Progress Review of Teraherz Spectroscopy in Composite Materials Non-Destructive Testing Applications

Dionysios E. Mouzakis[1], Irene Karanasiou[2]
1, 2: Hellenic Army Academy, Department of Military Sciences
Sector of Mathematics and Engineering Applications
Vari- Greece
[1]demouzakis@sse.gr, [2]ikaran@esd.ece.ntua.gr

Composite materials such as glass fibre epoxy, carbon fibre and Kevlar have shown a huge development during the last twenty years in structural applications. Their use in aeronautical engineering is now standardized and huge passenger aircrafts make use of them. For example, in the Airbus A380, fibrous composite materials have been deployed extensively in primary load carrying structures resulting in a 17% lower fuel use per passenger than comparable aircraft. More than 50% of the dead weight in composites, is expected to be reached in the A350 Airbus. Non-Destructive Testing (NDT) is acknowledged nowadays for the initial inspection of test samples and analysis of causes for failure. Several methods are currently used: ultrasonic testing with single element transducers and linear phased array probes in pulse echo and through transmission mode, resonance methods, shearography and thermography etc.

Non-destructive testing of materials using teraherz (THz) waves a relatively new methodology, can be an alternative when “traditional” methods exhibit poor efficiency (composite made from soft epoxy resin, for instance) or to improve spatial resolution. During the five past years, works have appeared in the literature focusing on characterization or imaging, in the THz range, of various composite materials. Most of these works used pulsed THz-Time Domain Spectroscopy (THzTDS). Rutz and coworker[1,2] studied low density polyethylene (LDPE) containing titanium dioxide nanospheres and glass-fibre reinforced polymers to measure the concentration of glass fibers. Orientation of glass fibers in reinforced plastics was also determined,[3] and more significantly, sand inclusion or metal in HDPE weld joints was also successfully detected.[4]

Determination of damage induced by flame on carbon fibres using reflectivity dependence to polarization was also reported.[5,6] Due to fiber orientation, the material exhibited a grid-similar structure. This effect caused the reflection coefficient to be related to the incident beam polarization state: reflectivity, for normal incidence, increases when the polarization is parallel to fiber orientation, penetration depth increases in the case of a polarization state perpendicular. Stoik et al.[7] also used THz-TDS to detect damage due to exposure to high temperature and delamination on glass fiber reinforced composites. However, a handful of these works have also been performed using CW THz imaging: at 1.63 THz with a gas laser[5] or with Gunn diodes at 0.2 and 0.38 THz [5]or 0.6 THz.[6] Damage diagnosis in composite materials diagnostics using CW THz waves produced by Quantum Cascade Laser have not yet been thoroughly investigated. This approach appears to be very promising as QCLs are THz sources emitting a few tens of mW, at frequencies in the [1-4] THz range, with a beam quality in constant improvement.

This review work focuses on the applications of Teraherz Spectroscopy in composite materials’, damage diagnosis. The principles behind Teraherz Spectroscopy and its applications in composites and other materials are presented and discussed.

Literature

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