Designation: D6105 – 04 (Reapproved 2012)

Standard Practice for
Application of Electrical Discharge Surface Treatment (Activation) of Plastics for Adhesive Bonding[1]

This standard is issued under the fixed designation D6105; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers various electrical discharge treatments to be used to enhance the ability of polymeric substrates to be adhesively bonded. This practice does not include additional information on the preparation of test specimens or testing conditions as they are covered in the various ASTM test methods or specifications for specific materials.

1.2 The types of discharge phenomena that are used for surface modification of polymers fit into the general category of nonequilibrium or non-thermal discharges in which electron temperature (mean energy) greatly exceeds the gas temperature.

1.3 The technologies included in this practice are:

Technology	Section
Gas plasma at reduced pressure	8
Electrical discharges at atmospheric pressure	9
AC dielectric barrier discharge	9.1
High Frequency Apparatus	9.1.1
Suppressed Spark Apparatus	9.1.2
Arc Plasma Apparatus	9.2
Glow Discharge Apparatus	9.3

NOTE 1—The term "corona treatment" has been applied sometimes in the literature to the different electrical discharge treatment technologies described in Section 9. This practice defines each electrical discharge treatment technology at atmospheric pressure presented in Section 9 and draws the necessary distinctions between them and corona discharge. See Test Method D1868 for "corona discharge."

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements appear in Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D724 Test Method for Surface Wettability of Paper (Angle-of-Contact Method) (Withdrawn 2009)[3]
D907 Terminology of Adhesives
D1868 Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems
D2578 Test Method for Wetting Tension of Polyethylene and Polypropylene Films
D2651 Guide for Preparation of Metal Surfaces for Adhesive Bonding
D5946 Test Method for Corona-Treated Polymer Films Using Water Contact Angle Measurements

3. Terminology

3.1 *Definitions*—Many terms are defined in Terminology D907.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *AC dielectric barrier discharge, n*—a self-sustaining AC discharge in relatively short gaps with a solid dielectric layer, where the discharge bridges the entire air gap.

3.2.2 *contact angle, n*—the angle in degrees between the substrate surface and the tangent line drawn to the droplet surface from the three-phase point.

3.2.3 *corona, n*—visible partial discharges in gases adjacent to a conductor.

3.2.4 *corona treatment, n*—see Note 1.

3.2.5 *electrical discharge, n*—any of several types of electrical breakdown of gases, primarily air.

3.2.5.1 *Discussion*—The type of discharge depends upon several controllable factors, such as electrode geometry, gas pressure, power supply impedance, etc. When, at atmospheric pressure, the voltage reaches a certain critical value, the current

[1] This practice is under the jurisdiction of ASTM Committee D14 on Adhesives and is the direct responsibility of Subcommittee D14.40 on Adhesives for Plastics.
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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

increases very rapidly and a spark results in the establishment of one of the self-sustaining discharges, such as corona, arc, glow and dielectric barrier discharge. In many electrical discharges, ionized regions called plasma exist.

3.2.6 *electrical discharge treatment, n*—activation of a polymer surface using electrical discharges to increase surface energy and create polar functional groups on the polymer surface; nonequilibrium discharges are used primarily for surface treatment.

3.2.7 *electric arc, n*—a self-sustaining discharge in the gap between two electrodes having a low voltage drop and capable of supporting large currents.

3.2.8 *gas plasma, n*—extremely reactive, partially ionized gas consisting of free electrons, positive ions, free radicals, metastables and other species; plasmas exist over a wide range of temperature and pressure and are capable of inducing chemical modifications on polymer surfaces.

3.2.8.1 *Discussion*—The positive ions, the electrons, and the neutral gas atoms of a plasma may or may not be in thermal equilibrium. Since plasma is usually established by an electric field, the temperature of the positive ions is usually greater than the gas temperature, and the electron temperature may be very high.

3.2.9 *glow, n—in electrical discharges*, a self-sustaining discharge in the air gap, where the gas near the sharply curved electrode surfaces breaks down at a voltage less than the spark breakdown voltage for that gap length.

3.2.10 *partial discharge, n*—electric discharge that only partially bridges the insulation between conductors.

3.2.11 *polarity, n—in surface chemistry*, value that quantifies concentration of polar functional groups on the polymer surface and is measured as a polar component of surface energy divided by a sum of polar and non-polar components.

3.2.12 *spark breakdown, n*—a sudden transition from the "dark" discharge to one of the several forms of self-sustaining discharge; this transition consists of a sudden change in the current.

3.2.13 *surface energy, n—for a given solid*, defines molecular forces of its interaction with other interfaces, J/m^2.

4. Summary of Practice

4.1 This practice identifies and defines several electrical discharge treatment technologies for surface modification of polymers. The practice outlines essential technical aspects of each technology.

5. Significance and Use

5.1 Bonding of many polymeric substrates presents a problem due to the low wettability of their surfaces and their chemical inertness. Adhesive bond formation begins with the establishment of interfacial molecular contact by wetting. Wettability of a substrate surface depends on its surface energy. The surface activation with electrical discharges improves wettability of polymers and subsequent adhesive bonding. The surface activation with electrical discharges results in addition of polar functional groups on the polymer surface. The higher the concentration of polar functional groups on the surface the more actively the surface reacts with the different polar interfaces.

5.2 To achieve a proper adhesive bond the polyolefin substrate's polar component should be raised from near zero to 15 to 20 mJ/m^2.

5.3 The pre-treated surfaces are ready for application of the adhesive immediately after the treatment.

6. Hazards

6.1 *Ozone*—Ozone is a by-product of the electrical discharge in atmospheric-pressure air. The ozone produced during the treatment can be vented into external atmosphere where dilution and subsequent breakdown will occur. If the ozone cannot be vented out, the station should be equipped with an exhaust hood and activated carbon filter or manganese dioxide catalyst.

6.2 *Electrical Hazard:* **Warning**—The users of these practices must be aware that there are inherent dangers associated with the use of electrical instrumentation and that these practices cannot and will not substitute for a practical knowledge of the instrument used for a particular surface preparation.

6.3 *Radio Frequency:* **Warning**—Persons with pacemakers may be affected by the radio frequency.

6.4 Electrical discharge treatments produce no volatile organic compound (VOC) emissions.

7. Procedure - General

7.1 *Surface Cleanliness*—The surface must be clean prior to submitting the specimen to any of the treatment processes. Potential surface contaminants include the following: additives, handling residue (fingerprints), mold release, machine oil, and grease.

7.1.1 *Techniques for Cleaning Surface*—Use a technique for cleaning the surface appropriate for the substrate. If no other cleaning method is specified, use a solvent wipe with isopropyl alcohol and clean, low lint cloth or wipes.

7.2 *Selection of Appropriate Electrical Discharge Treatment*—When making a choice the following factors must be considered:

7.2.1 Necessary treatment level,
7.2.2 Treatment speed,
7.2.3 Treated parts shape and size,
7.2.4 Process type – continuous, batch, etc, and
7.2.5 Economics.

Consult the attribute chart in Appendix X1 for comparison.

7.3 *Procedure for Polymer Surface Treatment*—Surface treatment with electrical discharges involves, in general, applying the discharge, and the plasma generated in the discharge, to the surface to be treated.

7.4 *Procedure for Determining Efficacy of Treatment:*

7.4.1 *Water Break Test,* Guide D2651, Section 5.5.4. A water-break test is a common method used to analyze surface cleanliness. This test depends on the observation that a clean surface (one that is chemically active or polar) will hold a continuous film of water, rather than a series of isolated