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(54) Titre : MESURE ET CONTROLE DE PRODUCTION DES CABLES ELECTRIQUES EN XLPE PAR PENETRATION RAYONNANTE NON DESTRUCTIVE DE COUCHE(S) SEMICONDUCTRICE(S) DANS LA BANDE DES TERAHERTZ

(54) Title: MEASUREMENT AND CONTROL OF XLPE ELECTRIC CABLE PRODUCTION BY NON-DESTRUCTIVE TERAHERTZ RADIATION PENETRATION OF SEMICONDUCTOR LAYER(S)

Measurement and Control of XLPE Electric Cable Production by Non-Destructive Terahertz Radiation Penetration of Semiconductor Layer(s)

On March 4, 2008 at about 2130 hours EST, I, Robert John Rayzak, carried out mathematical and physical assessments to determine the utility of the invention of Robert John Rayzak of 2616–1001 Bay Street, Toronto, Ontario M5S 3A6, Canada, citizen of Canada and Mark Stephen Kemper of 4774 Hooks Mill Dr., Adrian, Michigan 49221, USA, citizen of USA.

The invention provides for on-line identification and quantitative measurement within the extrusion production line of XLPE electric cable the chemical byproducts in the XLPE insulation, most importantly cumyl alcohol and acetophenone among others. This invention will apply to identification and quantitative measurement of components of similar products, too.

The importance of this invention is that it non-destructively identifies and measures the byproducts in the XLPE insulation by penetrating through the carbon black rich (i.e., carbon black "loaded") semiconductor ("semicon") cable layer(s).

This capability to penetrate the semicon layer(s) and identify and measure the XLPE byproducts has never been possible to do before this invention. The invention makes possible on-line, real-time process control in the electric cable industries for the first time.

The invention is based on adapting a measurement technique to utilize terahertz radiation to penetrate the cable (or other similar product) into the body of the XLPE insulation (or other similar material).

We have determined that the terahertz radiation penetration into common automobile SBR tire compounds allows for the measurement of inner physical properties such as belting adhesion, etc. SBR tire compounds have carbon black loading at typically 50% by weight.

The specific gravity of carbon black is in the range 1.9 to 2.1 for all applications.

The specific gravity of low density and cross-linked polyethylene and ethylene propylene rubber (EPR) – common constituents of cable semicon layer(s) – is 0.9.

The specific gravity of SBR rubber is, likewise, 0.9.

We have noted above that the carbon black loading of SBR rubber for automobile tires is 50% by weight.

We have determined that terahertz radiation will penetrate automobile tires to the inner belting. Thereby, we conclude that terahertz radiation will penetrate beyond the 1mm – 3mm thick semicon layer(s) into the XLPE insulation since the carbon black loading of the cable layer(s) is only 20% - 40% by weight. The lesser the carbon black loading of a material the greater the ability of the terahertz radiation to penetrate that material.

Penetration by terahertz radiation also reflects spectral information characteristics of the components it enters. The analysis of the spectral characteristics has been confirmed to identify the constituent components of certain polymers. We conclude that with appropriate analysis we will be able to identify and determine concentrations by weight % of the byproducts within XLPE cable insulation.

Calculations completed as described above confirm the terahertz radiation penetrates the normal range of carbon black loaded semicon layer(s). Moreover, semicon layer(s) made up of XLPE, EPR and other related compounds with similar carbon black loading will be penetrated also.

Terahertz radiation can also be used to identify and determine the concentrations by weight % of the byproducts within XLPE cable insulation without the need to penetrate a carbon black layer.

Intensive experiments are being conducted by the inventors with fresh samples of XLPE cables from commercial sources. This will define completely the carbon black loading weight % range of cable semicon layer(s) amenable to measurement into the XLPE cable insulation and will facilitate the chemical/physical/mathematical spectral analyses necessary to calibrate the terahertz radiation penetration data for production and laboratory applications.

Terahertz radiation penetration can be used to give an x-ray-like image of the interior cross section through the cable. It will show separation (air gaps) between, say, an inner semicon layer and the XLPE insulation. Also, since the terahertz radiation is sensitive to the presence of water it can be used to detect early stage and later water treeing. Each of the described phenomena is very detrimental to the integrity of the electric cable to withstand high voltage without physical and electrical breakdown.

Terahertz radiation, for the first time with these herein inventions, has been adapted to determine in a laboratory and on line in an XLPE cable production extrusion line byproduct concentrations and physical and electric fault characteristics and to provide a means for real time process control of said production facilities.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An on-line measuring system of an insulated power cable, the system comprising:

a radiation source penetrating a cross-linked polyethylene (XLPE) insulation layer of the insulated power cable with radiation;

a measurement device measuring the radiation penetrating the XLPE insulation; and

an analysis device analysing the measured radiation and determining a byproduct in the XLPE insulation.

2. The on-line measuring system as claimed in claim 1, wherein the radiation source is a terahertz radiation source penetrating the XLPE insulation with terahertz radiation.

3. The on-line measuring system as claimed in claim 1 or 2, where in the insulated power cable comprises a carbon black loaded semiconductor layer.

4. The on-line measuring system as claimed in claim 3, wherein the carbon black loading of the semiconductor layer is approximately 20% - 40% by weight.

5. The on-line measuring system as claimed in claim 4, when dependent upon claim 2, wherein the carbon black loaded semiconductor layer is approximately 1mm - 3mm thick and the terahertz radiation passes through the carbon black loaded semiconductor layer into the XLPE insulation.

6. The on-line measuring system as claimed in any one of claims 1 to 5, wherein the byproducts of the XLPE insulation layer comprise at least one of cumyl alcohol or acetophenone.

7. The on-line measuring system as claimed in any one of claims 1 to 6, wherein the analysis device further identifies constituent components of polymers of the XLPE insulation.

8. The on-line measuring system as claimed in any one of claims 3 to 7, when dependent upon claim 3, wherein the analysis device further determines air gaps between the carbon black loaded semiconductor layer and the XLPE insulation layer.

9. The on-line measuring system as claimed in any one of claims 1 to 8, wherein the analysis device further determines water treeing within the XLPE insulation layer.

10. A method of on-line measuring of an insulated power cable, the method comprising: penetrating a cross-linked polyethylene (XLPE) insulation layer of the insulated power cable with radiation;

measuring the radiation penetrating the XLPE insulation;

analysing the measured radiation; and

determining a byproduct in the XLPE insulation.