

SURFACE ENERGY ANALYSIS OF GRAFTED NYLON 66 FIBERS

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1. Introduction

Grafting vinyl monomers into Polyamide fibers has been one of the methods for the chemical modification of these textiles (Buchenska 1996). The aim of these modifications is to improve some properties of the polymer such as its dyeing affinity, its holding to fire and its wettability and also its water and soil repellency. In fact changing fiber chemical composition can alter its surface wetting because each fiber type has distinct wetting and surface properties (Hsieh *et al* 1996). Wettability can be valuable for characterizing fiber surfaces, liquid transport interaction of fibers with liquids and surfactants, and adhesion with polymers (Wong *et al* 2001). Graft copolymerisation of Methacrylic Acid (MAA) monomer onto Nylon 66 fibers using benzoyl peroxide as initiator was carried out in order to improve water absorbency. Contact angle is a convenient measure of wettability because it is sensitive to the variation of surface properties (Wolf *et al* 1999)

This paper will give an overview about the advantages of using wettability studies according to the Whilmey method, to evaluate the degree of surface graft modification and its effect on the wetting properties of the grafted Nylon 6,6 fibers.

2. Method of surface energy measurement

The theory of surface tension components assumes that the surface tension of a solid γ_s is the sum of two terms (Fowkes 1964) :

$$\gamma_s = \gamma_s^p + \gamma_s^d \quad (1)$$

γ_s^d is the surface tension of the solid due to dispersion forces and γ_s^p is the polar component due to dipole forces and hydrogen-bond effects. The 1-bromonaphtalen (BN), tricesylphosphate (TCP), glycerol and water contact angle data were used to determine the solid surface tension components (γ_s^p and γ_s^d) of the grafted fibers by using the combined Owens-Wendt-Young equation (Owens & Wendt 1969)

$$\gamma_l(1+\cos\theta)/2(\gamma_l^d)^{1/2} = \gamma_s^d + \gamma_s^p(\gamma_l^p/\gamma_l^d)^{1/2} \quad (2)$$

Where θ is the contact angle and γ_l , γ_l^d and γ_l^p are the surface tension of the liquid, its disperse component and its polar component respectively.

We used a dynamic technique for measuring contact angle. The dynamic method which is commonly referred to the Wilhelmy technique is the basis of the Dynamic Contact Angle analysis system (DCA) (from Cahn Instruments) (Milling 1999).

As soon as the fiber tip touched the liquid, the microbalance would detect a change in force due to the wetting of the fiber by the liquid.

A simple equation relates the cosine of the wetting contact angle (θ) to the magnitude of the wetting force recorded by the balance (F), the surface tension of the probe liquid (γ_l), and the wetted perimeter of the fiber (p) sample by the following equation ((Milling 1999):

$$F = p\gamma_l \cos\theta \quad (3)$$

The plot of $\gamma_l(1+\cos\theta)/2(\gamma_l^d)^{1/2}$ versus $(\gamma_l^p/\gamma_l^d)^{1/2}$ allow us to determine the slope which gives the square root of the polar surface tension and the intercept gives the square root of the disperse component of the surface tension of the solid fiber.

3. Results and discussions

Table I shows the values of contact angles (θ) and surface tension components (γ_s^p , γ_s^d , γ_s) of Nylon 6,6 fibers. The values of θ listed were calculated from eq (3) and represent the average of five measurements done on each type of fiber with the indicated liquid.

TABLE I
Contact angles in degree of reference liquids, and Surface tension components of Nylon 66 fibers.

	θ_{water}^a	$\theta_{\text{glycerol}}^b$	θ_{TCP}^c	θ_{BN}^d	γ_1^p (mN/m)	γ_1^d (mN/m)	γ_s (mN/m)
Nylon 66	64 ± 2	57 ± 2	24 ± 2	30 ± 1	26.32	20.86	47.18
%G=3.03	62 ± 3	58 ± 2	21 ± 2	23 ± 2	46.67	10.69	57.36
%G=6.53	57 ± 1	39 ± 2	17 ± 2	26 ± 1	63	7	70
%G=9.22	31 ± 2	36 ± 2	11 ± 6	29 ± 2	66	5.98	71.98
%G=24.08	25 ± 4	14 ± 2	14 ± 1	27 ± 2	68.15	3.21	71.36

^aSurface tension components of water: $\gamma_1^d=21.6\text{mNm}^{-1}$, $\gamma_1^p=51.0\text{mNm}^{-1}$

^bSurface tension components of Glycerol: $\gamma_1^d=37.0\text{mNm}^{-1}$, $\gamma_1^p=26.4\text{mNm}^{-1}$

^cSurface tension components of Tricresylphosphate: $\gamma_1^d=39.2\text{mNm}^{-1}$, $\gamma_1^p=1.7\text{mNm}^{-1}$

^dSurface tension components of Bromonaphtalen: $\gamma_1^d=44.6\text{mNm}^{-1}$, $\gamma_1^p=0.0\text{mNm}^{-1}$

The variation of surface tension component decreases with the increase of the percent grafting. The dispersant component decreases greatly from 20.86 (%G = 0) to 3.21 mNm⁻¹ (%G = 24.08). However, the polar component increases greatly from 26.32 (%G=0°) to 68.15 mNm⁻¹ (%G=24.08). The total surface free energy increases and reaches a plateau value at high percent of grafting. The values of the contact angles show that hydrophilic surface is reached at a percent grafting of 24,08%.

According to the Wakida *et al* (wakida *et al* 1993), the increased surface tension is due to oxygen incorporation. Introducing oxygen elements onto the fiber surface in the form of –OH, C=O, and –COOH can increase hydrophilicity (Sato *et al* 1995). In our case we can confirm that the increasing of surface tension of the grafted Nylon 6,6 fibers is due the introducing of Polar components –COOH from Methacrylic acid.

4. Conclusion

In this study, according to the Wilhelmy Method, wettability studies were performed. We obtain respectively qualitative and quantitative indications about the degree of the water absorbency and the surface free energy of the grafted Nylon 6,6 fibers. The results show that grafting Methacrylic Acid, greatly improves the hydrophily of these fibers. This finding is important for many textile processes, e.g dyeing, and finishing. Also, comfort of clothing made with these fibers, is closely associated with moisture absorbency.

5. References

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