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(54) **LONG FIBER THERMOPLASTIC PROCESS FOR CONDUCTIVE COMPOSITES AND COMPOSITES FORMED THEREBY**

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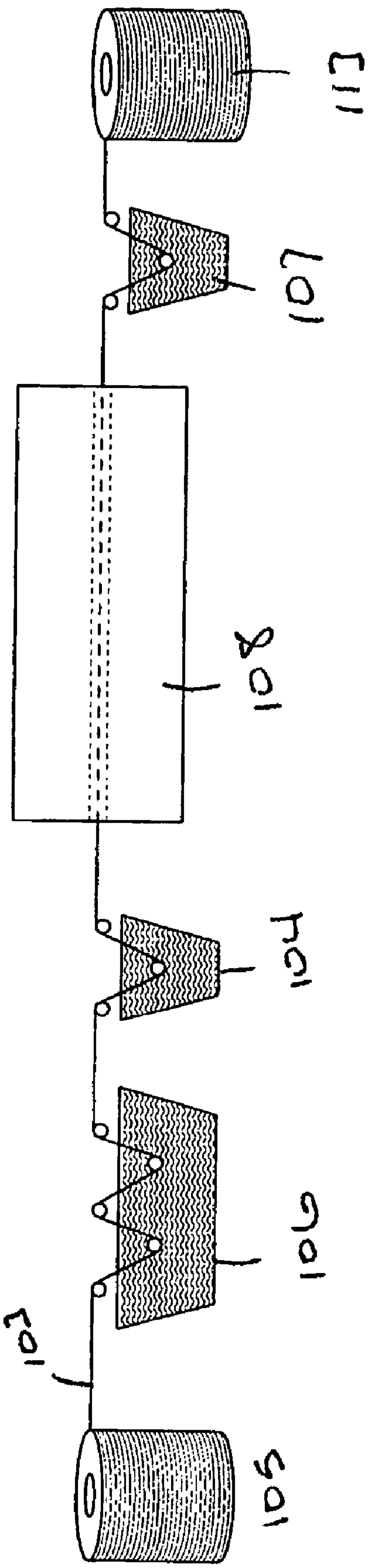
(57) **ABSTRACT**

The present invention relates to a polymer article that includes electrically conductive fibers to provide electrical electromagnetic interference (EMI) shielding and their method of manufacture. The invention includes a method for forming shielding materials by impregnating conductive fibers in a polymer material via direct injection of the conductive fibers into the extrusion process. The invention also includes EMI shielding polymers and products that are radio-frequency and electromagnetically shielded by parts formed of the shielding polymer.

FIG. 1 PRIOR ART



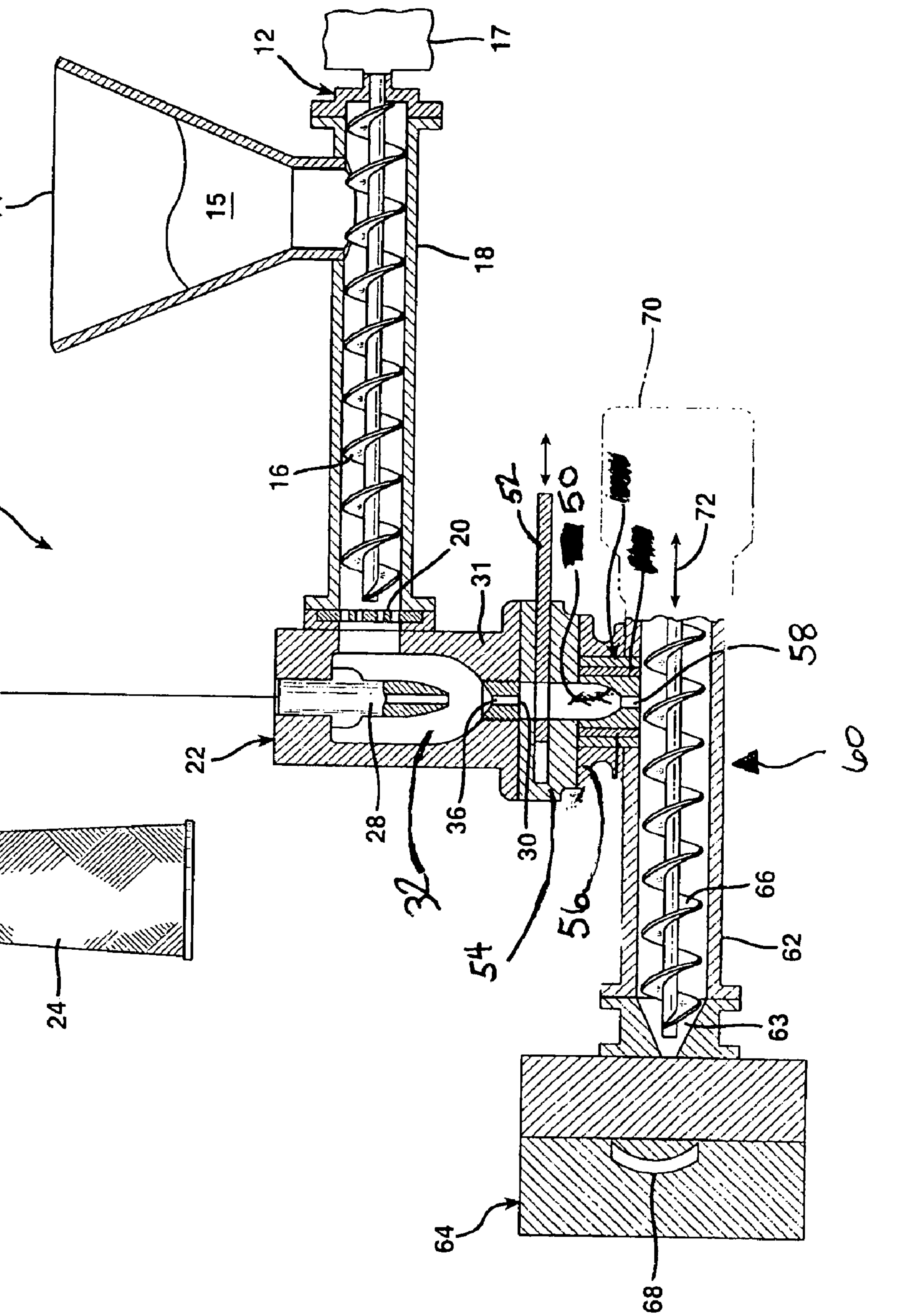

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FIG. 2

LONG FIBER THERMOPLASTIC PROCESS FOR CONDUCTIVE COMPOSITES AND COMPOSITES FORMED THEREBY

[0001] This Application claims the benefit of U.S. Provisional Application 60/729,695, filed Oct. 24, 2005.

TECHNICAL FIELD AND INDUSTRIAL APPLICABILITY OF THE INVENTION

[0002] The present invention relates to a polymer article that includes electrically conductive fibers to provide electrical electromagnetic interference (EMI) shielding and their method of manufacture. More particularly, the invention relates to a method for forming shielding materials by impregnating conductive fibers in a polymer material via direct injection of the conductive fibers into the extrusion process. EMI shielded polymers of the present invention may be formed into a wide variety of products such as radio-frequency and electromagnetic shielded plastic articles.

BACKGROUND OF THE INVENTION

[0003] With the increased usage of electronic equipment such as computers and other digital devices there is a heightened concern for the hazards associated with electromagnetic radiation, in particular radar waves, microwaves and electromagnetic radiation produced by electronic circuits. As the electronic industry continues to grow at a rapid pace, there exists a need to create improved electromagnetic wave shielding materials, which can be incorporated into electronic products.

[0004] A number of electrically conductive materials have been developed to fabricate composite articles, such as plastic articles, for electromagnetic shielding, electrostatic dissipation, and other electrically enhanced characteristics. Plastic articles formed from electrically conductive materials are particularly convenient as compared to traditional metal materials because they are lightweight, easily produced using injection molding techniques, and low cost. Typically these electrically conductive materials are composites of plastics and conductive powders and chopped fibers.

[0005] Various techniques have been employed when incorporating electrically conductive powders and chopped fibers into a composite article. FIG. **1** illustrates a traditional thermoplastic extrusion compounding technique, which has been commonly employed. A thermoplastic resin **112** is fed into the compounder **110**. The resin **112** is heated to a molten temperature and then fibers or powders (collectively indicated as **114**) are fed into the compounder **110** to mix in the conductive powders or chopped fibers. The resin/broken fiber mixture is extruded **118**, cooled in a water bath **120**, then chopped by a Strand Cutter **122** into pellets **124**. Pellets **124** are then typically fed into the melting section of an injection molding machine (not shown).

[0006] The pellets of the process shown in FIG. **1**, include fibers that are broken due to the cutting action by the screw **116** and by the shear force applied to melt the resin. The fibers are broken during the compounding process so that the resulting composite article contains only relatively short broken fibers. The shortened fibers impart reduced electromagnetic shielding properties to the composite due to their reduced ability to form a conductive fiber network and conduct electricity through the composite article. Alternatively, when mixing conductive powders with the molten thermoplastic it is typically necessary to employ a very large amount of the conductive powder. Such large amounts of powder can result in a poor dispersion of the powder or reduced mechanical strength of the final product. Accordingly, composite articles formed with broken fibers and powders require higher loadings or filler concentrations which leads to decreased mechanical strength of the composite article formed and higher material costs.

[0007] Published U.S. Application US 2002/0108699 entitled "Method for Forming Electrically Conductive Fibers and Fiber Pellets" (herein incorporated in its entirety by reference) discloses electromagnetic wave shielding pellets formed by (1) applying a sizing material to Ni-coated fibers to make the fibers compatible with the thermoplastic matrix material; (2) thermally drying the sizing; (3) wire coating the fibers with the thermoplastic matrix material; (4) quenching the thermoplastic matrix material; (5) drying the coated fibers; (6) chopping or pelletizing the coated fibers; (7) feeding the pellets into an injection molding machine; and (8) melting the pellets and injection molding the part.

[0008] Each step of the pelletized fiber approach allows for material loss and inefficiency, slows cycle times and provides an opportunity for defects. There are several additional drawbacks. Heating of the thermoplastic polymer during the wire coating process and again during the injection molding process degrades the performance of the polymer. Severe degradation can break down the polymer and form gasses that result in voids and a subsequent loss of shielding and mechanical properties. Additionally, to achieve good mold filling, the polymer must be at a melt flow sufficient to fill ribs or other small features of a part. Melt flow is achieved by the selection of the thermoplastic material, the temperature, dwell time and shear from the screw. High shear from the screw provides for sufficiently high melt flow but breaks the conductive fibers into smaller and smaller lengths and diminishes the ability of the fibers to form a continuous network of fibers.

[0009] Shielding effectiveness may be determined by ASTM-D4935, which measures far field shielding effectiveness, or by ASTM ES7-83, which measures near field effectiveness.

[0010] US 2002/0108699 produces a electromagnetic shielded article with a shielding effectiveness of 80-90 dB (far field) and less than 80 dB (near field) at a frequency of 30-1500 MHz and a 15 wt. % fiber loading.

[0011] An alternative dry blend method of forming shielded articles requires that chopped conductive fibers are mixed with the resin directly at the injection molding operation. This typically results in very poor fiber dispersion and inconsistent electrical performance from part to part. US 2002/0108699 discloses that the dry blend method produces a electromagnetic shielded article with a shielding effectiveness of 60-70 dB at a frequency of 30-1500 MHz and a 15 wt. % fiber loading.

[0012] FIG. **1** shows the in-line process according to US 2002/0108699 in which a fiber tow **103** is unwound from a package or spool **105** and drawn through an aqueous silane bath **106** to apply a conductive coating to the tow **103**. The tow **103** is then drawn through an aqueous silane bath **104** and through an oven **108**. The tow **103** then passes though a nonaqueous sizing bath **107**. The tow **103** is then wound onto a package (or spool) **113**. The coated fibers are subsequently pelletized and place into the extruder of an injection-molding machine.

[0013] Previous methods of forming EMI shielding composite articles have not been entirely satisfactory for due to short fiber length in the finished part which reduces the shielding and necessitates additional loading of fibers. The average fiber length from wire coating, pelletizing and subsequent injection molding the pellets was about 0.5 mm. Because the conductive fibers must touch one another to form a continuous network and provide shielding, 10-20 wt. percent of carbon fiber or nickel coated carbon fiber is required to provide sufficient EMI shielding. This high level of fiber loading increases the cost of the composite article due to the high cost of the fibers and inhibits the flow of the polymer in the mold. The high fiber loading also significantly increases the modulus of the article but lowers impact resistance. EMI shielding resins are used in goods such as mobile phones and lap top computers which are expected to resist the impact from a fall of up to a meter or more without breakage. A thermoplastic resin filled to 10-20 wt. % fibers becomes brittle and susceptible to breakage.

[0014] Another drawback to the previous methods of forming EMI shielding composite articles is poor fiber dispersion. The pelletized material is difficult to process such that the fibers are fully dispersed and do not form an efficient network of conducting fibers in the composite material. When good fiber distribution is sometime achieved; however, the pellets and fibers will have been comminuted to such an extend that the average fiber length is approximately 0.5 mm and, as a result, the short fibers do not form an efficient network of conducting fibers in the composite material. In either case, it is necessary to overload the composite with conducting fibers to compensate for the inefficient network of conducting fibers in the composite material.

[0015] U.S. Pat. No. 6,676,864 entitled "Resin and Fiber Compounding Process for Molding Operations" (herein incorporated in its entirety by reference) describes an apparatus and process for preparing fiber reinforced resin and molding that resin. The '864 patent shows an injection molding apparatus including a two stage extruder the first to impart shear forces to melt a polymer and the second to feed molten thermoplastic into a mold. Reinforcing fibers, such as glass fibers, carbon-graphite fiber or Kevlar fibers, are supplied between the two stages of the extruder. The molding device of U.S. Pat. No. 6,676,864 does not contemplate electromagnetic shielding.

SUMMARY OF THE INVENTION

[0016] The invention answers the problems connected with previous methods of forming EMI shielded polymer. Long fiber thermoplastic technology allows the conductive fibers, to maintain a length sufficient to provide EMI shielding at lower fiber loading. The long fiber thermoplastic process for forming EMI shielding composite articles also provides increased impact resistance, enhanced surface aesthetics and improved extrusion and injection molding processing at a lower material cost and with decreased waste and scrap.

[0017] The long fiber thermoplastic process for conductive composites and composites formed thereby of the present invention is simpler, more efficient and provides improved properties than the prior art methods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings, which are included to provide further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principle of the invention. In the drawings:

[0019] FIG. **1** is a schematic representation of a prior art wire coating process for compounding an EMI shielding thermoplastic extrusion material.

[0020] FIG. **2** is a plan view, partially in cross section, of one extruder useful in practicing the present invention.

DETAILED DESCRIPTION AND PREFERRED EMBODIMENTS OF THE INVENTION

[0021] Thermoplastic resin, preferably in the form of pellets, is provided to resin primary extruder **12** from a resin supply **14**. The resin may be any of a variety of acceptable thermoplastic resins for the product purpose intended, such as polypropylene, nylon, polyurethane, and polyesters. A melting screw **16** is rotates within melting barrel **18** of extruder **10**. While the shear force of melting screw **16** may provide sufficient heating to melt and condition the polymer, the melting barrel **18** may be provided with an additional heat source as is known in the art.

[0022] A flow control plate **20** may be used at the downstream end of barrel **40** to control the flow of resin **15** out of the extruder barrel **18** and into coating die **22**. The plate **20** typically restricts the flow of resin **15** by a reduction in the diameter or by otherwise constricting the flow within the barrel **18**. The coating die **22** and any apparatus in contact with the resin **15** may include suitable heat elements to maintain the desired temperature of the resin. The pressure within the coating die may be monitored by a pressure transducer which provides a control signal to the drive motor **17** of melting screw **16**.

[0023] Fiber spool **24** provides a direct feed of a tow of shielding fibers **26**. The shielding fibers may be of any suitable composition for example nickel, copper or and conductive material coated on carbon, aramid, glass or other suitable substrate, alternatively stainless steel, copper or similar metallic fibers may be used. The fibers are pulled though injection nozzle **28** into the coating chamber **32** of coating die **22**. The shielding fibers **26** are then intimately blended and coated with the molten polymer material **15**. The coated shielding fibers **26** then exit the coating die **22** through die orifice **36** of interchangeable insert **30**. The diameter of the die orifice **36** can adjusted by changing insert **30** to control the ratio of shielding fibers **26** to resin **15**.

[0024] The resin **15**, fiber **26** mixture exits coating die **22** and the shielding fibers **26** may be cut by blade **52** in cutting chamber **50** in housing **54**, **56**. The mixture of resin **15** and fibers **26** exit chamber **50** via orifice **58** into extruder **60**. The extruder **60** typically includes a barrel **62** that feeds the mixture of resin **15** and fibers **26** into extrusion die **64**. A feed screw **66** rotates with barrel **62** and may optionally reciprocate along axis **72** to feed a charge of molding material through orifice **63** into the molding cavity **68** of die **64**. The feed screw **66** is driven by a power unit **70**.

[0025] The temperature within the barrel **18**, coating chamber **32**, cutting chamber **50** and extruder **60** may be controlled by one or more heating elements and temperature probes controlled a microprocessor (not shown). Suitable polymers include thermoplastic polymers such as acrylonitrile-butadiene-styrene (ABS), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polyethylene (PA) and other thermoplastic materials have suitable mechanical, thermal and melt flow properties.

[0026] Other fibers include metal coated glass and carbon fibers including coatings of metals such as aluminum, copper, nickel, and lead. Plasma deposition, molten liquid deposition and electrodepositing of the metals are preferred methods of coating the fibers.

[0027] The article molded within molding cavity **68** includes a number of individual shielding fibers **26** where each fiber is of a predetermined length, as established by the action of blade **52**. The molded article includes fibers which are roughly 3 times the length of wire-coated and pelletized method shown in FIG. **1**. Average lengths from wire coating, pelletizing and injection molding the pellets was about 0.5 mm. Expected average lengths of the Ni—C fiber would be 1.5 mm or more.

[0028] The shielding properties of the molded material are defined by the number of fibers in contact to create a conductive network. The long fiber thermoplastic should be able to reduce the number of fibers needed to achieve the same connectivity to ¼ to ⅓ the original amount.

[0029] Thus, rather than needing 15%-20% by weight fiber loading, LFTP could reduce the fiber needed to as low as 4-5% by weight of composite.

[0030] Reducing the amount of carbon fiber to say 5% loading would vastly improve the impact strength. The loss of impact strength severely limits the number of applications for conductive composites: e.g. cell phone exteriors. We could anticipate up to 50% impact improvement or more reducing fiber volumes to 5% by weight.

[0031] 5% fiber loading would also improve the surface aesthetics, another issue with exterior housings for consumer products. Fibers at the surface give a poor appearance.

[0032] 5% fiber loading would save up to 75% of the fiber costs, which can cost $30/lb or more.

EXAMPLES

[0033] The following examples are prophetic and all mechanical and shielding properties are estimated. In Example 1, acrylonitrile-butadiene-styrene (ABS) polymer is melted and 10% by weight Nickel coated carbon (NCC) fibers are added to the ABS. The fibers are cut to length and the ABS/fiber melt is extruded to form a composite part.

[0034] In Example 2, ABS polymer is melted and 7.5% by weight NCC fibers are added to the ABS. The fibers are cut to length and the ABS/fiber melt is extruded to form a composite part.

[0035] In Example 3, ABS polymer is melted and 5.0% by weight NCC fibers are added to the ABS. The fibers are cut to length and the ABS/fiber melt is extruded to form a composite part. The properties of the examples are estimated below.

EXAMPLE	WT % NCC	Impact
1	10	Pass
2	7.5	Pass
3	5.0	Pass

[0036] The invention of this application has been described above both generically and with regard to specific embodiments. Although the invention has been set forth in what is believed to be the preferred embodiments, a wide variety of alternatives known to those of skill in the art can be selected within the generic disclosure. The invention is not otherwise limited, except for the recitation of the claims set forth below.

I claim:

1. A fiber reinforced polymer article having improved electromagnetic shielding properties, comprising:

a thermoplastic polymer; and

less than 10 percent by weight conducting fibers wherein the composite article has an electromagnetic shielding efficiency of at least 70 dB.

2. The fiber reinforce polymer article of claim 1, wherein the electromagnetic shielding efficiency is least 90 dB.

3. The fiber reinforce polymer article of claim 1, wherein said conducting fibers are present in an amount less than 5 percent by weight

4. The fiber reinforce polymer article of claim 1, wherein said thermoplastic is selected from the group consisting of acrylonitrile-butadiene-styrene (ABS), polyethylene terephthalate (PET), polybutylene terephthalate (PBT) and polyethylene (PA).

5. The fiber reinforce polymer article of claim 1, wherein property deterioration of said thermoplastic due to melt history is substantially reduced

6. A method of manufacturing a composite article including the steps of:

melting a thermoplastic material;

adding conductive fibers to said melted thermoplastic material;

cutting said conducting fibers to a predetermined length; and

injection molding the thermoplastic material to form a composite article having a electromagnetic shielding efficiency of at least 70 dB.

7. A digital device having an electromagnet shield, said shield comprising:

a thermoplastic polymer; and

less than 10 percent by weight conducting fibers wherein the composite article has an electromagnetic shielding efficiency of at least 70 dB.

8. The fiber reinforce polymer article of claim 7, wherein the electromagnetic shielding efficiency is least 90 dB.

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