TC-17 Progress: Advances in Materials and Measurements

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Despite the difficulties imposed by the worldwide spread of COVID-19, some recent advances have been made by the Technical Committee 17 (TC-17) in topics regarding measurements and materials.

The characterization of fiber networks and stochastic materials has been challenging researchers for decades. However, a theory has been developed that may help interpret the stochastic structure of such materials using maximum likelihood fitted distributions or empirical frequency distributions. The important provision is of a natural measure structure on families and approximations on mixed families of distributions, that shall enable dissimilarities among samples of such stochastic materials to be computed. Also, information geometry provides straightforward ways to measure departures from randomness and departures from uniformity, which are frequently needed in testing. According to this theory, fiber networks can be characterized as random, clustered or evenly distributed based on their inter-fiber spacing distributions, making it possible to develop a categorization for a wide variety of stochastic fiber structures based on objective criteria. The group lead by Prof. Scharcanski has been working on these issues in recent years.

The measurement of transport properties in stochastic porous media is a related issue that finds several applications in areas such as soils science. One of the relevant research issues in this field is learning how moisture infiltrates in the soil. Despite the fact that several methods have been proposed to estimate the static (unsaturated) stochastic porous medium structure, by evaluating parameters like pore size distributions and pore connectivity, handling the dynamic features of porous media as they saturate still challenges researchers. For example, learning how moisture infiltrates in porous media, such as soils, it is possible to describe and measure the dynamic properties of such heterogeneous complex stochastic materials [1]. The group lead by Prof. Scharcanski has been working to develop non-invasive techniques for objectively describing such phenomena and characterizing porous media dynamics.

Prof. George Giakos (Manhattan College) and Dr. Tannaz Farrahi (University of Virginia) are working towards the optical characterization of thin film polymer-based nanostructures which may be utilized for the development of nanoantennas for communications, imaging and quantum cognitive detection applications [2]. Recent advances in nanotechnology, make possible to control and efficiently manipulate the light by creating novel multifunctional nano domains. The interactions of incident near-infrared and infrared light with nanostructures result contribute to scattering and absorption processes. At optical frequencies the scattering and absorption proper characteristics of nanoparticles are of primary significance. The scattering and absorption properties can be highly affected by several parameters such as the particle size, shape, concentration, physical, chemical, as well as the optical material characteristics of the nanoparticle and the polarization properties of its surrounding medium. Metal nanoparticles have various unusual chemical and physical properties which make them attractive for applications such as optics, sensing, electronics, chemistry, defense and security, medicine, and biology. Gold, and silver nanoparticle monolayer substrates offer unique opportunities. By incorporating both polymers and gold nanoparticles (Au NPs) into films and devices increased flexibility and tunability of the resulting film optical and electrical properties, it results. In addition, incorporation of metal nanoparticles enhances conductivity of the polymers. The electronic structure of the polymer chain strongly influences the characteristic of embedded metal nanoparticles. The realization of technologically useful nanoparticle-based materials depends not only on the quality of the nanoparticles (e.g., size and shape) but also on their spatial orientation and arrangement. The building and patterning of the metal nanoparticles into organized structures is a potential route to chemical, optical, magnetic, and electronic devices with useful properties. The U.S. Air Force Research Laboratory (AFRL) liquid crystal (LC) polarimetric multifunctional imaging platform, has been used for the characterization of polymer-based nanostructures. This multifunctional imaging platform was built under the leadership of Prof. Giakos, through a contract between AFRL and academia. It comprises a complete polarimeter capable of deriving the full 16 element

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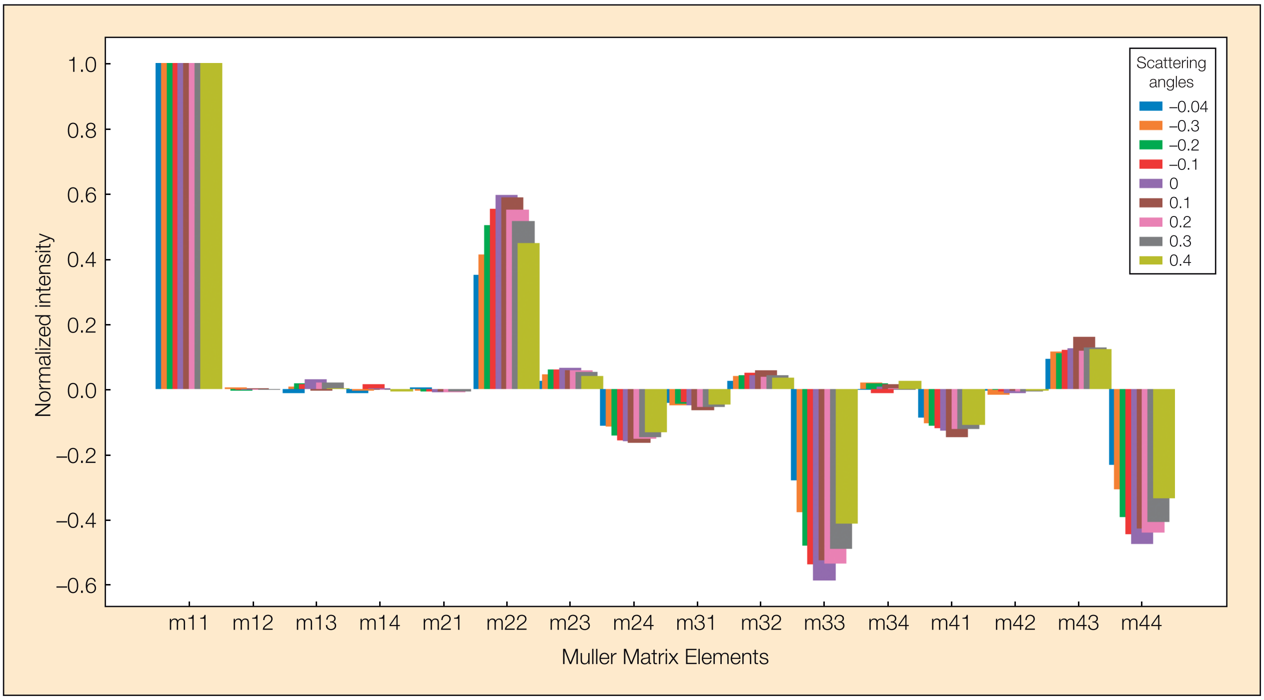

Fig. 1. The Muller matrix elements vs. normalized intensity of each element calculated through detection of infrared (1050 nm) backscattered signal, under differed scattering angles, from Au NPs dispersed into a 180 nm thin film PS-b-PMMA.

Mueller Matrix (MM) of an object using liquid crystal (LC) devices. The system is highly automated by utilizing NI Labview software to control the devices and measurement states and perform a detailed calibration of the optical system. It is fully reconfigurable and scalable providing enhanced multifunctional imaging capabilities through dedicated spatial, timing and spectral modules, supported by advanced calibration and image pre-processing and post-processing techniques developed in-house, thanks to the dedicated support of our students. The polymer nanostructured film is mounted to a motor that can be rotated or translated with a rotation accuracy of 0.01 degrees, so that to detect different backscattered light orientations. For the calculation of the Mueller matrix, 16 backscattered intensities are recorded. These intensities are obtained by combining four polarization states in the generator and analyzer arms.

Always referring to Dr. Giakos and team workers' study, gold nanoparticles were dispersed within a Polystyrene-block-meth methacrylate (PS-b-PMMA) thin film. The polarimetric backscattered infrared light response from different thickness PS-b-PMMA with Au NPs was studied. The Muller matrix elements vs. normalized intensity of each element calculated through detection of infrared (1050 nm) backscattered signal, under differed scattering angles, from Au NPs dispersed into a 180 nm thin film PS-b-PMMA, are shown in Fig. 1.

The majority of non-zero elements are found in elements m14, m22, m24, m32, m33, m34, m42, and m44. The m34 and m43 elements indicate the presence of small amount of linear diattenuation. The elements m14 and m32 indicate that silicon exhibits the presence of small amount of circular diattenuation, and circular birefringence, respectively, on both materials with prevalence on silicon. Deviation of the m44 element from -1 indicates the depolarization of the light from the two media. Small values of m21, m31, m41 indicate the presence of little polarizance. The non-zero values of m34 and m43 indicate the presence of finite retardance into the samples between the s and p planes.

In another project, Dr. Giakos and team workers are exploring the electrical, chemical and optical properties of bioinspired materials that would apply to the development of quantum computing and artificial neural networks and systems. This is a new area of research and a seminar is planned at New York City, sponsored by the local NYC Chapter of the IEEE Instrumentation and Measurement Society.

The Technical Committee on Measurements in Materials (TC-17) plans to offer seminars and lectures as well as a future workshop.

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