Other prior art methods in this general field are disclosed in US patent numbers US4632844, US4312575 and US5000831.

Summary of the Invention

The present ~~invention~~disclosure seeks to provide a method of producing a highly cross-linked polypropylene-like material and devices such as electronic circuits and opto-electronic circuits which incorporate such a material.

According to an ~~aspect~~embodiment of the present ~~invention~~disclosure, there is provided a method of producing a highly cross-linked polypropylene material including the steps of: providing a reaction chamber; selecting one or more carbon containing gases from a plurality of carbon containing gases; feeding said one or more selected carbon containing gases into said chamber; striking a plasma in said chamber, said plasma causing said gas or gases to dissociate into a phase including methyl radicals; causing said dissociated phase to nucleate and thereby to create highly cross-linked polypropylene material, preferably under high UV radiation.

Advantageously, the polypropylene material comprises a plurality of polymer chains of repeating structural units, with an average of at least one cross-link per six structural units and/or a plurality of cross-links across adjacent polymer chains.

The polypropylene material made by this method, it has been found, exhibits significantly improved characteristics compared to conventional polypropylene, including a very low dielectric constant, good structural characteristics and a high melting point, with enhanced mechanical stability. This makes the material suitable in a wide variety of applications, including as a dielectric or insulating layer for integrated, electronic or opto-electronic circuits. It is also suitable is a great many other applications, such as to provide a protective, lubricating, load-bearing and/or heat resistant coating.

As is explained below, it is believed that the material produced by the method is polypropylene-like. The material exhibits the properties of polypropylene, although has a high incidence of three dimensional cross-linking and has substantially improved characteristics compared to conventional

It is preferred that the material is also annealed. It has been discovered that annealing can change or reduce the dielectric constant of the polypropylene material.

In practice, it is preferred that the annealing step is carried out in a vacuum or controlled gas environment which uses, for example, one or a composition of inert gases.

Advantageously, the method includes the step of providing additional heating in the chamber by non-plasma means during the plasma nucleation or synthesis step.

A practical embodiment includes the following steps: providing a substrate in the chamber, wherein the said substrate is in contact with an electrode; striking a plasma in the chamber by applying a voltage to a counter electrode inside the chamber, thereby causing a layer of material to form on the substrate; wherein the plasma has an ultra violet radiation component which enhances the cross-linking of the polymer in three dimensions to give mechanical integrity and thermal stability to the material formed.

In one aspect, there is provided a method of producing a highly cross-linked polymer material including the steps of:

providing a reaction chamber;

selecting one or more carbon containing gases from a plurality of carbon containing gases, wherein at least one of the gases is acetylene;

feeding said one or more selected carbon containing gases into said chamber;

feeding acetone into said chamber;

feeding a carrier gas which includes hydrogen into said chamber;

wherein the pressure in said chamber is set to be greater than 200 mTorr (0.0267 kPa) and less than 5 Torr (0.667 kPa);

striking a plasma in said chamber, said plasma causing said gases to dissociate into a phase including methyl radicals;

causing said dissociated phase to nucleate and thereby to create highly cross-linked polymer material.

According to another aspect ~~of the present invention~~, there is provided a highly cross-linked polypropylene material obtained by a method as taught herein.

A particular ~~aspect~~embodiment of the present ~~invention~~disclosure provides a highly cross-linked polypropylene material which comprises a plurality of polymer chains formed of a plurality of repeating structural units, wherein the polypropylene material comprises carbon-carbon double bonds at least once in every six structural units and/or carbon-carbon double bonds linking adjacent chains.

The highly cross-linked plasma polypropylene material can have any one or more of the following characteristics: Young's modulus in excess of 1.5 GPa, having a hardness of at least 10MPa, and a k value of between 1.5 and 2.6.

According to another ~~aspect~~embodiment of the present ~~invention~~disclosure, there is provided a substrate including a layer of highly cross-linked polypropylene material obtained by a method as taught herein.

Another aspect of the present ~~invention~~disclosure provides an integrated circuit including at least one dielectric layer formed of highly cross-linked polypropylene material obtained by a method as taught herein.

0.25 Watts/cm^2. More preferably, the applied power per unit area of the electrode is less than 0.1 Watts/cm^2. The mechanical stress can be lowered further with an applied power per unit area to the electrode.

Preferably, the plasma and bias conditions are arranged to minimise damage to the polypropylene layer as it is formed by controlling ion bombardment of the layer. Thus, the substrate may be electrically grounded to produce the high quality films.

The high degree of three dimensional cross-linking in the polymer material provides a higher melting temperature than conventional polypropylene. This cross linking may extend in all three dimensions of the structure. This allows the cross-linked polypropylene material to be used for a wide range of functions. Moreover, such a polymer material benefits from minimal creep and enhanced mechanical properties.

The integrated circuits provided by a polypropylene layer of the type taught herein are able to operate more effectively than conventional integrated circuits which adopt silicon dioxide as a dielectric layer. This is because the dielectric constant or k value of the cross-linked polypropylene layer taught herein is significantly less than that of silicon dioxide. This reduces the energy stored in the layer and correspondingly reduces interference, thereby allowing faster switching times.

In a further embodiment it is possible to have two or more layer dielectric stack whereupon the said polypropylene layer is combined with or encased within a sandwich structure of standard silicon dioxide or silicon nitride layers.

According to another ~~aspect~~embodiment of the present ~~invention~~disclosure, there is provided a method of producing a highly cross-linked polypropylene material including the steps of: providing a reaction chamber; feeding one or more selected carbon containing gases into said chamber, which gases do not include propylene; striking a plasma in said chamber, said plasma causing said gas or gases to dissociate into a phase including methyl radicals; causing said dissociated phase to nucleate and thereby to create highly cross-linked polypropylene material.

AThis aspects of the present invention can use any of the preferred features taught herein including those set out in any or each of the dependent claims appended or related to claim 1.

Brief Description of the Drawings

Preferred embodiments of the present invention will now be described by way of example only with reference to the accompanying figures, in which:

Figure 1 illustrates a plasma enhanced chemical vapour deposition apparatus;

Figure 2A illustrates the Fourier transform infra-red (FTIR) spectrum of a first cross-linked polypropylene material;

Figure 2B illustrates the FTIR spectrum of a second cross-linked polypropylene material;

Figure 3 illustrates a structural unit of a polypropylene polymer chains;

Figure 4A illustrates the effect of annealing upon the FTIR spectrum of the first cross-linked polypropylene material;

Figure 4B illustrates the effect of annealing upon the FTIR spectrum of the second cross-linked polypropylene material;

Figure 5 illustrates a capacitor device comprising a cross-linked polypropylene material;

Figure 6 illustrates the effect of annealing upon the k value of a cross-linked polypropylene material;

Figure 7 illustrates an integrated circuit comprising a cross-linked polypropylene material; and

Figure 8 illustrates an alternative integrated circuit comprising a cross-linked polypropylene material.

Detailed Description of Preferred Embodiments

Referring to Figure 1, an apparatus 1 for plasma enhanced chemical vapour deposition (PECVD) comprises a chamber 2 housing a chuck 3 on which a