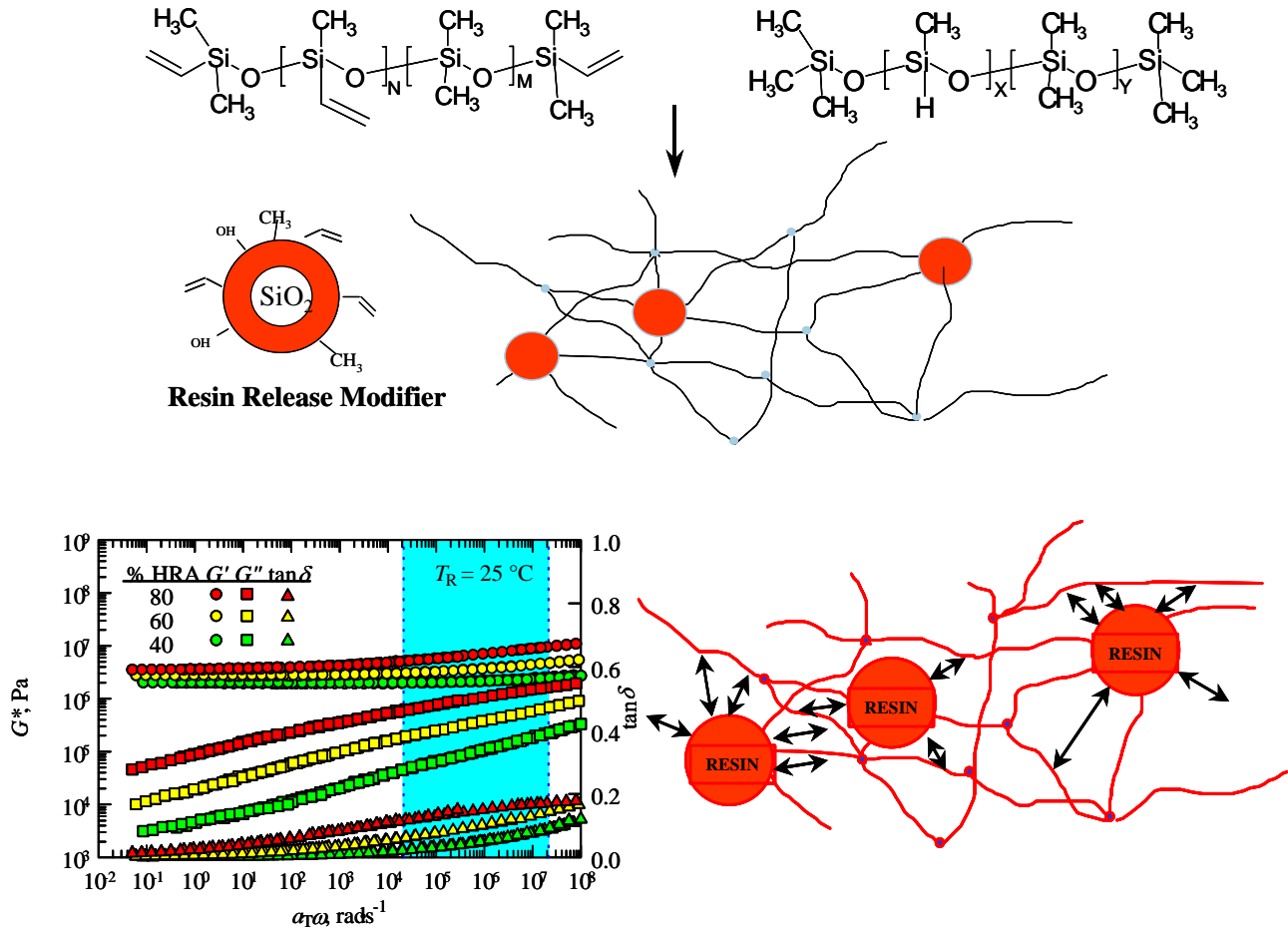


Figure 4 – Anatomy of a Silicone Release Coating with Resin Modifier.

The effect of adding HRA to a silicone coating increases the energy-dissipating ability of the silicone network. This is shown by a change of parameters of share modulus G' , G'' and $\tan \delta$ in rheology testing. On the other hand, the release force increase could be seen as an increase of HRA amount. The performance of the HRA is also dependant on the type of adhesive. The rheological interaction is quite different when using an acrylic adhesive versus a rubber adhesive, as shown in Figure 5.

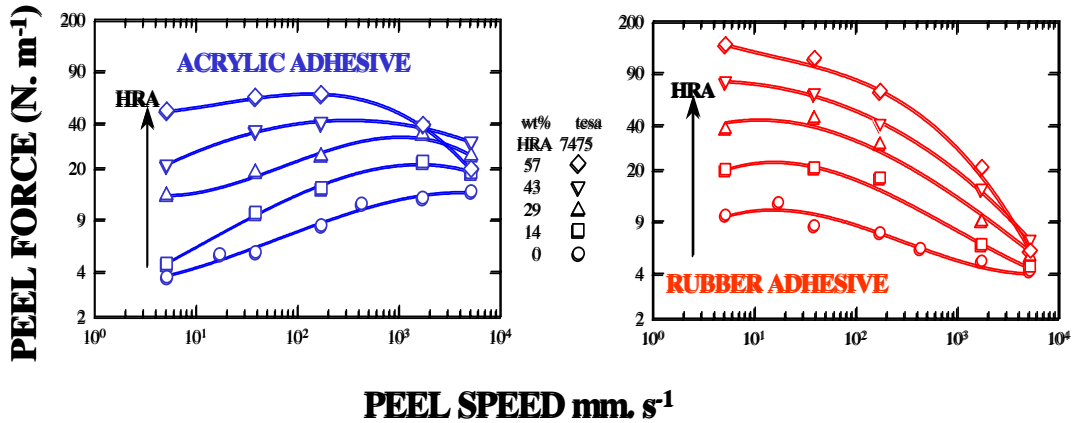


Figure 5 – Effect of HRA on Release Profiles.

Several approaches to understanding the release mechanism have been evaluated in literature. The most reliable proposed release mechanism for silicone release can be divided into two parts. One is silicone coating without HRA, where the silicone network is stressed at interface failure, and the crack propagates easily – easy release. The other mechanism is polymer/resin network, where the resin reduces surface mobility of the polymer reinforcing the interface, thereby more efficiently using the dissipating power of the adhesive. (See Figure 6.)

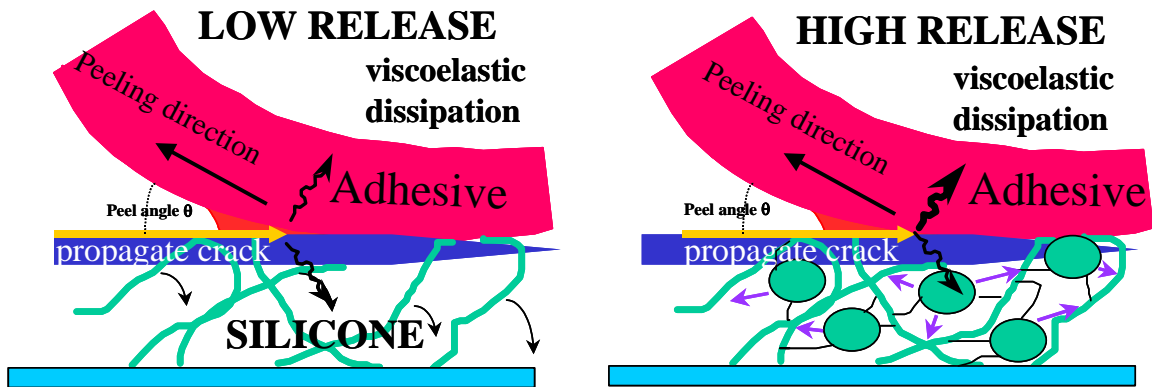


Figure 6 – Approaches to Understanding the Release Mechanism.

Another release additive for low release force is a migration additive. The function works due to incompatibility of organo-substituted siloxane additives in the formulation. In addition, a very trace amount of non-crosslinked silicone fluid additive migrates to the liner surface, causing a low release-force profile.

Factors Affecting Release

In addition to the function of a silicone release liner with a pressure sensitive adhesive, release force is related to how, and with what materials, the release coating is used. Release is affected by many physical, chemical and testing factors, including:

1. The nature of the adhesive and silicone coating; e.g., chemistry, network structure, coat weight, the degree of cure and the interaction between the silicone release coating and the adhesive.
2. Factors associated with the paper substrate and face stock; e.g., surface treatment, roughness, porosity and liner thickness.
3. The lamination and converting process; e.g., coater design, web temperature and speed.
4. The liner stripping process; i.e. peeling speed and peeling angle.

Figure 7 – Factors Affecting Release Performance.

