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# DEVELOPMENT OF ADVANCED COMPATIBLE MATERIALS FOR THE RESTORATION OF CULTURAL HERITAGE ASSETS (MYTHOS): FIRST RESULTS

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*Received*

For the restoration and preservation of textile cultural heritage objects it is essential to use similar or identical materials for *e.g.* testing cleaning or restoration processes before treating the unique and irreplaceable originals. Main focus of the MYTHOS project is to develop such reference materials for enhanced restoration and conservation of hemp and linen based ancient arts. First issue is genetic analysis of original samples to identify actual hemp and flax species close to the ancient varieties. In parallel selected original samples are analysed in detail for damages and their mechanical and morphological characteristics. This information will be used as base for artificial ageing of actual fibres to achieve the desired restoration materials. Due to the nature of the samples analytical methods have to be either non-destructive or restricted to minimal sample amounts. Fibre tenacity and elongation have been analysed in a single-element test (Dia-Stron) on 90 single elements. The fibre width distribution is assessed by Fibreshape. Finally a part of these single elements is examined by SEM to identify degradation effects (*e.g.* fungal attack) and traces of the processing equipment used in spinning / weaving. The results are compared to data of actual hemp and flax fibres.

*Keywords*: textile restoration; fibre analysis; bast fibres; Fibreshape; Dia-Stron; scanning electron microscopy (SEM).

## INTRODUCTION

The things that are showing our humanity are found in what we are creating, thinking, projecting, in our passing-through existence in life. In order to understand and be connected with Who and What we are we must return to the past and keep as much as we can its “remains”. Textile materials have accompanied mankind on every step of its evolution, accomplishing different functions: protection – daily clothes, textiles for house, for food storage and transportation, aesthetic and social, a certain type of material or design carrying symbols of social status or cultural identity. In the Recommendation of the European Commission[1] the Cultural Heritage is recognized as a very fragile patrimony that is subjected to the consequences of ageing, adverse environmental conditions and human pressure. Thus, a common effort is required by the Member States of UE in order to ensure the security and sustainable exploitation of Cultural Heritage.

Textile based works of art restoration and conservation techniques applied today use structurally different materials (glues, additives, polymers etc.)[2] that are incorporated directly in the works of art. There are no experimental materials appropriate to the different type of textiles in historical objects, in terms of technical and biological similarity that can supplement and enhance the restoration and conservation techniques directly on the work of art.

MYTHOS project proposes to develop novel ways of treating and storage textile based European arts. The main objective of the project is to develop a set of reference materials, to be used by the cultural national and international organization (Museums, restoration Centres, Ministries of Culture, Education centres etc.). *The reference materials will have similar biological and technical characteristics as the ancient textile arts which are on based hemp (Cannabis sp.) and flax (Linum sp.) fibres and will be dedicated to the restoration and conservation of the hemp and linen based arts.* The cultural heritage textile objects are part of the Romanian National Peasant Museum (Bucharest, Romania) collection that are in an advanced degradation state and in need of immediate action. The solution offered by MYTHOS will provide a long term conservation strategy preserving their originality and cultural identity.

Hemp (*Cannabis sativa* L.) and flax (*Linum usitatissimum* L.) plants represent one of the ancient culture that humans tried to domesticate since the early ages of civilizations and most likely the first plant cultivated by mankind for its textile use[3]. It is believed that the centre of origin of Cannabis is central Asia, from where it subsequently spread to Mediterranean countries as well as to Eastern and Central European countries[4].

Crop breeding has lead to an immense change of wild plants during the centuries. These changes mainly regard to yield, resistance against pests and diseases or adaptations to soil and climate conditions. In case of fibre plants like hemp, fibre content increased very often threefold while original genetic resources were lost. In case of MYTHOS the collection and regeneration of genetic material will be used to restore cultural art for future generations.

Search for accessions of old varieties is very difficult if those plants are not used in agriculture today and/or can be found in national and international genebanks. In case of flax Brutch[5] describe the difficulties in restoring former genetic characteristics from modern varieties. He relies to the Russian Vavilow Research Institute which holds a genebank of about 6000 accessions from all over the world. The majority are local folk bred varieties where the chance of finding accessions with characteristics similar to those used in historic textile art is bigger than with modern varieties. In case of hemp, Meijer[6] described the origin, ancestry and availability of fibre hemp cultivars.

Due to the value of historical textiles for the cultural heritage and the necessity to preserve them for the future generations all the investigations will be micro-destructive or non-destructive. The analysis of such objects requires cooperation between researchers from different areas of science, *i.e.* archaeology, chemistry, history of art, textile technology, biology etc. In the frame of this project it is necessary to collect data about the tenacity of the original fibres to have initial target information for the new breed variants and the ageing processes in the later phases. This is normally not essential for the description of historical textiles and thus rarely reported in the literature (historical linen yarn tests[7]). In order to minimize the impact on the textiles only small subsamples can be taken to perform a micro-destructive analysis, *e.g.* yarn pieces from the hem. After the new cultivars with old genetic profiles are obtained they will be cultivated in specific greenhouses with controlled conditions until their vegetal maturity. The bast plants will be now used for obtaining the fibres, yarns and new reference materials. Old processing techniques will be used for this, because all the physical and mechanical processes to which a fibre, yarn or material is subjected, are fundamental for its final state.

This paper describes first results obtained from mechanical analysis of samples taken from historical textiles.

## MATERIALS AND METHODS

### MATERIALS

Historical fabrics, yarns and fibres were supplied by the National Peasant Museum, Bucharest. For the first analytical approach samples were selected which could be supplied in larger amounts than usual: fibres from preserved complete bobbins / clews and material used as decorative fibres from historical objects. The samples analysed here are listed in Table 1 and displayed in Figure 1. For comparison two samples of technical flax and hemp fibres are added. Both are grown in Germany and were mechanically separated as raw material for the automotive industry. For this reason the fibres are in general less fine and have a broader property distribution than fibres for textile yarn production. Detailed data about the reference materials can be found in[8].

*Table 1*

Historical samples analysed

| Sample name | Fibre type | Origin |
|---|---|---|
| M 3870 | flax[1] | clew |
| M 3871 | flax[1] | clew |
| Tech. Flax A | flax | Germany 2004 |
| L 7024 | hemp[1] | decorative fibres |
| GDE02 | hemp | Germany 2001 |

[1] to be confirmed by genetical analysis (in progress)

a b c

Figure 1. Images of historical fibre samples (a) L 7024, (b) M 3870 and (c) 3871.

Actually a genetic analysis of the sample materials is in progress to prove the fibre type declaration and identify the varieties in detail. Up to now the mechanical and SEM analysis of the fibres have been performed as described below and will be reported here. Additional analysis on fibre fineness distribution is in progress and will be reported later.

## METHODS

To assess the mechanical and morphological properties of the fibres obtained from original historical textiles the use of destructive methods is unavoidable. To have minimised impact on the textiles only small subsamples are allowed to be taken, *e.g.* yarn pieces from the hem. For this reason fibre tenacity and elongation is analysed in a single-element test (Dia-Stron) on 90 single elements. This makes the analysis possible based on only 2–4 yarn snippets of approx. 2 cm length yielding approx. 200 single elements.

Preceding the analyses all samples have to be conditioned in standard climate at 20 °C and 65% relative humidity according to DIN EN ISO 139 [9] for at least 16 h. The mechanical characterisation is conducted on single elements based on DIN EN ISO 5079 [10] (1996), using a Dia-Stron System (Dia-Stron Ltd., Andover, UK) with clamping length 3.2 mm. Preceding the tensile test the cross-section of each single specimen is measured via laser beam. At least 90 specimens are measured to ensure statistically firm results [8].

A part of the remaining single elements was used for fineness analysis by the image processing system Fibreshape: fibres were cut into snippets of < 5 mm length and prepared in glass slide-frames (GePe type 6004). These were analysed in a slide scanner (Minolta) at 4800 dpi (measuring mask ‘ALFM48Z5’), using Fibreshape V4.2.

Finally a part of these single elements is examined by SEM to identify degradation effects (*e.g.* fungal attack) and to find characteristic traces of the processing equipment used in spinning / weaving. Prior to the measurement the fibres are sputtered 2 min. at 50 mA with gold dust (Edwards Sputter Coater S150B; Crawley, West Sussex, GB). SEM images of the fibres are recorded using a Cam Scan CS24 device (EO Elektronen-Optik-Service GmbH, Dortmund, Germany; acceleration voltage 20 kV; Software: analySIS 3.2, SIS Soft Imaging System GmbH, Münster, Germany).

## RESULTS AND DISCUSSION

The results of tenacity measurement of the samples are displayed in Figure 2 as *box-and-whisker* plots. The plots comprise the upper and lower deciles ($X_{0.90}$ and $X_{0.10}$) as outer dots, the upper and lower quartiles ($X_{0.75}$ and $X_{0.25}$) as box limits, and the median ($X_{0.50}$) denoted inside the box. In addition, the average values ±95% level of confidence are printed in the diagram. It is obvious that all historical samples are in the same range of tenacity, but the hemp sample is with median 258 N/mm² significantly below both flax samples with median 383 and 484 N/mm². Comparing this to the technical fibres from actual production there is an obvious difference: both of them display a higher tenacity of approx. 800 N/mm², combined with a much broader distribution, ranging to nearly 2000 N/mm² for the flax sample.

A similar tendency can be observed for the Young's moduli displayed in Figure 3: all historical samples are in the same range of 10,000–13,000 N/mm² and display a similar width of distribution. Again the distribution of the reference samples is broader, but only for the flax reference it is significantly broader. It is only the flax reference sample, which has a slightly higher level of Young's modulus (19,000 N/mm²). All other samples including the hemp reference are in the same range.

In general most results presented here are in accordance with the literature [11]. Flax single element tenacity is reported to be in the range of 343–1500 N/mm² with mostly cited values around 700 N/mm². Both historical samples are at the lower end (383 and 484 N/mm²), but clearly inside the frame. The literature range for Young's modulus of flax is 8,000–100,000 N/mm² with mostly cited values around 70,000 N/mm². Again the samples are slightly above the lower end of the frame (10,700 and 13,300 N/mm²), *i.e.* clearly inside. The reference flax sample is in the mostly cited region of tenacity, but is at the lower end of the frame in Young's modulus.

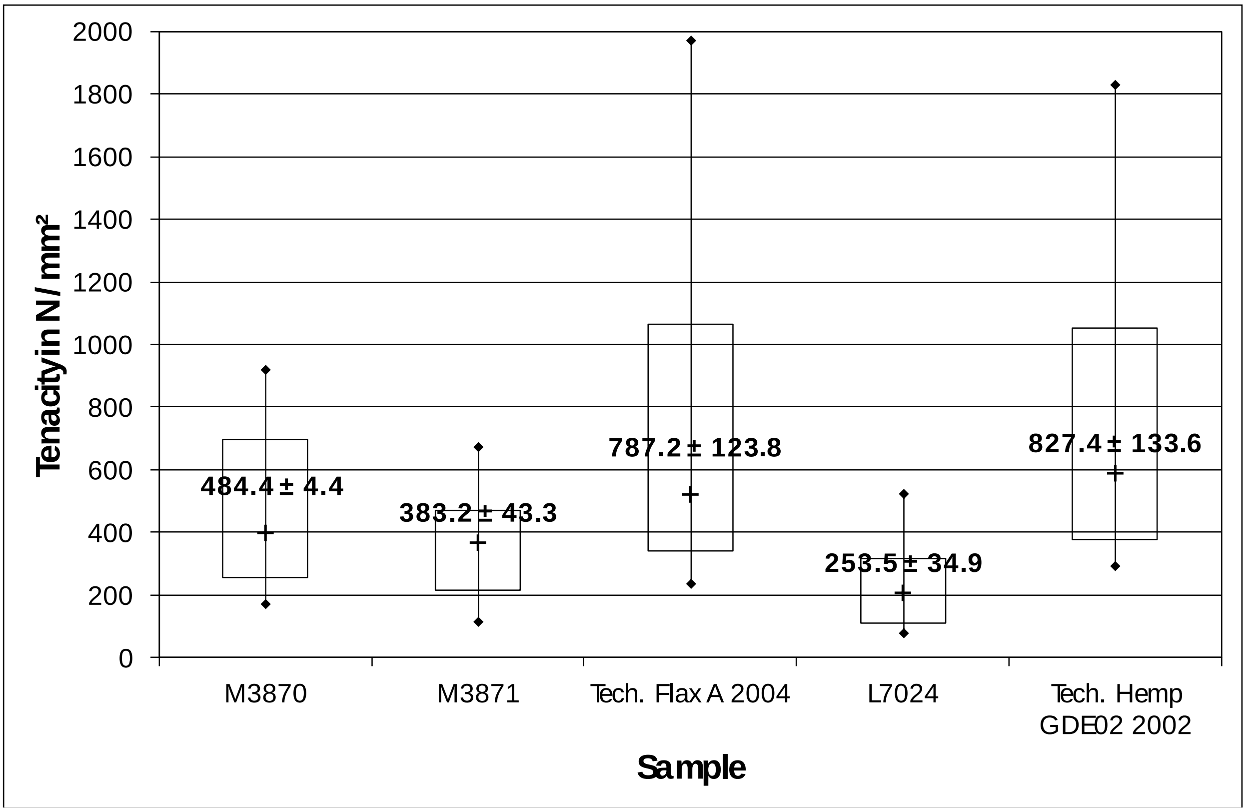


Figure 2. Tenacity distributions of historical fibre samples compared to actual technical fibres with average values ±95% level of confidence.

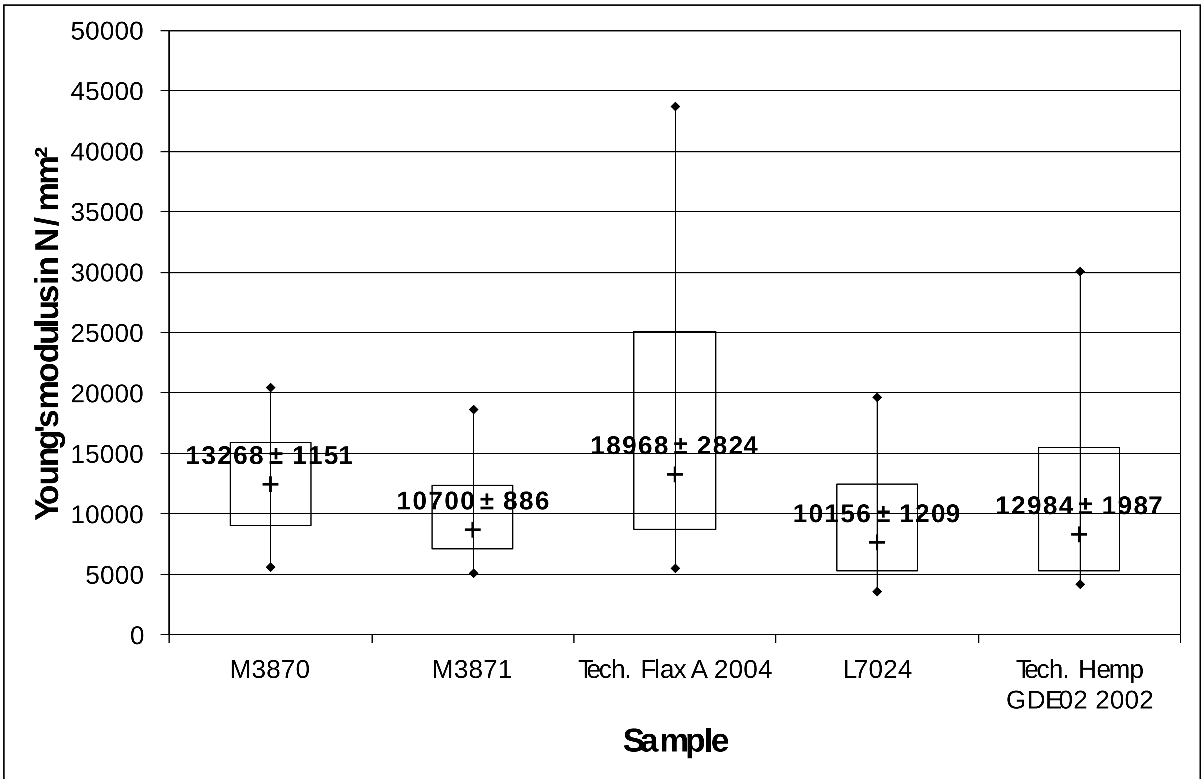


Figure 3. Young's modulus distributions of historical fibre samples compared to actual technical fibres with average values ±95% level of confidence.

Concerning the historical hemp and the hemp reference sample the situation is similar. Hemp single element tenacity is reported to be in the range of 310–1110 N/mm² with mostly cited values around 800 N/mm². The historic sample is slightly below this area (258 N/mm²), and the reference (827 N/mm²) fits into the mostly cited region. Young's modulus is reported in the range of 3,000–90,000 N/mm² with mostly cited values around 65,000 N/mm². The historic (10,156 N/mm²) as well as the reference sample (12,984 N/mm²) are at the lower end but clearly inside the frame.

The fineness distributions of the historic and reference sample are displayed in Figure 4. Due to the nature of these materials fibre bundle fineness or width are reported in very broad ranges in the literature[11]. Nevertheless the samples observed here are very fine for such materials. Flax fibre bundle width is reported in the range of 40–620 µm. Both the historic samples (27/35 µm) as well as the reference sample (20 µm) are clearly below this frame. This indicates the influence of the processing steps in spinning etc. for the historic samples as well as the coarse separation for the reference samples. The processing causes separation of the fibre bundles into finer elements. Similar observations were made for the historic and reference hemp. With 47 µm and 38 µm both are very similar to each other, indicating a similar intensity of processing. Compared to the literature range[9] of 25–500 µm, both are inside the frame, but clearly at the lower end.

The only difference between the materials observed here is, that both flax samples are very fine, whereas the hemp fibres are a little bit coarser. This corresponds to the former application of these fibres: for the flax fibres spun into a textile yarn such fineness has to be expected. The historic hemp fibre bundles were used for decorative purpose and thus less intensively separated. The selected reference materials correspond to the historic ones.

SEM analysis of the historic samples gave no hints on fungal damages. This must not be seen as general finding for historic textiles, but is valid for these analysed subsamples. Selected images of the three samples are displayed in Figure 5. For all of them mechanical damages like cracks (marked by red arrows) or bucklings (marked by blue arrows) could be identified.

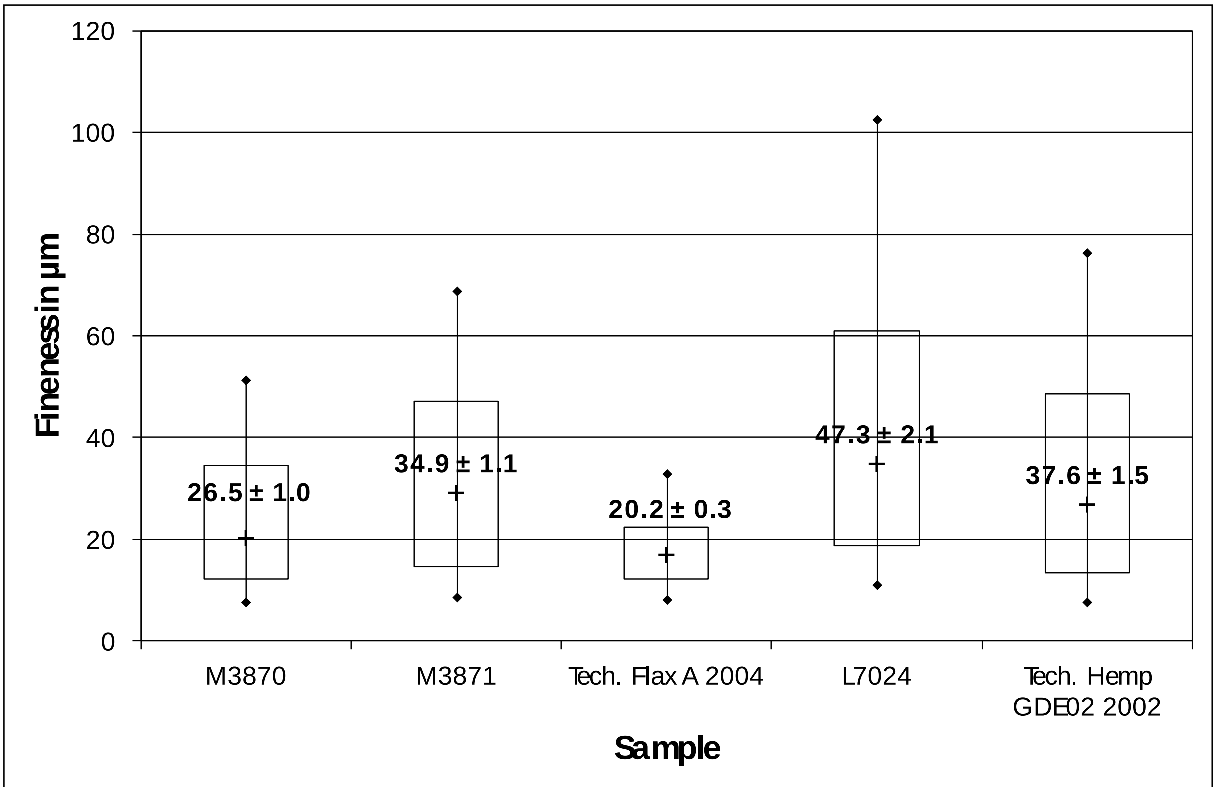


Figure 4. Fineness distributions of historical fibre samples compared to actual technical fibres with average values ±95% level of confidence.

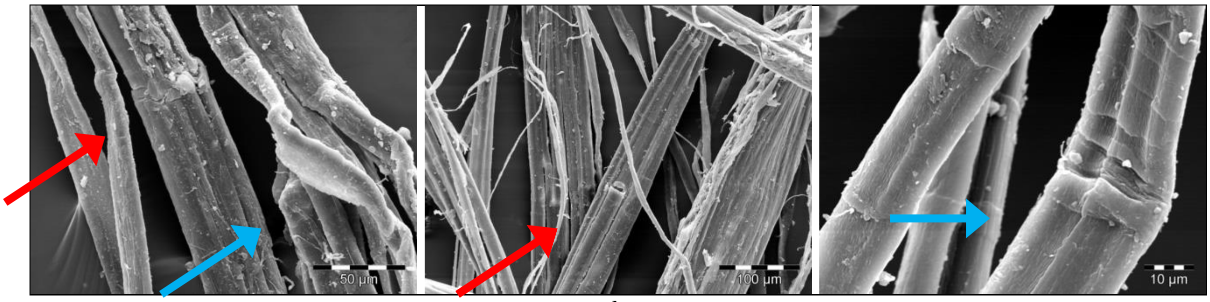


Figure 5. SEM images of (a) L 7024, (b) M 3870 and (c) 3871 with identified cracks (red arrows) and bucklings (blue arrows).

Such damages are well-known from new fibres which underwent erroneous processing[12]. Small cracks can also be caused by natural deterioration[13]. This indicates that the samples analysed here have been damaged more by processing than by degradation during storage.

## CONCLUSIONS AND OUTLOOK

All historical samples assessed here are at the lower end of the literature range[11] in terms of tenacity Young's modulus. On the one hand this corresponds to the efforts of plant breeding during the last centuries, which led to actual bast fibres with higher tenacities and higher Young's moduli. On the other hand the selected reference samples represent varieties in actual use, whose mechanical fibre properties are only slightly above the level of the historical fibres. This indicates that these actual varieties used in mass production are not so far away from the historical ones (at least in terms of their mechanical properties).

This fact becomes more obvious looking deeper into details of the results: the main differences between historical and reference fibres have been found in terms of fibre tenacity, whereas all samples are in the same range of Young's modulus. Having in mind, that the tenacity is determined by the weakest point of the tested fibre (*e.g*. fungal or process-induced damages), but that Young's modulus represents the mechanical behaviour determined by the arrangement of the cellulose chains (crystallinity, fibril angle etc.)[14], it becomes obvious, that the difference between the material of historic and actual fibres is small.

As to be seen in the SEM images, the difference found in tenacity is presumably caused by processing damages, but this finding cannot exclude additional degradation effects during the centuries of storage (*e.g.* embrittlement)[13], but the fibres are still in a good state.

In addition, the historic and corresponding reference fibres were in the same range of fineness, indicating a similar intensity of processing. Based on these results it will be possible to set up a scheme for artificial ageing of new fibres to adapt them to the properties of the historic originals.

## ACKNOWLEDGEMENTS

Financial support by the Romanian Ministry of Education, Executive Unit for Financing Higher Education Research Development and Innovation, Project PN-II-PT-PCCA-2011-3.1-0408/Mythos is gratefully acknowledged. The authors are much indebted to N. Emde, H. Gerardi, M. Mirzaghavam & T. Slootmaker (all Faserinstitut Bremen, Germany) for their support in Fibreshape, Dia-Stron and SEM analyses.

The authors would like to thank Dr. Roxana Radvan's research group at National Institute of Research and Development for Optoelectronics (INOE 2000, Bucharest, Romania), project Coordinator as well as the Romanian National Peasant Museum from Bucharest, Romania for kindly provindg historical textile samples.

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