Faculty of Textile Technology
University of Zagreb

NANOFUNCTIONALIZED MULTIPROTECTIVE FEMALE HEADWEAR

Adriana ŠTIMAC
Antoneta TOMLJENOVIĆ
Slavica BOGOVIĆ

- Female headwear for personal protection against the harmful impact of sunlight should be constructed in such way that shading as soon as greater part of face and neck and to provide protection against direct and scattered ultraviolet (UV) radiation.

- They should also fulfill special requirements regarding their exposure to different weather conditions (rain, sun and environmental pollutants) and insure good breathability.

- In this work, undyed cotton and white polyester woven fabrics nanofunctionalized with rutile TiO_2 nanoparticles incorporated in fluorocarbon finish were used. The influence of nanoparticles on modified fabrics multifunctional properties and durability of the tested materials after three month outdoor exposure was evaluated.

- Two models of multipurpose constructed and designed female hats are present: protective wide brim hat with creased veil that hangs from the back and hat with functionally designed cap without protective brim, of adaptive design - for daily and evening occasions.

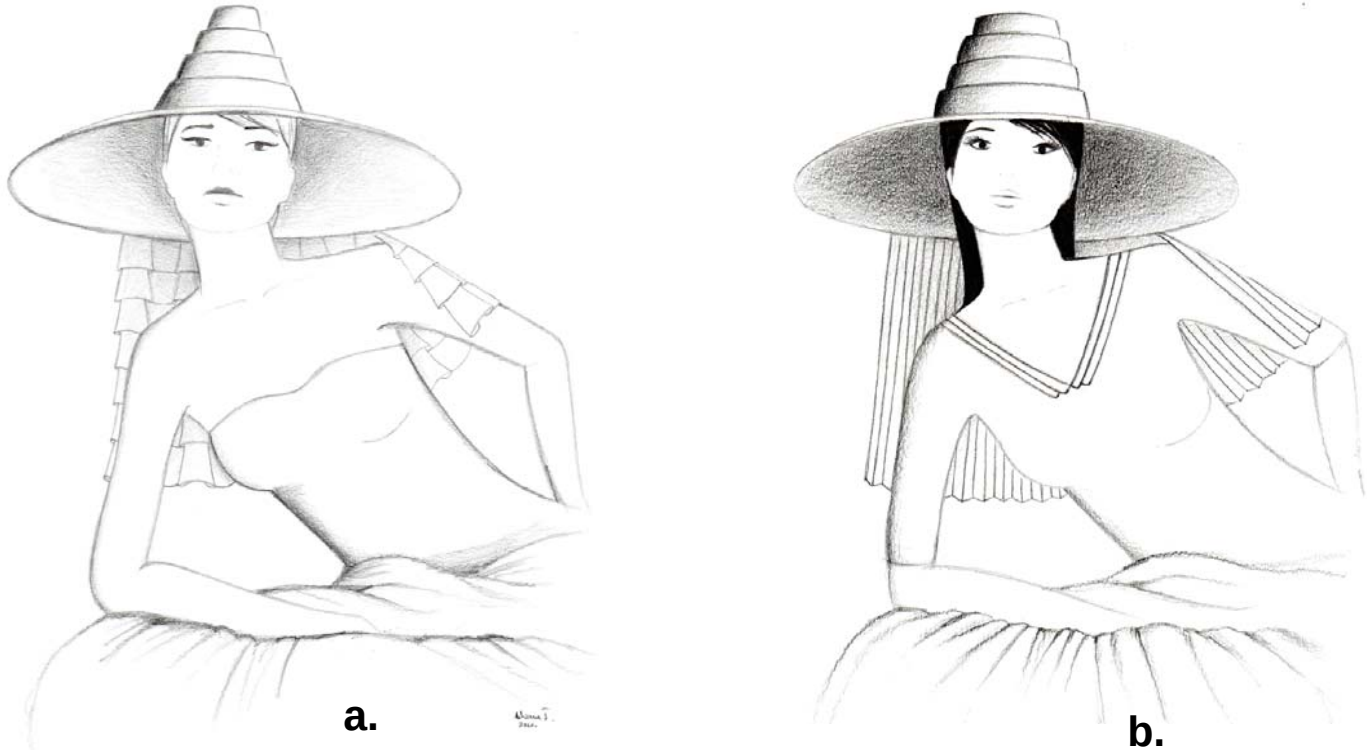
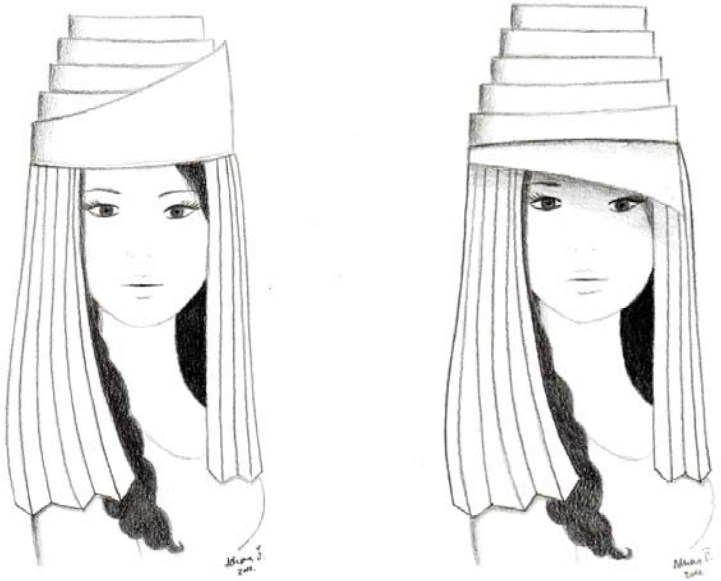


Figure 1: Protective wide brim hat with veil that hangs from the back: a. crinkled, b. folded



a. **b.**

Figure 2: Hat with functionally designed cap without protective brim - of adaptive design: a. with raised or b. lowered styled visor

- Application of multilayer construction increases reflected and scattered part of incident UV radiation light between fabrics layers and UV absorption as well. Usage of folded (plissé) fabrics increases UV reflection and reduces the fabric direct contact with skin.

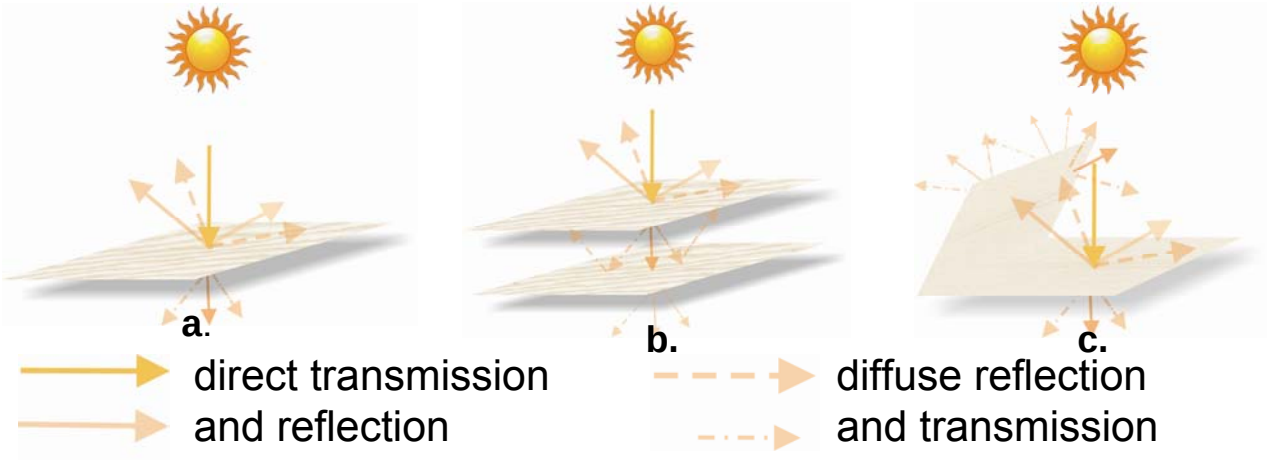


Figure 3: UV protective function of fabrics: a. single layer fabric, b. two layer construction, and c. folded construction

- Investigations were performed on gray cotton (C) and white polyester fabrics (P) that can improve the thermal comfort of product by increasing reflection of visible and infrared radiation.

Table 1: Structural and constructional characteristics of the investigated fabrics

Fabric sample	Fiber type	Weave	Weight (g m^{-2})	Thickness (mm)	Percentage cover (%)	Number of threads/cm	
						Warp	Weft
C	Cotton	Plain	179	0.41	97.4	31	27
P	PET, dull	Plain	67	0.13	89.4	42	34

- Knowing that fluorocarbon based coatings repel water and dirt particles, and do not affect fabric breathability, the fabrics were coated with the fluorocarbon finish employing standard processes, but with the addition of nanoparticles with the crystal size approximately 20 nm.

- With the aim of determination of their durability under real conditions of use, all the fabric samples were exposed to full elements of weather 24 hours a day, without any protection during three months, at a non industrial area - Croatian island Lošinj according to the EN ISO 105-B03:1997.

- The functional efficiency of the untreated and functionalized woven fabric samples, before and after natural weathering, were evaluated by measuring:
  - UVA and UVB transmission
  - tensile properties
  - water-repellency
  - oil-repellency
  - the handling
  - air permeability

UV protective properties

Table 2: UPF values, mean UVA and UVB transmission of untreated and TiO_2 functionalized (T) cotton (C) and polyester (P) fabrics before and after weathering

Fabric sample	Non-weathered			Weathered		
	Mean UVAT (%)	Mean UVBT (%)	UPF	Mean UVAT (%)	Mean UVBT (%)	UPF
C	6.447	3.247	22.83	13.090	8.556	9.51
CT	1.931	0.149	264.47	1.323	0.236	221.69
P	13.589	1.109	30.30	8.209	0.753	50.11
PT	6.696	1.055	43.02	6.848	0.530	63.46

- The results indicate that there was a considerable decrease of UV transmission trough the nanofunctionalized fabrics and increase in their UV protective properties.
- As the lowest UPF value should be higher than 40 according to the EN 13758-2, the results obtained confirm applicability of nanofunctionalized fabrics for making of UV protective headwear.

Water- and oil- repellency

Table 3: Water- and oil- repellency ratings of untreated and TiO_2 functionalized (T) cotton (C) and polyester (P) fabrics before and after weathering

Fabric sample	Water-repellency, 3M Test II		Oil-repellency, EN ISO 14419	
	Non-weathered	Weathered	Non-weathered	Weathered
C	1	W	Non-repellant	Non-repellant
CT	10	9	7	6
P	W	Non-repellant	Non-repellant	Non-repellant
PT	9	8	7	6

- Fabrics, functionalized with nano-TiO_2 incorporated in fluorocarbon finish, exhibited excellent water- and oil-repellency, which were slightly reduced after weathering. The above shows high applicability of nanofunctionalized fabrics for protection from rain and stains.

Bending rigidity

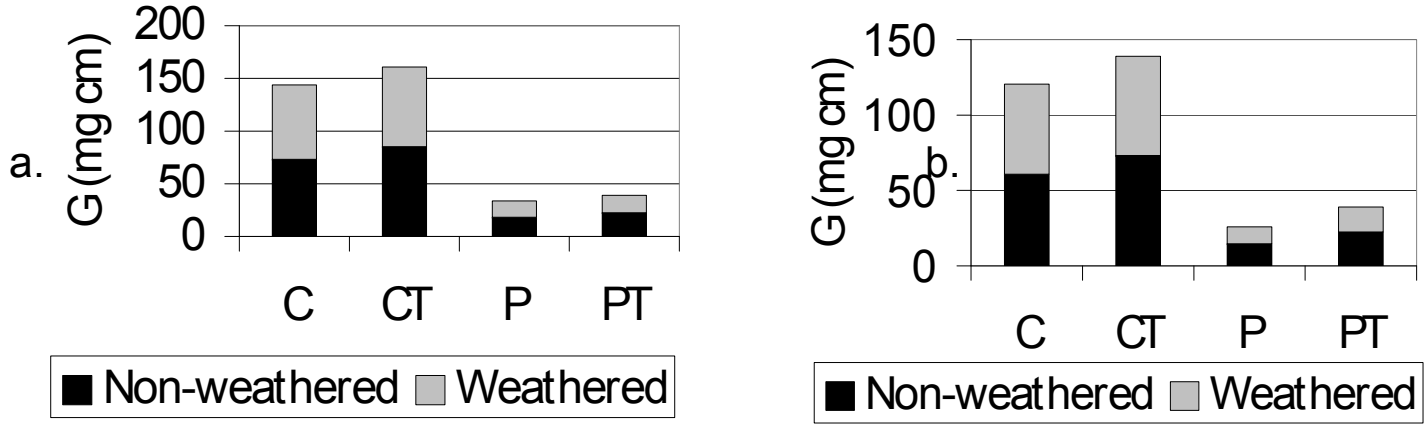


Figure 4: Bending rigidities of untreated and TiO_2 functionalized (T) cotton (C) and polyester (P) fabrics before and after weathering: a. warp direction, b. weft direction

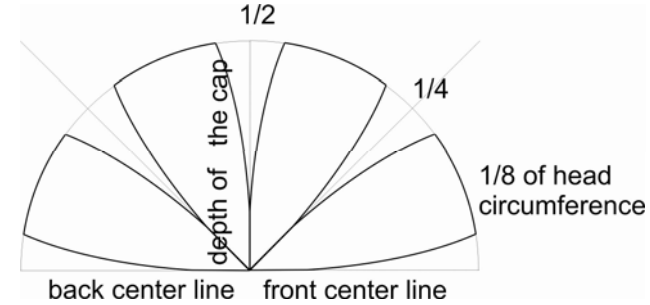
- Bending rigidity of the samples functionalized was higher than for the untreated once, what is important for wide brim hats. Handling was improved after weathering.

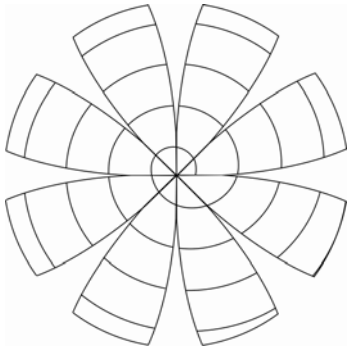
Breaking strength and air permeability

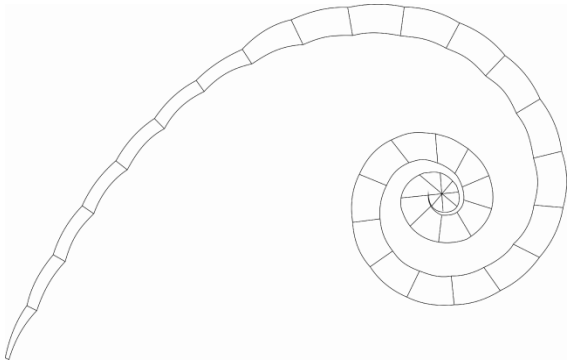
Table 4: Breaking strengths and air permeability of untreated and TiO_2 functionalized (T) cotton (C) and polyester (P) fabrics before and after weathering

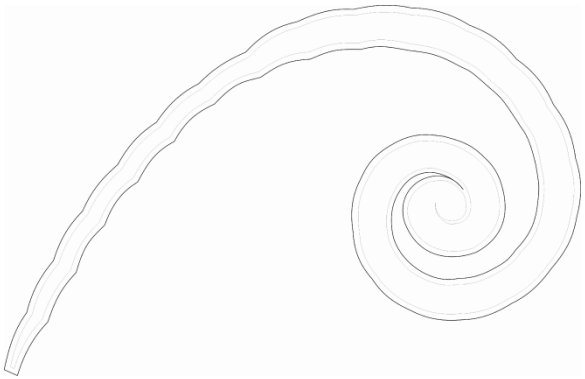
Fabric sample	Breaking strength (N)				Air permeability (mm s^{-1})	
	Non-weathered		Weathered		Non-weathered	Weathered
	Warp	Weft	Warp	Weft		
C	510	600	435	575	108.2	110.2
CT	513	602	507	608	115.2	116.2
P	713	592	268	206	158.6	172.4
PT	710	591	350	270	168.8	184.4

- Nano-TiO_2 used had a stabilizing effect on fabrics photo-degradation. The breaking strength of PET samples after weathering decreased, but still showed higher values than that of untreated sample.
- By padding and after weathering, the air permeability of fabrics increased, which could improve the headwear comfort.









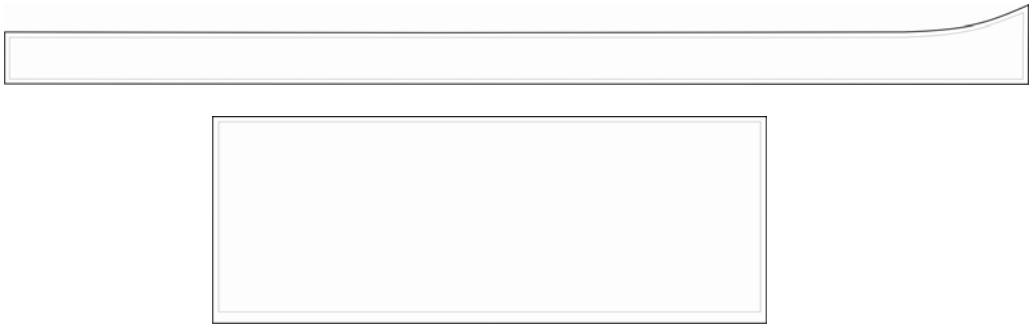


Figure 5: Construction of headwear - cutting parts

- The results obtained indicate that using the TiO_2 nanoparticles at low concentration (of 6 gL^{-1}) incorporated in a fluorocarbon based coatings, offers a possibility of producing textile materials that could provide desired multifunctionality and acceptable durability of multipurpose designed female headwear.

- By innovative designing and application of the knowledge about the multi-layered and folded fabric constructions, it is possible to get a functional and adaptive finished product.


Thank you for your attention!