Security Paper Sheets Using Kapok Fibers Containing Chromic Materials

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Abstract
Kapok fiber is natural half-transparent hollow tube whose inner and outer diameters are 18 and 20 μm, respectively. This fiber excels in water repellence and absorbs oil due to the capillary force. In addition, the hollow rate of this fiber is higher than those of conventional synthetic fibers. The focus of this present work is to develop a novel paper sheet which integrating Kapok fibers containing chromic materials. The solvent which contains chromic materials was absorbed into Kapok fibers due to the capillary force. We found that the paper sheet exhibits reversible color change.

Keywords: Security paper, Chromic material, Kapok fiber

1. Introduction
Kapok fibers are downy fibers obtained from the fruits of Kapok trees as shown in Fig.1. The Kapok fiber is natural half-transparent hollow tube whose inner and outer diameters are 18 and 20 μm respectively as shown in Fig.2. This fiber exhibits superior water repellant property and absorb oil due to capillary force. Furthermore, the fibers have high hollow rate. In general, synthetic fibers have hollow rate of 50% and below, however, those of Kapok fibers are 80% and over. At present, applications of the Kapok fibers are limited to very simple stuffing such as pillows, cushions, and life jackets. The focus of this present work is to develop a novel functional fiber by utilized the Kapok fiber. It is well known that fluorescent fibers are integrated into banknotes such as Chinese Yuan. This fiber was presumed synthetic fiber dyed with fluorescent dye. Therefore, the
determination of real or fake is sometimes difficult when the fluorescent dye is exuded in the presence of water and/or oil. We think that problems above can be solved to insert the chromic material into hollow part in Kapok fibers[1-10].

2. Chromic material

We used a fluorescent material, a thermochromic material, and a piezo chromic material.

We selected 5,5'-Bis(4- (N-carbazolyl) phenyl]-3-dimesitylboryl-2,2'-bithiophene produced by Wako as fluorescent material.

We selected a thermosensitive produced by Narika Ltd. as the thermo chromic ink which shows blue color at under 40°C and pink color at over 40°C such as shown in Fig.3.

![Fig.3](a) Color change of a thermo-sensitive ink a) 21°C, b) 42°C

We selected Bianthrone produced by Tokyo Chemical Industry Co., Ltd, as the piezo chromic material, which shows yellow color at folded form, and green at twisted form (applied pressure) as shown in Fig.4 and Fig.5, respectively.

![Fig.4](Piezo chromic material (in the absence of pressure)

![Fig.5](Piezo chromic material (in the presence of pressure)

Furthermore, we made Kapok fibers containing a silver nano ink in order to examine the availability for electrically conductive material.

3. Experimental method

3-1. Paper sheets integrating chromic Kapok fibers

Chromic material was dissolved in volatile solvent and Kapok fibers were dropped gradually into the solvent. Chromic material solution was absorbed into Kapok fibers due to the capillary force. Then, the volatile solvents were eliminated by drying. In addition, we prepared a banknote model made of fibers containing chromic material.

3-2. L*a*b* measurements by Photoshop

The images of paper sheet integrating Kapok fibers containing chromic material were captured by a digital camera (PowerShot S110 CANON). Using these images, the L*a*b* value of Kapok part and pulp part by Photoshop. Fig.13-15 show responsiveness of these paper sheets.

3-3. Kapok fiber containing the silver nano ink

The Kapok fiber containing silver nano ink was prepared as follows: silver nano ink of 0.5 g was placed in beaker. Then 0.2 g of Kapok fiber was dropped gradually into the beaker. The silver nano ink (DryCure-Ag-JB 0410B COLLOIDAL INK) was absorbed into Kapok fiber due to the capillary force. The Kapok fiber was dried after removal from the beaker. After that, we observed a silver nano ink Kapok fiber using a scanning electron microscope (SEM).

4. Results and discussion

We have succeeded in making paper sheets integrating Kapok fibers containing chromic material as shown in Fig.6-11. Furthermore, we observed reversible color change of these paper sheets. Fig.12 shows that pressure sensitive material is inserted in a Kapok fiber. These observations suggest the potential for use in rewratable paper and anti-counterfeit utilizing Kapok fibers.

However, as shown in Fig.16, it was impossible to insert silver nano-ink to the kapok fibers. We found no
Fig. 7: Paper sheet integrating kapok fibers containing fluorescent material appearance under U.V light

Fig. 8: Paper sheet integrating thermo-sensitive Kapok fibers with low-temperature

Fig. 9: Paper sheet integrating thermo-sensitive Kapok fibers with high-temperature

Fig. 10: Paper sheet integrating pressure-sensitive Kapok fibers

Fig. 11: Paper sheet integrating pressure-sensitive Kapok fibers (applied pressure)

Fig. 12: Scanning electron microscope (SEM) image of a Kapok fiber containing pressure-sensitive material

Fig. 13: Light responsiveness of paper sheet integrating photochromic Kapok fibers

Fig. 14: Thermal responsiveness of paper sheet integrating thermo-sensitive Kapok fibers

Fig. 15: Pressure responsiveness of paper sheet integrating pressure-sensitive Kapok fibers

Fig. 16: Scanning electron microscope (SEM) image of a Kapok fiber containing silver nano ink
conductivity of the silver nano-ink kapok fiber.

5. Conclusions

We have succeeded in making Kapok fibers containing chromic materials. We have also succeeded in making paper sheets integrating Kapok fibers above. We found that some of paper sheets exhibit reversible color change. We think that the Kapok fibers containing chromic material have a potential as anti-counterfeit and/or rewritable paper.

References