

[54] **ELECTROSTATIC PINNING OF
DIELECTRIC FILM**
[72] Inventor: **William E. Hawkins**, Circleville, Ohio
[73] Assignee: **E. I. du Pont de Nemours and Company**,
Wilmington, Del.
[22] Filed: **Mar. 23, 1970**
[21] Appl. No.: **21,695**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 823,848, May 12,
1969, abandoned.
[52] U.S. Cl.....**425/109, 264/22, 264/24,**
425/174, 425/151, 425/71, 425/162
[51] Int. Cl.....**B29d 7/22**
[58] Field of Search18/15, 15 R, 15 F, 15 S;
264/22, 23, 24

[56] **References Cited**
UNITED STATES PATENTS
3,427,686 2/1969 Busby.....18/15 M
3,520,959 7/1970 Busby.....18/15 R X
Primary Examiner—J. Spencer Overholser
Assistant Examiner—Norman E. Lehrer
Attorney—Donald W. Huntley

[57] **ABSTRACT**
Apparatus for electrostatically pinning a moving dielectric
web to a roll which comprises a first electrode and a second,
insulated electrode independent of the roll, and means for
establishing a potential difference therebetween.
9 Claims, 6 Drawing Figures

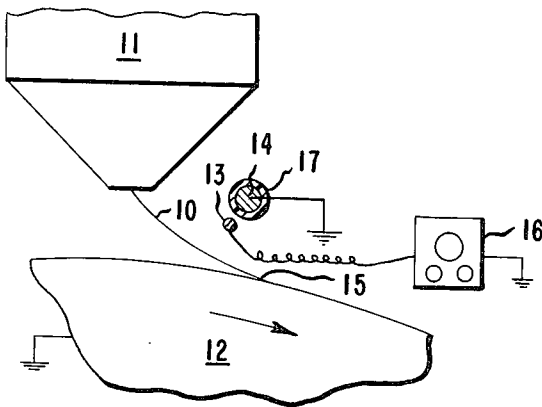


FIG. 1

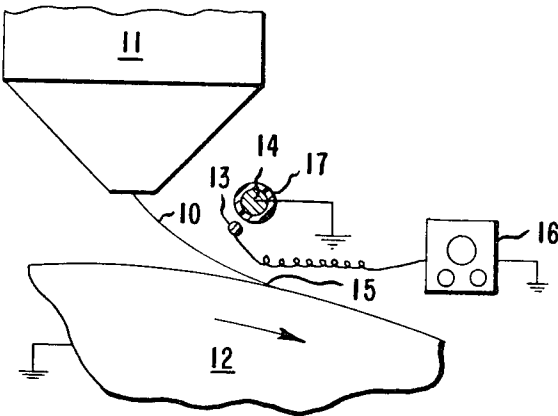


FIG. 2

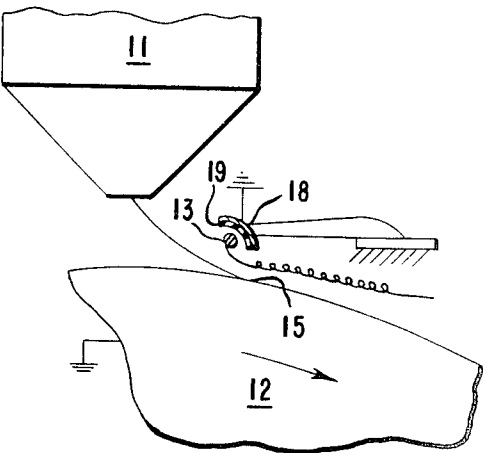


FIG. 3

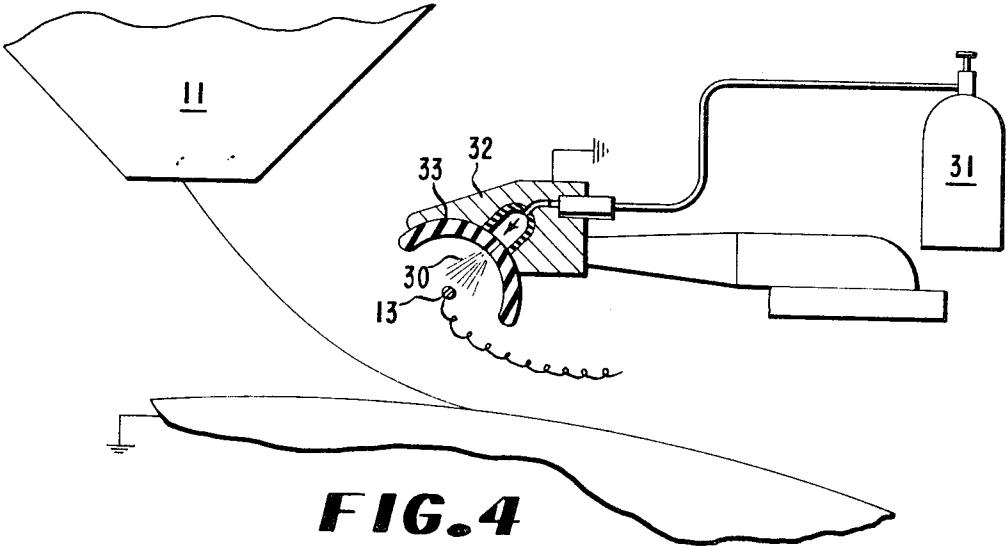
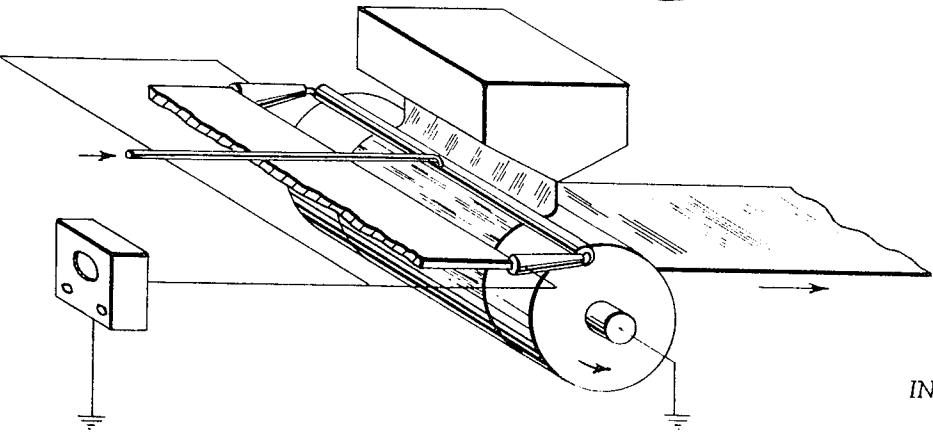


FIG. 4



INVENTOR

WILLIAM E. HAWKINS

BY *Donald W. Huntley*
ATTORNEY

FIG. 5

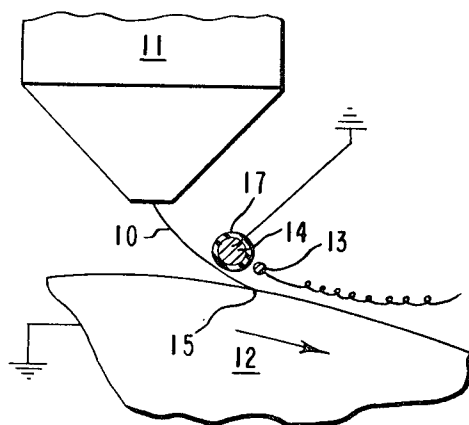
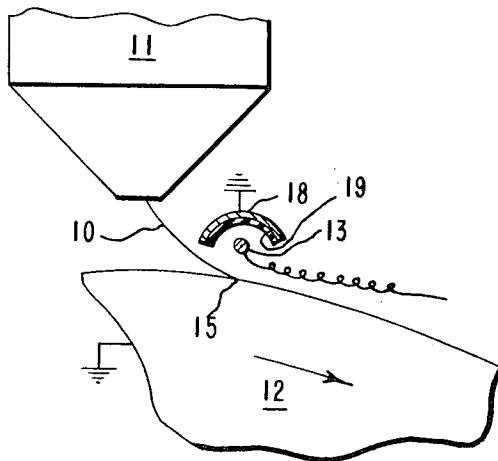


FIG. 6



INVENTOR
WILLIAM E. HAWKINS

BY *Donald W. Huntley*
ATTORNEY

ELECTROSTATIC PINNING OF DIELECTRIC FILM

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of copending application Ser. No. 823,848, filed May 12, 1969, now abandoned.

BACKGROUND OF THE INVENTION

In the preparation and treatment of dielectric films, it is often necessary to apply a force to the film to bring or hold it in contact with rolls or belts. For example, films are regularly subjected to coating and stretching treatments where firm contact with rollers is essential to the operation, but where the application of conventional mechanical forces would be undesirable. One of the most widely used methods of pinning film involves imparting an electrostatic charge to the film through an electric field between the wire or point electrode and the grounded surface on which the film is carried. However, for certain high-speed operations, even electrostatic pinning is less than completely satisfactory.

Certain unique requirements have been encountered, for example in the casting of molten, crystallizable thermoplastic web, where it is necessary to quickly cool the molten web to a temperature below the glass transition temperature to minimize crystallization. The extruded web is generally cooled by casting the molten thermoplastic material onto a moving chilled surface, using electrostatic pinning to bring the web into intimate contact with the chilled surface. Previous attempts to increase the speed of this procedure for more efficient and economical operation have resulted in poor gauge uniformity and regularly recurring haze patterns known in the art as venetian blind haze.

The higher speeds are believed to result in the entrapment of air between the drum and the web, which hinders quenching by diminishing heat transfer between the drum and the web. Attempts have previously been made to increase the electrostatic force generated by the wire or probes by increasing the voltage. These attempts, however, have for the most part been ineffective, since increased voltage generally causes a catastrophic electrical breakdown between the electrode and the web long before any substantial increase in the pinning force is effected. The sparking between the electrode and the surface of the web or other parts of the apparatus interrupts the electrical field which contributes to the pinning force. In addition, the sparking can cause pinholes in a freshly cast soft web, which holes are greatly enlarged by an orientation of the film.

Consequently, the pinning force available through electrostatic pinning means has heretofore been inadequate for some high-speed applications.

SUMMARY OF THE INVENTION

The instant invention provides an apparatus for electrostatic pinning which can produce a substantially higher and more uniform pinning force than has heretofore been available.

Specifically, the instant invention provides an apparatus for pinning a dielectric film to an electrically grounded moving surface which comprises a first electrode and a second, grounded electrode electrically insulated from the first electrode, a high voltage current source and means connecting the current source to the first electrode to establish an electrical potential difference between the first and second electrodes, the first electrode being in spaced relationship to the moving surface, the distance between the first and second electrodes being less than the distance between the first electrode and the moving surface. Preferably the apparatus further comprises means for substantially surrounding at least the first electrode with a gas.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1, 2, and 3 are schematic representations of cross-sectional views of specific embodiments of the apparatus of

the instant invention, shown in conjunction with extrusion and quenching apparatus; and

FIG. 4 is a view in perspective of an apparatus of FIG. 3;

FIGS. 5 and 6 are cross-sectional views of additional specific embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first electrode used in the instant invention can be made from any metallic conductor having adequate strength and dimensional stability to withstand the stresses encountered in the operation of the instant process. Such materials can include, for example, tempered steel, tungsten, "Inconel" nickel-iron alloy, "Monel" nickel alloy, copper, brass, and stainless steel. The particular configuration of the first electrode can be similar to that of electrodes generally used in the art of electrostatic pinning, such as those described in Owens et al., U.S. Pat. No. 3,223,757, hereby incorporated by reference. For full sheet electrostatic pinning, a thin wire, substantially circular in cross-section, is especially preferred due to the exceptionally high rate of ion formation believed to result from the minimum surface area. However, in those embodiments of the invention using a knife edge or a plurality of pointed electrodes as described in the Owens et al. specification, the functional edge of the electrode should be directed toward the second electrode of the instant apparatus instead of the quenching surface as required in Owens et al.

The primary electric field for the generation of pinning ions is established between a first electrode, described above, and a second, grounded electrode. Accordingly, an important feature of the instant invention is that the distance between the first and second electrodes be less than the distance between the first electrode and the grounded moving surface. Outside of this basic requirement, the positioning of the second electrode can vary widely. However, since the point of ion formation is believed to be at or near the first electrode, the straight linear paths between the first electrode and the grounded moving surface should be substantially unimpeded, particularly prior to the point of initial or strongest contact of the dielectric and the grounded moving surface. Thus, while a rod-like or relatively small second electrode can be beneficially placed between the first electrode and the grounded moving surface for the acceleration of ions toward that surface, it is generally preferred that the second electrode be placed farther from the dielectric film than the first electrode so as to minimize interference with the deposition of ions onto the film. It is also preferred that the distance between the first and second electrodes be less than about 1 inch, for optimum ion formation.

In addition to the higher pinning force obtainable through the use of the two electrodes in accordance with the instant invention, another advantage can be realized through a specific position of the second electrode. It has been found that the charging of a freshly extruded thermoplastic web along the span extending from an extrusion orifice to the touchdown point onto a quenching surface irregularly increases the attraction of the web to the quenching surface so as to result in increased variation of the touchdown point along the width of the film. This variation in the touchdown point can result in the intermittent entrapment of small air bubbles, an effect often encountered at high quenching speeds. Accordingly, the second electrode is preferably positioned so as to prevent charging of the web substantially before the touchdown point onto the drum. Such positioning is illustrated in FIGS. 5 and 6 wherein electrodes 14 and 18, together with insulating layers 17 and 19 are positioned so as to intersect a substantial percentage, and preferably at least about 50 percent, of the straight linear paths between wire electrode 13 and the freshly extruded web 10. It may be noted that this positioning does not interfere with the straight linear paths between the first electrode 13 and the quenching surface 12, the extreme linear paths being defined by tangents to the quenching surface from the wire.

A gap should be maintained between the second electrode and the freshly extruded web sufficient to prevent the web contacting the second electrode due to the aerodynamic effects of the moving web. A set gap of at least about $\frac{1}{8}$ inch is generally sufficient to prevent contact.

The second electrode can be prepared from the same materials suggested above for use in the first electrode. In addition, the second electrode is insulated from the first electrode by a dielectric material. It is found that the dielectric insulation of the second electrode prevents the discharge of gaseous ions on the second electrode and enables the application of exceptionally high voltages to the first electrode without a breakdown in the gap between the electrodes, thus preventing interruption of the pinning force. In addition, ions attracted to the grounded second electrode retain their positive or negative charge, thereby repelling like ions toward the web to effect the desired pinning.

The degree to which the second electrode is covered by the dielectric material will vary with the particular configuration of the second electrode. For purposes of the instant invention, the second electrode is considered to be insulated when all of the straight linear paths between the first and second electrodes are intersected by dielectric.

Dielectric material which can be used to insulate the second electrode include natural and synthetic rubbers as well as resinous materials such as polyimides, fluorocarbon resins, urea formaldehyde resins, phenol formaldehyde resins, nylons and cast epoxy resins. It has been found that "Teflon" fluorocarbon resins are particularly well suited for this application due to their excellent electrical insulating properties and stability at elevated temperatures.

The particular physical configuration of the second electrode is not critical to the instant process, as long as the second electrode does not surround the first electrode to the extent of intersecting a substantial percentage of the straight linear paths between the first electrode and the moving surface. Accordingly, the second electrode, in a basic form, can be a metal rod, as illustrated in FIG. 1. In that figure, a thermoplastic web 10 is extruded from hopper 11 onto a moving quench drum 12. A first electrode 13 and a second electrode 14 are positioned approximately above the touchdown point 15 of the web onto the drum. The first electrode is connected to high voltage source 16 and the second electrode is insulated by sheath 17.

The second electrode, in a preferred embodiment of the invention, is arcuate in cross section and is positioned farther from the web than the first electrode, with the first electrode positioned within the arc defined by the second electrode. This particular embodiment facilitates the direction of the ions formed by the electric field toward the thermoplastic web. One such embodiment of this type is illustrated in FIG. 2 wherein arcuate second electrode 18 is positioned adjacent first electrode 13 and is insulated therefrom by a dielectric insulating sheath 19. The arcuate configuration of the second electrode permits the use of an insulating barrier on only one side of the second electrode, while intersecting all of the straight linear paths between the two electrodes.

Both the second electrode and the moving surface in the instant invention are generally grounded to provide the requisite potential difference between the first and second electrode and the attraction of the formed ions by the drum. The grounding can be direct or through nominal resistance, such as the framework of the mechanism involved.

The high voltage source applied to the first electrode can have a voltage of about from 2 to 30 kilovolts and an amperage of about from 1 to 3,000 microamperes, for electrodes generally used for pinning operations. In general, a unidirectional current, and especially a unidirectional positive current are preferred.

In a preferred embodiment of the instant invention, a gas stream is directed so as to substantially surround at least the first electrode. The gas is believed to contribute to the pinning force by increasing the current generated on the wire without

causing sparking. Accordingly, gases which can be used in this embodiment are selected from those in which a Wire Current Before Breakdown of at least about 100 microamperes/inch of wire can be generated, as measured by the Current Generation Test. The requirements of the Current Generation Test, as well as specific gases in which the required Wire Current Before Breakdown can be generated are set forth in full detail in copending, coassigned U.S. Pat. application Ser. No. 21,696, (F-1988-R) filed simultaneously herewith, which is hereby incorporated by reference.

It is preferred that the difference between the Voltage at Threshold Current and the Voltage at Spark Breakdown of the gas be at least 2.0 kilovolts. This minimizes the need for close control of the voltage applied to the pinning apparatus to prevent sparking.

Preferred gases in which a Wire Current Before Breakdown of at least 100 microamperes per inch of wire can be generated include nitrogen, helium, air having a moisture content of less than about 5 percent oxygen, Freon 114 dichlorotetrafluoroethane, Freon 12 dichlorodifluoromethane, air having a moisture content of less than 5 percent and substantially saturated with carbon tetrachloride at room temperature, and tetrachloroethane.

In those embodiments where the second electrode is of a semicircular or arcuate configuration, the gas is best directed so as to surround the first electrode as well as pass over the insulated surface of the second electrode facing the first electrode. An apparatus illustrating this lattermost embodiment is shown in FIG. 3, wherein a gaseous stream 30 supplied from gas source 31 is passed through second electrode 32 and dielectric insulator 33 to escape along the surface of the insulating layer and over first electrode 13 onto the thermoplastic web.

The gas should be supplied at a minimal pressure necessary to maintain an atmosphere around the electrodes, since extremely high gas pressure can cause distortion of the web in some applications.

The apparatus of the instant invention is applicable to the pinning of any dielectric film. Preferred films include those of organic thermoplastic polymer including, for example, polyesters such as polyethylene terephthalate, polyolefins such as polyethylene and polypropylene, vinyl acetate polymers and copolymers, vinylidene chloride polymers and copolymers, polyamides, cellulosic esters and ethers, styrene polymers and copolymers, rubber hydrochlorides and polycarbonates. The apparatus is particularly applicable to the quenching of crystalline polymers and especially polyethylene terephthalate, since the drawing and resulting optical properties of these films, when produced at high speeds, are greatly enhanced.

The instant apparatus is additionally applicable to the handling of other dielectric films, for example, in coating or printing operations for papers, cellophane, and thermosetting resins such as "Kapton" polyimide resin.

The instant invention provides a higher and substantially more uniform pinning force than has heretofore been available through the use of known methods of electrostatic pinning. The reasons for the improved pinning are not fully understood, but are believed to be primarily a function of the independence of the pinning apparatus from the grounded roll to which the dielectric film is pinned and the insulation of the second electrode. The instant apparatus is found to provide increased pinning force even when positioned substantially further away from the dielectric film than has been possible using apparatus arrangements wherein the primary electrical field is established between an electrode and a grounded roll. Further, the apparatus is relatively independent of external mechanical vibration, resulting in a more uniform generation and deposition of gaseous ions onto the thermoplastic film.

The higher voltages which can be used in the instant invention and the higher pinning forces which can be obtained permit the use of correspondingly higher operating speeds, as illustrated by the following examples.

EXAMPLE 1

Polyethylene terephthalate is extruded and pinned to a quench drum substantially as described in Example 1 of Owens et al., U.S. Pat. 3,223,757, to establish a control standard. The film is thereafter biaxially oriented to a thickness of about 0.75 mil. The maximum rate of production for films of consistently high quality is determined and designated as R.

The procedure is repeated, using a pinning apparatus of the type illustrated in FIG. 3 of the instant specification. The first electrode is a steel wire having a diameter of 0.006 inch. The second, arcuate electrode is steel and is positioned about 0.6 inch away from the first electrode. The second electrode has a 10 mil insulating layer of polytetrafluoroethylene resin on the concave surface. The first electrode is about 0.75 inch away from the drum. A positive unidirectional current of about 2 milliamperes having a voltage of about 18 kilovolts is applied to the first electrode. Oxygen is supplied to the apparatus through the aperture formed in the second electrode and its insulating layer at a minimal pressure necessary to maintain a continuous stream around the first electrode.

The maximum production rate using the pinning apparatus of the instant invention is determined, and found to be 1.60R.

EXAMPLES 2-11

In Examples 2 to 11, polyethylene terephthalate is melt extruded at a constant rate onto a cooled quench drum. The quench drum has a diameter of 6 feet and the extruded sheet is 16½ inches wide. The thickness of the film on the quench drum varies with the speed of the drum.

In Example 2, a single 0.008 inch diameter stainless steel wire electrode is situated ¾ inch above the quench drum surface at a position which gives the best possible pinning effect. A positive unidirectional voltage is applied to the wire at the highest voltage possible without sparking, and the speed of the drum is increased to the greatest rate possible without the appearance of "pinner bubbles" between the surfaces of the drum and the extruded web. The results of this control standard are summarized below.

Example	Gas	Film thickness (mils)	Maximum drum speed (ft./min.)	Voltage (kv.)	Current (µa./in. wire)
2.....	Room air..	7.4	80	9.2	30

In Examples 3-5, the procedure of Example 2 is repeated, except that an electrode apparatus of the type illustrated in FIG. 3 is used instead of the bare wire electrode of Example 2. The electrode apparatus is positioned at the same point as the bare electrode, and the same voltage is applied to the wire. In Examples 4 and 5, oxygen and nitrogen are supplied to the apparatus to substantially surround the pinning wire. These gases effect a moderate increase in the amount of ions formed which causes an intermittent force increase across the width of the film. This causes variations in the touchdown point which actually decreases the maximum operating speed without pinner bubbles.

Example	Gas	Film thickness (mils)	Maximum drum speed (ft./min.)	Voltage (kv.)	Current (µa./in. wire)
3.....	Room air..	6.0	110	9.2	37
4.....	Oxygen...	6.0	105	9.2	44
5.....	Nitrogen..	6.0	105	9.2	89

In Examples 6-8, the procedure of Examples 3-5 is repeated, except the voltage is increased to the maximum without sparking. The increased voltage results in a high enough increase in ion formation using oxygen and nitrogen gas to apply a uniformly increased pinning force at the

touchdown point and effect an increase in the maximum speed without pinner bubbles.

Example	Gas	Film thickness (mils)	Maximum drum speed (ft./min.)	Voltage (kv.)	Current (µa./in. wire)
6.....	Room air..	5.0	130	10.5	89
7.....	Oxygen...	5.0	135	10.8	94
8.....	Nitrogen..	5.0	135	11.3	81

In Examples 9-11, the procedure of Examples 6-8 is repeated, except that the position of the pinning apparatus is adjusted to the best possible, as opposed to placing the apparatus at the point of best performance of the bare wire.

Example	Gas	Film thickness (mils)	Maximum drum speed (ft./min.)	Voltage (kv.)	Current (µa./in. wire)
9.....	Room air..	4.75	150	10.1	69
10.....	Oxygen...	4.75	160	10.9	100
11.....	Nitrogen..	4.75	160	10.7	81

I claim:

1. An apparatus for pinning a dielectric film extruded from a hopper onto an electrically grounded moving surface which comprises a first electrode and a second, grounded electrode spaced from said hopper and electrically insulated from the first electrode by a dielectric coating thereon which intersects substantially all of the straight linear paths between the first and second electrodes, a high voltage current source and means connecting the current source to the first electrode to establish an electric potential difference between the first and second electrodes, the first electrode being in spaced relationship to the moving surface, the distance between the first and second electrodes being less than the distance between the first electrode and the moving surface.
2. An apparatus of claim 1 wherein the high voltage source is a unidirectional current source.
3. An apparatus of claim 2 wherein the high voltage source is positive.
4. An apparatus of claim 1 wherein the distance between the first electrode and the moving surface is less than the distance between the second electrode and the moving surface.
5. An apparatus of claim 1 further comprising means for substantially surrounding at least the first electrode with gas.
6. An apparatus of claim 1 wherein the electrically grounded moving surface is a quenching surface and the film is thermoplastic, melt-extruded onto the quenching surface from a die orifice.
7. An apparatus of claim 6 wherein the second electrode is so positioned as to intersect at least 50 percent of the straight linear paths between the first electrode and that portion of the melt-extruded film extending from the die orifice to the point of touchdown of the film onto the quenching surface.
8. An apparatus of claim 1 wherein the second electrode is arcuate in configuration and is positioned farther from the moving surface than the first electrode, the concave surface of the second electrode facing the moving surface, the second electrode being insulated from the first electrode by a layer of dielectric resin on at least the concave surface thereof and wherein the first electrode is positioned within the arc defined by the second electrode.
9. An apparatus of claim 7 wherein the second electrode and the layer of dielectric resin have at least one aperture formed therethrough, the apparatus further comprising means for passing a gaseous stream through the aperture and toward the first electrode and the film.

* * * * *