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EFFECTS ON THE ELECTRO-MECHANICAL PROPERTIES OF ANILINE- DOPED POLYESTER FIBRIC

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ABSTRACT
The effects of Electro-mechanical properties of doped polyester fabric with aniline were investigated. The effects of various concentrations on the electrical as well as mechanical were examined and the percolation threshold was established. Chemical polymerization of aniline on Polyester in hydrochloric acid using potassium dichromate as oxidant was carried out. Polyester based conductive polymer composites were prepared by means of melt mixing with a twin screw. The samples were investigated for electrocoductivity and mechanical properties. The results obtained shows polyester fabric became electrically conductive at a percolation threshold between 1-2.5% concentrations and also the electrical conductivity increased with the concentration, up to $5.0x10^{-3}$ S/m at 5 % concentration. The tensile characteristics such as average breaking force, work-to-rupture, and % elongation, of the fabric were all improved. Also Scanning Electron Microscope (SEM) analysis of the samples was studied. ***Keywords: Doped, percolation, threshold, conductivity, elongation***

INTRODUCTION

Since the discovery of intrinsically conductive polymers (ICPs) for which Alan Macdiarmid, Alan Heeger and Hideki Shirakawa won a Nobel Prize in Chemistry in 2000, attempts have been made to introduce electrical conductivity into textile fibres, yarns and fabrics by compositing them with conductive polymers such as polypyrole (PPy), polyaniline (PANI) and polythiophene (PT) (Lekpittaya *et al.*, 2004; Patil and Deogaonkar, 2012). The demand for electrically conductive textiles is growing rapidly not only in relation to industrial needs such as sensing, electromagnetic interference (EMI) shielding, electrostatic discharge, data transfer in clothing, dust and germ-free clothing, corrosion protection, but also for military applications such as camouflage and stealth technology. Polyaniline is outstanding, due to its thermal, environmental and chemical stability, low cost and easy synthesis (Kim *et al.,* 2006; Kutanis *et al.,* 2006). In addition there are reports of PANI-coated or in-situ polymerized non-woven fabrics such as nylon 6, cotton, polyester and Nomex fabrics.

The electrical resistance of the PANI-PET yarns decreased as the concentration of the PANI solution increased. It remained fairly constant up to 55°C, after which the electrical resistance started increasing with increase in temperature. And, like a typical conductor, the longer the yarn length, the higher the electrical resistance. The modulus and other tensile properties also improved. In all, the conductive yarns showed good environmental stability, and the strength and flexibility were preserved. Wu *et al.,* (2009) used a molecular template (a sulphonated polyaniline) to facilitate integration of a complementary conductive polymer (polyaniline) into wool-based textiles. The efficiency of the polymerization/coating process was enhanced because the template localized the reaction within the textile substrate. The presence of the molecular template resulted in the formation of an adherent, uniform and stable conducting polymer layer. The integration of PANI also improved the electrochemical reversibility of the coating. The coated textile material was suitable for use in biomedical monitoring. Neelakandan *et al.*, (2009) polymerized PANI on woven polyester fabric samples (plain, twill and satin). Each polymerization cycle represented one coating, and as the number of coatings was increased, more of the conducting polymer was deposited on the fabric, forming a stable, adherent coating on the textile substrate; this also caused an increase in % weight add-on as well as fabric thickness. This was clearly demonstrated by SEM observations. The resistivity can be varied from an antistatic level ($10^{10}\ \Omega$ cm) to a high conductivity level (10 Ω cm) by varying the concentration of the oxidant and dopant.

The aim of this study is to introduce electrical conductivity onto polyester fabric using aniline as dopant, so as to investigate the effects of Electro-mechanical properties of the fabric.

MATERIALS AND METHODS

Materials

Plain woven, 171 g/m² 100 % Polyester (Dacron) was obtained from the Polymer and Textile Science Departmental store Ahmadu Bello University Zaria. Nigeria, Primasol (NMB), soda ash, Triton X-100, acetone, aniline, potassium dichromate, hydrochloric acid and dimethyl formamide (DMF) were all obtained from Sigma-Aldrich. Instruments used include Scanning Electron Microscope (SEM), Instron Tensile testing machine, Water bath sonicator, Probe sonicator and Electrical conductivity.

Methods

Fabric Scouring

The polyester fabric was scoured at 100°C for 30 minutes in a bath containing 2g/l non-ionic surfactant (Primasol NMB) and 2g/l soda ash. It was rinsed copiously with water and dried.

Doping of the Fabric

In a 250 ml flat-bottomed flask 0.3 M aniline (monomer) was stirred in 0.25 M H_2SO_4 for 10 minutes. 1 g of the fabric was impregnated in this solution at room temperature for 30 minutes with mild agitation. Potassium peroxydisulphate was added slowly to initiate polymerization. Polymerization was allowed for 3 hrs and then the fabric was removed and washed with aqueous 0.25 M H_2SO_4 in a beaker (to remove loose polymer, unconsumed monomer and oxidant). The residue washed with deionized water before drying.

Tensile Strength Test

Instron automatic testing machine with an IBM computer interface and printer according to the ASTM International D 5035-11 (2013),was used to investigate the tensile characteristic such as; average breaking force, percent elongation at break, work of rupture.

Electrical Conductivity Measurement

METEX auto/manual range dual display digital multimeter with interface (M-3860D) was used to measure the resistance between two probes separated by a known distance.

Results and Discussion

Figures 1 and 2 are micrographs of control polyester sample and polymerized aniline on the fabric respectively. The Polyaniline deposited as a spongy microfilm within the fabric (Figure2) was observed to have actually penetrated into the filaments, and of course, a larger percentage can be seen coating the filaments and also lodged between their interstices which functions as the electrically conductive layer (ECL).. This corroborates the results from the work of Fugetsu *et al*., (2009).

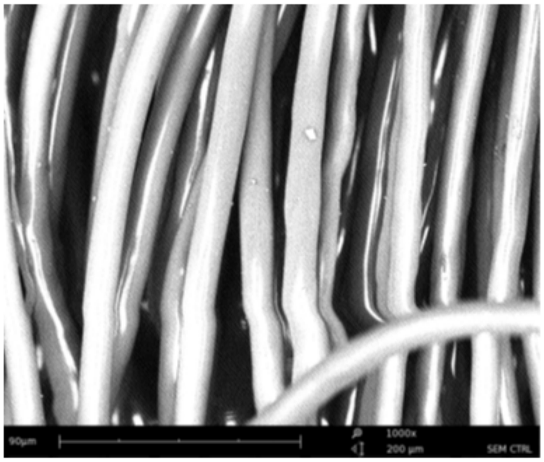

Figure 2: SEM micrograph of the control sample.

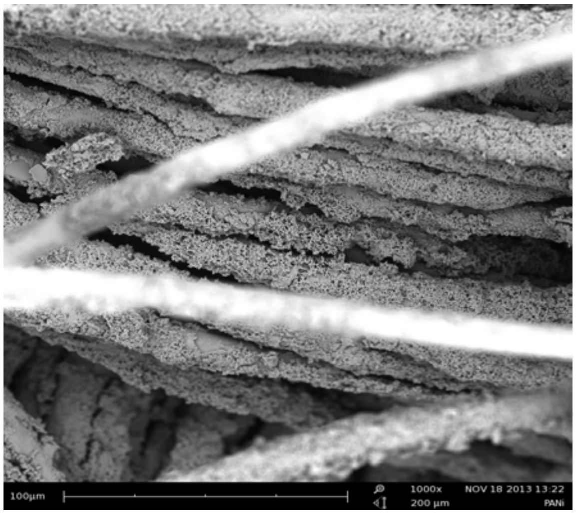

Figure 2: SEM micrograph of polymerized aniline on the fabric (magnified X 1000)

Figure 3, shows the relationship of the conducting sample as the function of doped concentration. It can be observed that there is a sharp increased in conductivity between 2.5 %. and 3.5%., This region highlighted the percolation threshold. It is the critical concentration above which electrical conductivity started manifesting in the fabrics. After the percolation threshold, conductivity increased with increase in the concentration, up to a maximum of 5.5 % after which the fabric ceases to absorbed more (Grossiord *et al*., 2008).

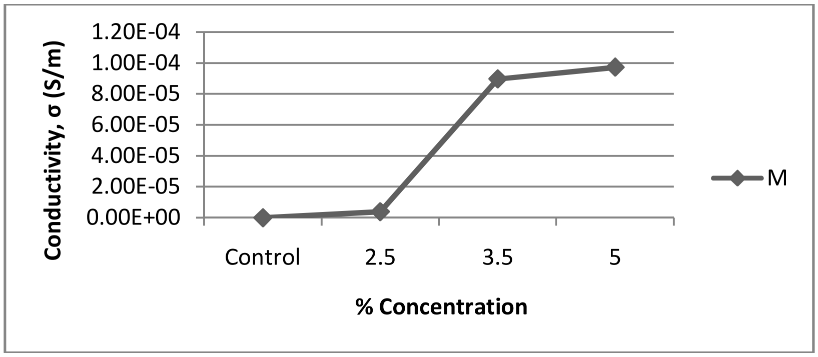

Figure 3: Conductivity, σ, as a function of % concentration of aniline

Fig. 4, shows the plot of average breaking force against % concentration. There was an increase in average breaking force with increase in concentration, this is ascribed to the difference in the compactness of the yarns, brought about by the interaction of twist levels and number of filaments per cross section of the yarns (Mun *et al.*, 2008).

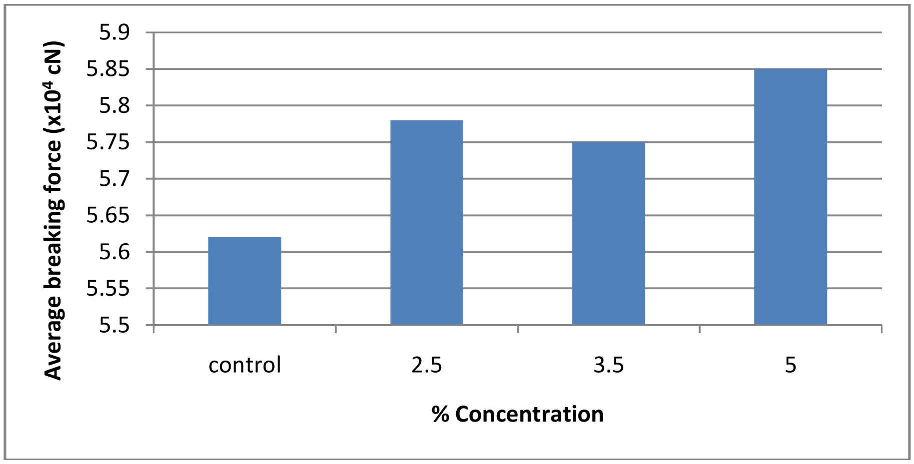

Figure 4: Average breaking force as a function of % concentration

Figure 5 and 6, show the plots of % elongation and work of rupture versus concentrations, which depicted that they increased with the increased in concentration. Applying a lubricant between the filaments in this way, when a load is applied at the two extremes of a fabric piece, the filaments tend to first straighten out, then untwist, then slide against each other as they attempt to resist stress-bearing This explains why there was an increase in average % elongation and work of rupture .The 3.5% concentration abnormal behaviour were observed because, it is the critical concentration above which the tensile strength started manifesting in the fabrics After the percolation threshold, tensile strength decreased with increase in the concentration (Favini *et al.*,2012).

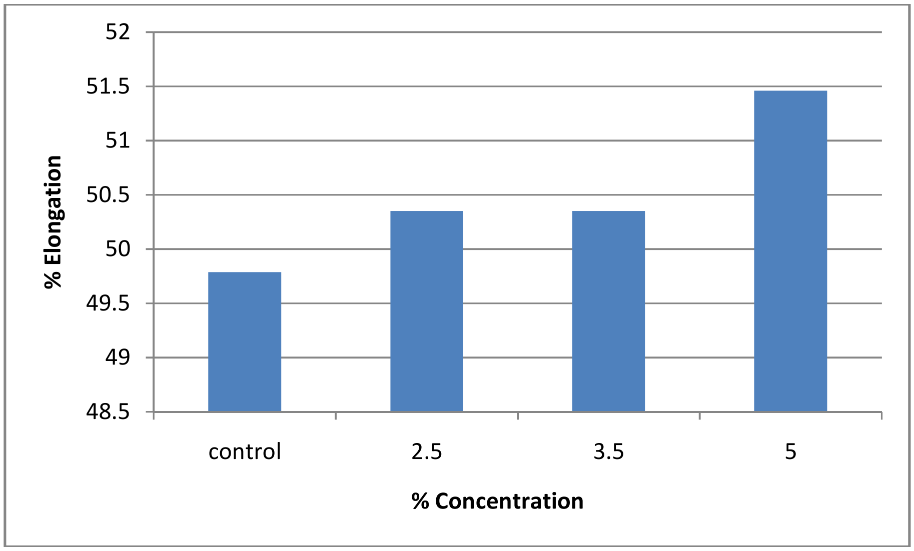

Figure 5: Percent elongation versus % concentration.

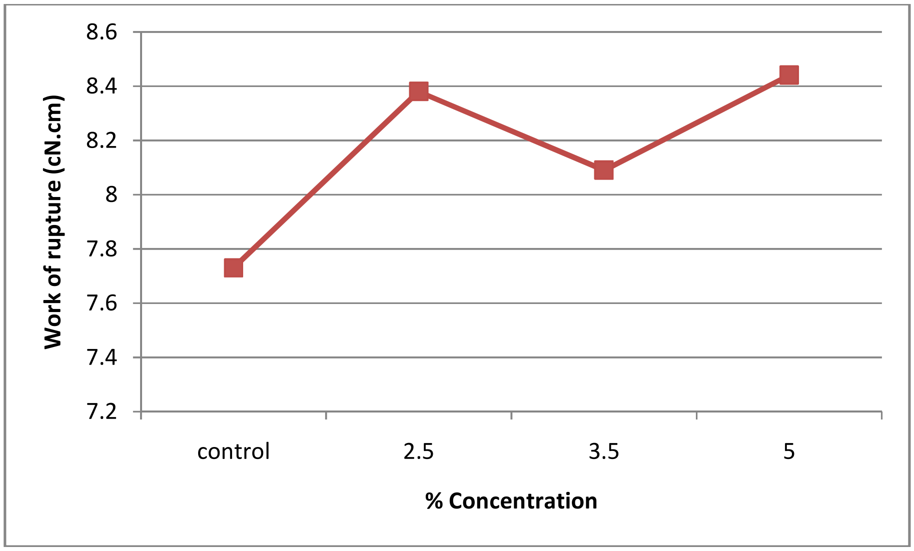

Figure 6: Work of rupture as a function of % concentration

Conclusion

Based on its higher yield, aniline was adopted as the intrinsically conductive polymer of choice for our purpose. As it was being polymerized within the fabric, it passed through some landmark, as the dispersion increased the conductivity of the doped fabric was found to vary in a similar way as that of metals i.e., the resistivity or conductivity varies with the length of the conductor and tensile characteristics such as average breaking force, work-of-rupture and % elongation, of the fabric were all improved.

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