STUDIES OF THE POSSIBILITY OF ESTIMATING THE GROWTH OF THE CUXSE LAYER FROM THE CHANGE IN THE MASS OF FIBRES

AUTEX 2022
21st World Textile Conference

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Introduction:

➢ Recently, researchers face the challenging task of finding a way to use industrial waste as secondary raw material for new applications. Using industrial textile waste for the creation of new functional composites is a viable area for the development of sustainable technologies. In the past decades, semiconductor nanomaterials have received broad attention because of their novel electronic, optical, photoelectric, and thermoelectric properties. As an important semiconductor, copper selenide (Cu_xSe) with nanostructure has potential applications in various fields, such as optical filters, highly efficient solar cells, superionic conductors, electro-optical devices, photo-thermal conversion, electro-conductive electrodes, microwave shielding coatings, etc. [1].

➢ In this study, the part of the results of the investigation of possibilities of the copper selenide layer formation on the surface of the different fibres is presented.

Methods:

➢ The investigated samples were treated in a thermostatic vessel using a continually stirred K2SeS2O6 solution (0.1 mol·dm–3 solutions of K2SeS2O6 in 0.1 mol·dm–3 HCl at 60 °C). Then the samples were treated with a Cu(II/I) salt solution [1], the copper selenide layers on samples have formed. Cu(II/I) salt solution was prepared using a crystalline CuSO4·5H2O and a reducing agent hydroquinone. It is a mixture of univalent and divalent copper salts consisting of 0.34 M Cu(II) and 0.06 M Cu(I) salt.

➢ The mass of the investigated fibre samples was measured with AB104-S Analytical Balance (Mettler Toledo) featuring a measurement range of 110 g ± 0.1 mg, a scale interval of 0.1 mg and an error (0 ± 0.1) mg. The percentage change in the mass of the samples Δm was calculated according to the formula:

$$\Delta m = ((m_n - m_0) / m_0) \times 100\%$$

where, m0 is the mass of an untreated sample (mg); mn is the mass of the sample after treatment (mg); n is the number of the treatment cycle.

➢ The morphological analysis of the investigated materials was executed applying the Scanning Electron Microscope (SEM) Quanta 200 FEG (FEI, Netherlands).

➢ Nine types of waste from different fibres (cotton, flax, bamboo, ramie, wool, PES, PA6, PA66, and PAN) were used for this experiment.

Results:

➢ A successful course of the treatment process is the visible change in the colour of the investigated fibres. The change in colour of the investigated samples from white to grey indicates the formation of copper selenide crystals on the surface of the thread microfibers. By repeating the modification cycles, the coating layer of Cu_xSe thickens and the fibre samples become completely black (Fig. 1)

PAN Bamboo Ramie

Figure 1. Example of modified fibres (from left to right): before treatment, after the first cycle of treatment, after the second cycle of treatment

➢ In the case of the modification of the wool fibres, the formation of a Cu_xSe crystal coating was visibly confirmed by an increase in the mass of the investigated wool fibres after each treatment cycle (Fig. 2).

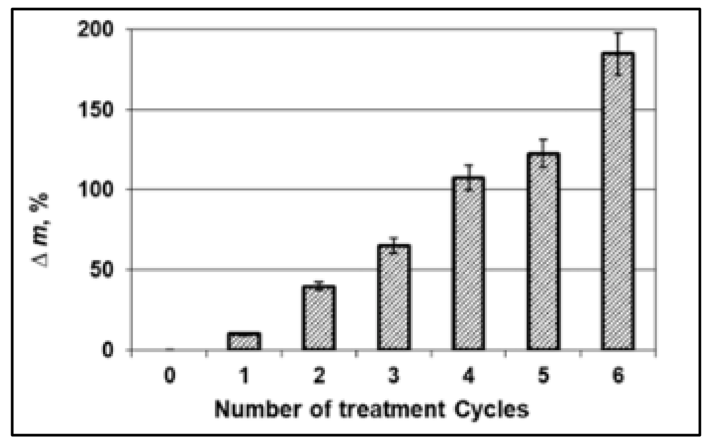

Figure 2. Influence of the number of treatment cycles on the fibres mass change [1].

➢ Similar tendency of results was obtained for synthetic fibres. It can be seen that the mass growth of different nature synthetic fibres differs, and the mass growth of PES fibres clearly increases less, but in all cases, we can see the nature of the tendentious process (Fig. 3).

➢ In experiments with some natural fibres, it has been observed that the mass of the test specimens often decreases after the first treatment cycles it depend the split-off of short parts of the fibres during the treatment process resulted in an overall decrease in sample weight.

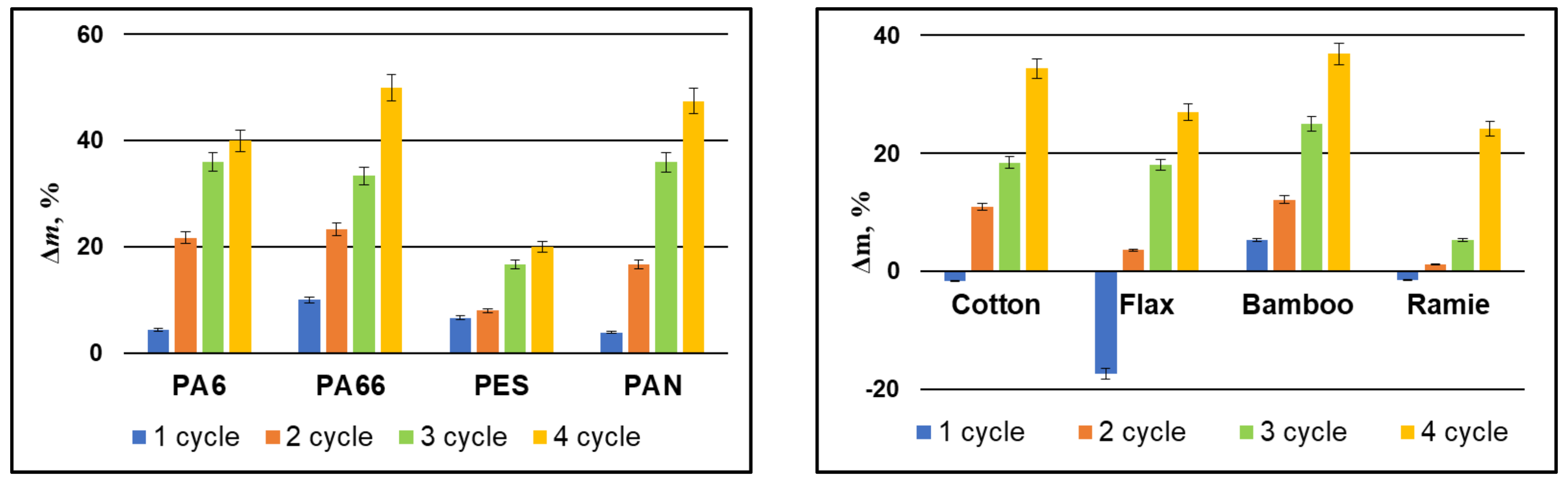

Figure 3. Variation in the mass of fibres of different nature during the process of modification with copper selenide

➢ Greater weight loss after the first cycle was observed by treating the threads with higher hairiness such as flax and ramie, but a similar decrease of mass was also observed for cotton.

➢ Although the copper selenide coating layer formed on the surface of the fibres after the second treatment cycle visibly thickens (Fig. 5), the loss of mass of the high-hairiness fibres due to short part breakdown is the factor that decides the peculiarity of fibres mass gain. In all cases, the situation changes only after the third or even fourth cycle of treatment. It can be assumed that the growing and thickening layer of copper selenides strengthens and splices the fine filaments of the treated fibres, which causes the mass of the samples to increase visibly.

➢ The experiment showed that the weight gain dependence of the investigated samples after the first few treatment cycles may be inaccurate when working with natural cellulosic fibres.

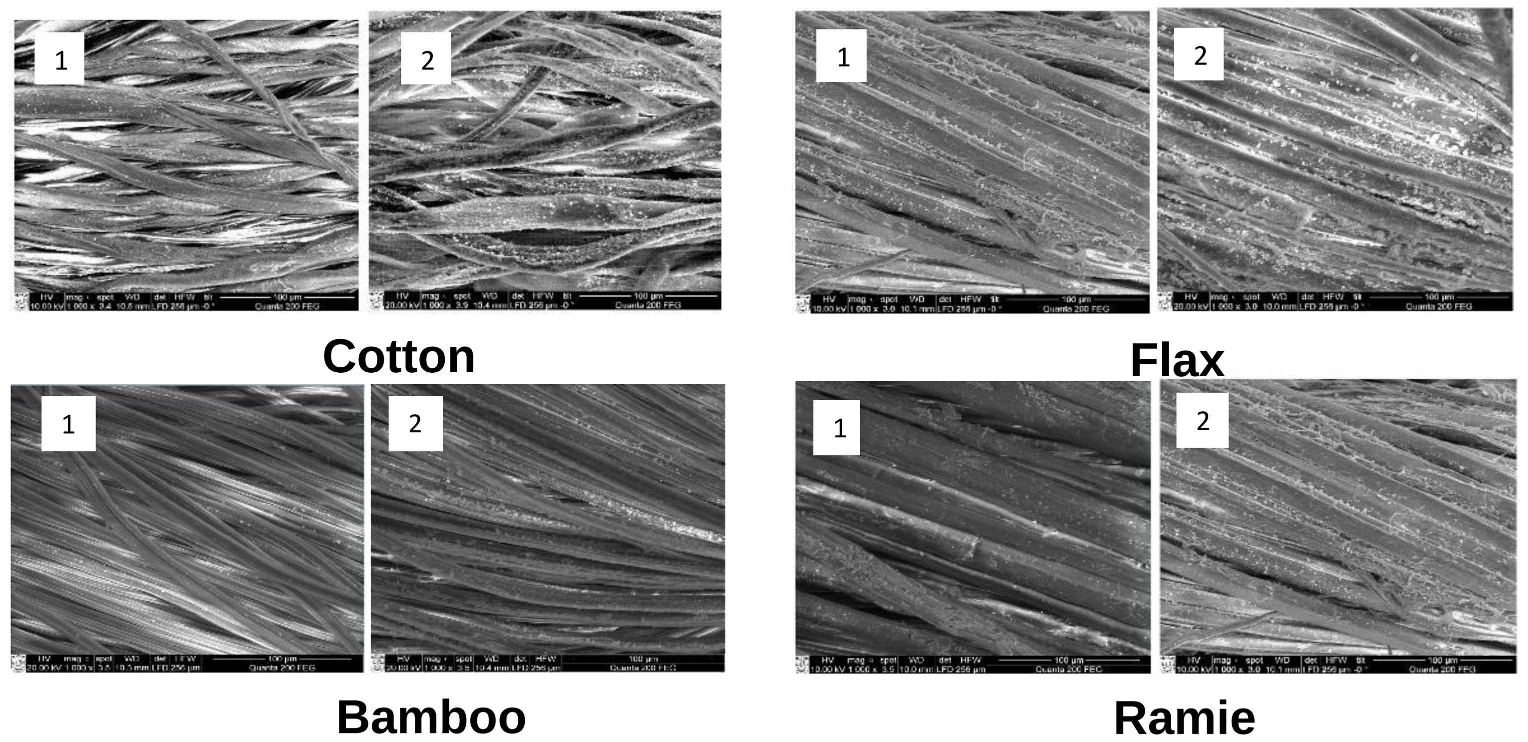

Figure 4. SEM images of copper selenide coated natural fibres after the first and fifth treatment cycle (mag. 1000×): 1 - after first treatment cycle, 2 - after second treatment cycle.

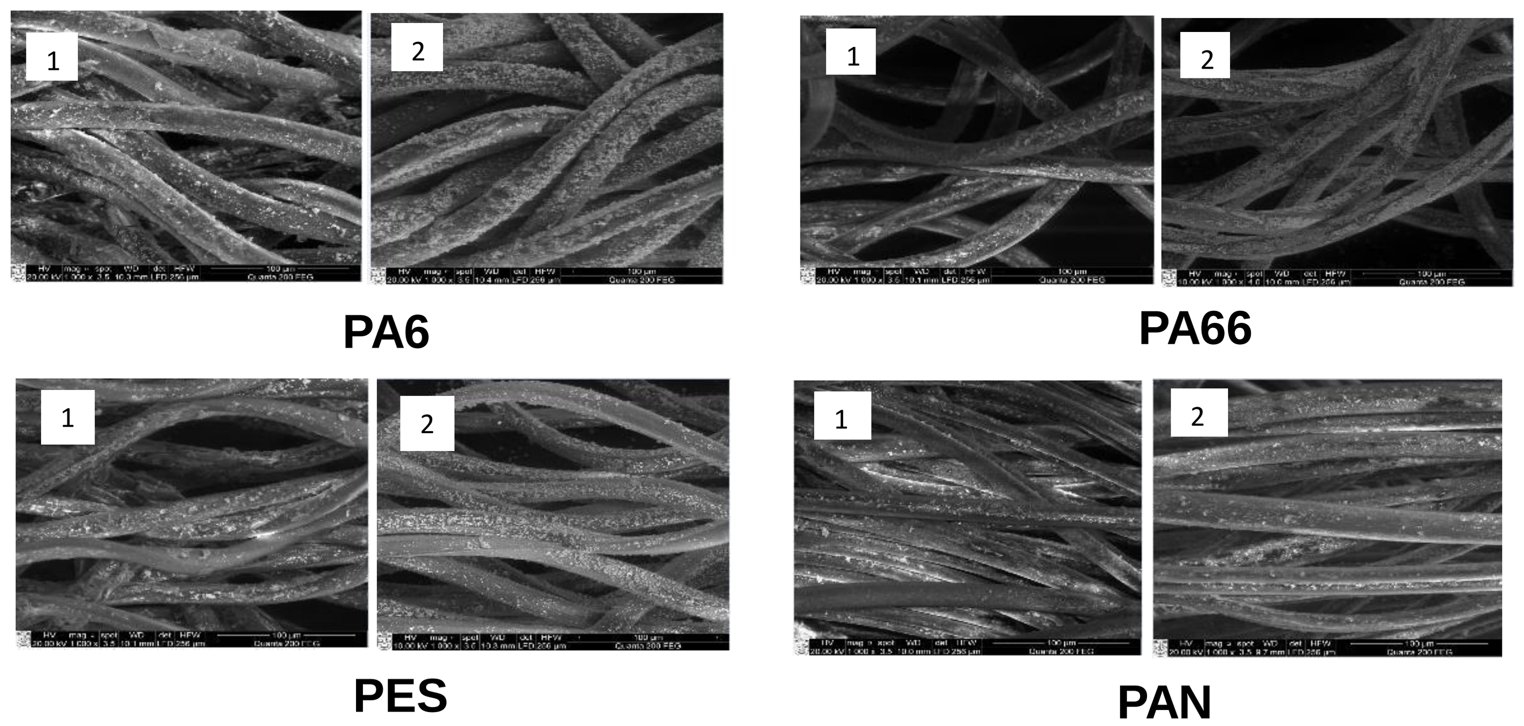

Figure 5. SEM images of copper selenide coated synthetic fibres after the second treatment cycle (mag. 1000×) :1 - after first treatment cycle, 2 - after second treatment cycle.

Conclusions:

➢ The experiment showed that monitoring the weight gain of the samples after each treatment cycle is a suitable way to evaluate the growth of the cupper selenide crystal layer when the yarns of synthetic polymer fibres and wool are modified. In the case of natural cellulose, monitoring of fibre mass growth after the first treatment cycles does not provide accurate data due to the separation and fall of fine particles of modified fibres.

[1] Belukhina, O., Milasiene, D., Ivanauskas, R. Investigation of the Possibilities of Wool Fiber Surface Modification with Copper Selenide. (2021). Materials, 14(7):1648. https://doi.org/10.3390/ma14071648