FIELD OF DISCLOSURE

The present disclosure relates to oriented products of polyethylene.

More particularly, the present disclosure relates to thermally conductive oriented products of ultra-high molecular weight polyethylene.

DEFINITION

The term "oriented products" as defined herein refers to polymer products in the form of fiber, sheet, film or tape or other forms having oriented polymer chains.

BACKGROUND

Polymers exhibit many advantageous properties such as low mass density, chemical stability, high strength-to-mass ratio and the like. Polymeric materials typically are thermal insulators and hence are not used in the heat transfer applications. However, alignment of polymer crystallites can significantly enhance both the mechanical strength and thermal conductivity of polymers along the direction of the covalently bonded molecular chains.

Polyethylene polymer is used in a variety of industrial and commercial applications due to its low manufacturing cost and light weight. Packaging material such as films, bottles, container and the like are typically made from polyethylene. Ultra-High Molecular Weight Polyethylene (UHMWPE) is a type of polyethylene comprising long, aligned polymer chains. The long extended molecular chains due to their high molecular weight contribute to the thermal conductivity of high strength UHMWPE fiber. Thermal conductivity of high strength UHMWPE fiber increases lineally with tensile modulus.

Polyethylene oriented products are typically produced by gel spun fiber using UHMWPE. However, the process requires large amount of solvents, plasticizers, softeners and the like. Furthermore, the degree of crystallinity and connectivity between crystallites is reduced by the use of solvents..

Hence there is a need to produce thermally conductive polyethylene oriented products without the use of solvents wherein degree of crystallinity and connectivity between crystallites is retained and at the same time is cost effective.

OBJECTS

Some of the objects of the present disclosure, aimed to ameliorate one or more problems of the prior art or to at least provide a useful alternative, are listed herein below.

An object of the present disclosure is to provide polyethylene oriented products that have high thermal conductivity.

Another object of the present disclosure is to provide polyethylene oriented products that have high mechanical properties.

Another object of the present disclosure is to provide a process for producing polyethylene oriented products that does not involve use of solvents.

Another object of the present disclosure is to provide a process for producing polyethylene oriented products wherein the degree of crystallinity and connectivity between crystallites is retained during production.

Another object of the present disclosure is to provide an economical process for producing polyethylene oriented products.

Other objects and advantages of the present disclosure will be more apparent from the following description which is not intended to limit the scope of the present disclosure.

BRIEF DESCRIPTION

The embodiments do not limit the scope and ambit of the disclosure. The description relates purely to the examples and preferred embodiments of the disclosed apparatus and its suggested applications.

The embodiments herein and the various features and advantageous details thereof are explained with reference to the non-limiting embodiments in the following description. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

Organic polymers are known to be thermally insulating materials where the thermal conductivity is usually found to be <1 W/mK at room temperature. However the axial thermal conductivity of oriented polyethylene polymer measured parallel with the alignment of polymer chains increases with the orientation. The degree of crystallinity and connectivity between crystallites further adds to the thermal conductivity of polyethylene. Typically, polyethylene oriented products prepared by gel spun fiber using Ultra-High Molecular Weight Polyethylene (UHMWPE) exhibit high thermal conductivity, which is about 30-100 times more than the polymer resin. Highly oriented UHMWPE fibers and sheets typically exhibit thermal conductivity >30 W/mK. In order to achieve that fiber, or sheet having oriented polymer chains, UHMWPE is solubilized in suitable solvents to loosen the molecular entanglements and then processed to achieve orientation. The removal of solvent is one of the steps of achieving oriented fibre or sheet. However, the process of making unidirectional thermally conductive UHMWPE products involves gel extrusion requiring large amount of solvent.

The present disclosure envisages a thermally conductive polyethylene oriented products and a process for producing/manufacturing polyethylene oriented products using a solvent free process.

The thermally conductive polyethylene oriented products of the present disclosure is produced by a solvent free process using a low bulk density and high crystallinity UHMWPE resin which is preferentially highly disentangled and where the crystallinity of the polymer is retained or increases during the conversion process as the process temperature does not reach to its melting temperature, and where the pressure applied is adequate enough to compact the resin in the required form. The so compacted resin when stretched to attain high orientation results in high axial thermal conductivity. The process has a unique advantage in that it does not involve use of any solvent, plasticizer, softener and the like, to loosen the entanglement of the polymer chains to facilitate orientation. The economics both in terms of energy and materials of the process of the present disclosure is due to the direct compacting of the resin and stretching of the polymer resin into oriented products.

The process involves solid state formation of oriented products below the melt temperature of UHMWPE of very high order of crystallinity and high preferential disentanglements which when stretched can align the molecular chains in the direction of applied stress. The molecular alignment during stretching facilitates heat transfer through C-C covalent bond of polyethylene chain unidirectionally.

The thermally conductive polyethylene oriented products thus produced comprises, UHMWPE of molecular weight 0.3 million g/mol or more having bulk density 0.03g/cc or more, and crystallinity >75% in the form of single or multiple layers of a composite product. The UHMPWE is used with or without additives which facilitates processing and product performance, thus obtaining highly oriented products. The process involves compacting of the polymer powder or compounded mass under pressure > 90 kg/cm^2 in a continuous or batch mode using suitable thermo-compressive device wherein the temperature of the polymer is maintained below its

melt temperature, typically <140°C. The stretching for the orientation of the polymer product can make the process continuous or multistep. The stretching ratio can be as high as 250. The thermal conductivity of the oriented product like tape in the axial direction is > 30 W/mK in the temperature range of -50 to 70°C.

The key features of the oriented products of the present disclosure and of the process for producing the oriented products are listed herein below.

- Solid compacting of UHMWPE below its melt temperature and achieving high orientation of polymer chains maintaining high crystallinity.
- Using a UHMWPE of molecular weight 0.3 to 15 million g/mol having bulk density in the 0.03-0.2 g/cc and crystallinity> 75%.
- Avoiding any processing aid in the form of plasticizer, softener like solvents or low molecular weight waxy material.
- Using additives which can further add functionality in the product.
- The oriented products can be obtained in the form of a sheet, tape, fiber, film or other oriented forms.
- The process for producing the oriented products can be stepped or continuous.
- The thermally conductive polyethylene oriented products can be single or multiple layered composite of similar or different materials but necessarily having at least UHMWPE of the characteristics as mentioned herein above.
- The thermally conductive polyethylene oriented products can be anisotropic having ultra-high mechanical properties and very high thermal conductivity in the axial direction.
- The thermally conductive polyethylene oriented products can be a part of an assembly requiring efficient heat transfer up to a particular temperature range which does not cause molecular mobility of UHMWPE and does not disturb the chain alignments.

The advantages of the process for producing thermal conductive oriented products of polyethylene by direct solid compacting of UHMWPE below its melt temperature is achieving high orientation of polymer chains maintaining high crystallinity on hot stretching. Further, the process does not involve use of solvent thereby making the

process highly economical with respect to energy and material. Also, as the order of crystallinity maintained is high during solid state processing the probability of having defect free linear segments in the polymer chains eases thermal conductivity and therefore the process can be used for UHMWPE of very high molecular weight (as high as 15 million g/mol).

TECHNICAL ADVANTAGES AND ECONOMIC SIGNIFICANCES

The technical advancements offered by the thermally conductive polyethylene oriented products of the present disclosure and the process for producing the oriented products include the realization of:

- Uniaxial high thermal conductivity;
- Very high mechanical properties;
- Eliminating the use of solvents for producing polyethylene fibers;
- Retaining the degree of crystallinity and connectivity between crystallites of the polyethylene fibers during production; and
- An economical process for producing polyethylene oriented products.

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

The use of the expression "at least" or "at least one" suggests the use of one or more elements or ingredients or quantities, as the use may be in the embodiment of the invention to achieve one or more of the desired objects or results.

Any discussion of documents, acts, materials, devices, articles or the like that has been included in this specification is solely for the purpose of providing a context for the invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the invention as it existed anywhere before the priority date of this application.

The numerical values mentioned for the various physical parameters, dimensions or quantities are only approximations and it is envisaged that the values higher/lower than the numerical values assigned to the parameters, dimensions or quantities fall within the scope of the invention, unless there is a statement in the specification specific to the contrary.

Wherever a range of values is specified, a value up to 10% below and above the lowest and highest numerical value respectively, of the specified range, is included in the scope of the disclosure.

The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the spirit and scope of the embodiments as described herein.

Dated this 27th day of February, 2014

MOHAN DEWAN
of R. K. DEWAN & CO.
APPLICANTS' PATENT ATTORNEY.