Raman Spectroscopy in Diagnostic Methods

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Materials in the nanoscale are currently highly in demand in many fields – from textile manufacturing and paints to biomedical and tissue engineering. This work focuses on the nanofibrous materials made of various polymers. However, there are few applications of such materials and many applications are still more or less far in the future. Nanofibrous materials have so unique properties that the number of research groups focusing on topic increases every year, hand in hand with the amount of published works. This work deals with nanofibrous materials suitable especially for use in cosmetics, pharmaceuticals and medicine.

There are several ways to prepare nanofibers. We used the method known as electrospinning. This method is very simple, versatile and efficient in producing nanofibrous materials. Electrospinning uses electrostatic forces to produce nanofibrous layers from a polymer solution. Its basic operation requires only a high-voltage power source and two electrodes connected to opposite potentials. One of the electrodes (emitter or jet) administers a polymer solution and forms nanofibers. The second one (collector) is used for the deposition of the produced fibers. There are already many modifications of the basic electrospinning arrangement, which make it possible to produce nanofibrous layers with various structures. These structures enhance the resulting parameters of nanofibrous materials and make them more attractive for a wide range of applications. Each application requires a proper modification of product parameters such as chemical, physical or biological properties. These parameters can be achieved for example by the right choice of materials or by structuring the nanofibrous layers. In each case, one of the most important factors is the determination of all substances present in the composite nanomaterial and the estimation of their distribution homogeneity within the sample. This problem is most apparent in composite materials, which are prepared from two or more polymers where each of them is spun separately from its own emitter. In this case, significant inhomogeneities can occur in the distribution of the polymers throughout the nanofibrous layer – the polymers do not compose the layer equally but create areas where one or the other is dominant. This can significantly affect the parameters of the product. It is therefore crucial to find a method which would enable a rapid and non-destructive analysis of nanofibrous samples on the level of their molecular structure, allow to determine their homogeneity and at the same time preserve them for further analyses or specific applications.

Confocal Raman microscopy has become a promising contactless non-destructive method suitable for the characterization and structural study of various materials, including in the field of nanofibers. Exploiting chemical contrast, micro-Raman can be used for chemical mapping and imaging down to the micrometre scale. Furthermore, micro-Raman analysis can be automated and integrated into the manufacturing and/or quality inspection processes. Confocal micro-Raman spectroscopy with its chemical sensitivity and spatial resolution may be used to identify inhomogeneities in nanofibrous materials and could be of great help in the optimization of the electrospinning process. The aim of this work is to introduce Raman spectroscopy as a method suitable for the study of nanofibrous structures. Furthermore, the work aims to define its possible uses in the field of nanofibers and present its application on a specific product. As a result, the work presents a method for the determination of the chemical composition of nanofibrous mats based on Raman spectroscopy and singular value decomposition. The combination of vibrational spectroscopy and mathematical analysis enables the analysis of polymer distribution in nanofibrous samples as well as the subsequent conversion of the obtained spectral and coefficient results into content percentages of the individual polymers. The method was designed by a wide array of users – not only Raman spectroscopy experts – and is also applicable for routine analyses.