Abstract—Effects of plasma treatment on chemical and physical properties of indigenous fibers such as water hyacinth and pineapple were investigated. Oxygen, argon, hydrogen and mixed oxygen/argon gases were used to produce plasma in a plasma-enhanced chemical vapour deposition device. Yarns were produced from the plasma treated indigenous fibers with 80% polyester, 10% water hyacinth and 10% pineapple composition and were characterized using Raman spectroscopy, atomic force microscopy (AFM), Fourier transform infrared analysis (FTIR) and tensile strength. Results show that yarns made from plasma treated indigenous fibers such as water hyacinth and pineapple possess comparable properties of commercial 100% polyester yarns.

Keywords—Fibers, plasma, yarns, textile.

I. INTRODUCTION

The search for innovative production techniques to improve textile quality has been the hallmark of the textile industry (Han, et. al.). Low temperature plasma surface treatments offer an alternative to wet chemical processes. Plasma technology has distinct advantages in modifying the surface properties of inert environment-friendly materials. Plasma technology operate at low-pressures, low-temperature, therefore energy saving and are eco-friendly. The main advantage of plasma processing is that it is a dry, energy-efficient and clean process (Radetic, et. al., 2007; Tyner, 2007).

Previous study involves using PECVD in treatment of coconut fibers to determine the efficacy of plasma treatment as compared to chemical treatment of fibers (Guhit, 2012). The study aims to produce yarns made from plasma-treated indigenous fibers with physical and chemical properties comparable to yarns made of pure polyester and untreated indigenous fibers. Future research works may vary, increase and optimize the percentage of indigenous fibers to produce another blend of yarns made of synthetic/indigenous fiber blends with cheaper and more biodegradable materials, not just environmentally-friendly but economically fashionable.

II. METHODOLOGY

Room temperature for the experiment was maintained at 18°C and occasional argon discharge cleaning was executed for the maintenance of the PECVD equipment and between different gas usages. Gases used for plasma treatment of pineapple and water hyacinth indigenous fibers were combined oxygen and argon, hydrogen, oxygen, and argon gases for 5 min and 15 min exposure to plasma. The first steps undergone by fibers in spinning process aimed to open and loosen the fibers. Blending was done manually to achieve the desired blend ratio combining water hyacinth, pineapple and polyester fibers. Industrially, DOST-PTRI manufactures only up to 80/20 blend of polyester/indigenous fiber to ensure good quality of yarns produced. The blended materials were opened further, cleaned and separated the short fibers to form a continuous slivers using a miniature carding machine Type SC Platts Bros Sales LTD from England at 10 m/min. With 100 m/min speed, a laboratory scale draw frame machine MTE Control Gear LTD. from Germany further straightened the fibers and combined the output of several carded slivers giving a more uniform product. Ring spinning was then done to reduce the roving materials produced from speed frame machine using ring frame machine Platts Saco Lowell USA with capacity of 11.29 kg/hr at speed of 8.53 m/min. The process of reducing the materials to required size in spinning is called drafting, wherein the size of the yarn was determined and established. The yarn that emerged from the ring spinning process cannot usually be woven directly and needed some preparation. Winding was done to transfer the yarn to larger bobbin or cone/packages using Meng Seung cone winder with capacity of 16.20 kg/hr at 800 rpm drum speed. To get a long continuous length for non-stop operation of weaving or knitting, regulate the yarn tension and remove thick places, slubs or quality defects. Yarns are produced directly from drawn slivers, which are fed into a feed-tube and are drawn
out from a doff-tube and wound onto a cone. The properties of the yarns were largely dependent on several factors, including the structure and composition of the fiber, the kind and amount of modifier, the spinning method and the degree of stretching of fiber during yarn production. These affect the molecular orientation and crystallinity of yarns.

III. RESULTS AND DISCUSSION

A. Fourier Transform Infrared Spectroscopy (FTIR Spectroscopy)

Various chemical interactions at the surface as the electrons and ions bombards the fibers made into yarns. The interactions break the backbone or side chain bonds of the molecules, allowing secondary reactions to occur. Formation of C=O bonds occurred and at the same time the breaking of C-H bonds. Yarns produced were found to have decreased O= of C=O bonds occurred and at the same time the breaking of C-H bonds. Formation of stretching of fiber during yarn production. These affect the molecular orientation and crystallinity of yarns.

B. Raman Spectroscopy

Based on the Raman shift, the best treatment would be the hydrogen gas with significant peaks as compared to the other treatments. C=C bond was generally more intense in Raman than in IR spectra. The Raman spectrum was not dominated by O-H bands as its infrared spectrum was. The bands represented cellulose can be seen at 2906 cm\(^{-1}\) (CH, CH\(_2\) stretch), 1478 cm\(^{-1}\) (H-C-H and H-O-C bend), 1379 cm\(^{-1}\), 1334 cm\(^{-1}\) (H-C-C, H-C-O, and H-O-C bend), 1108 cm\(^{-1}\) (C-C and C-O stretch).

C. Atomic Force Microscopy (AFM)

Scanning of the yarns made from untreated and plasma treated fiber was carried out in contact mode AFM with a silicon cantilever. Scanning size was at 20 µm × 20 µm and all images were obtained at ambient conditions.

A smoother surface was observed with polyester as compared to yarns made of untreated indigenous fibers.

![Fig. 1 AFM Images of Plasma-Treated Indigenous Fibers (Phase)](image1)

![Fig. 2 AFM Image of Yarns made of Indigenous Fibers Plasma-Treated with Combined Oxygen and Argon, Hydrogen, Oxygen, and Argon Gases (Sense)](image2)

Fig. 1 and Fig. 2 showed considerable changes in fiber surface morphology after plasma treatment. Decrease in surface roughness or smoother surface for yarns treated with hydrogen and argon gas. Upon O\(_2\)/Ar treatment, further uniform etching yielding tinier, more organized, and uniform and flatter beads leading to decreased surface roughness as compared to polyester. With oxygen treatment, etching of the very upper layer of the fibers lead to more uniform scale-like structures which increased the surface roughness of the manufactured yarn. Deformation of the scale-like structure formed as a result of plasma treatment was observed as a disordered surface structure with big bumps as compared to untreated indigenous fiber. The surface of the fiber was obviously roughened after the plasma treatment. The fibril structure was not visible and aggregate structures with various sizes were seen on the yarn surface. The different sizes of the aggregates indicated the uneven effect of the surface etching by plasma treatment. Oxygen plasma treatment further roughened the yarn surface, resulting in the formation of the pit-like structures on the surface. It must be recognized, that smoothening takes place with hydrogen and argon gases. With sense images unevenness is still visible. Distribution of pores affect fiber properties including their swelling in water, accessibility to chemical reactants such as cellulase, fiber shrinkage, and fiber strength with increased of small pores results in decrease in fiber strength. It was observed that the surface topography of the yarn changed after the argon-plasma treatment some concavo-convex states and bulges were observed. Simultaneously, pits appeared on the yarn surface. Many irregular condensation clusters and large hollows appeared on the surface. High-energy electrons, radicals, and excited molecules and atoms were emitted during plasma discharge. Also, ultraviolet rays, visible rays, etc, were emitted from the excited molecules and atoms.

Plasma electric discharge caused physical and chemical changes on the surface of polymers because of the presence of various activity groups. Many craters formed on the surface because of etching and exfoliation. The findings indicated that the remarkable effects of argon plasma treatment on the yarn surface observed by AFM were due to plasma bombardment on the surface and the splitting of the macromolecule chains, which rearranges them and formed a new surface morphology causing increased in wettablity on the yarn surface (Khan, et. al., 2007; Yang, et. al., 2009). The primary etchant species
formed in an oxygen plasma are oxygen radicals (O*) and oxygen atoms (O•), which etch cellulosic indigenous fiber (P) via the following reaction pathways (Balu, et. al., 2008):

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P + O^* \rightarrow P^* + OH
\]

\[
P^* + O \cdot \rightarrow P'O + CO + CO_2
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Tensile Strength Testing

With plasma treatment of water hyacinth and pineapple indigenous fibers, increased in yarn strength was caused by argon gas treatment. But, decreased strength was observed with oxygen treatment due to etching of fibers as compared to untreated 80/10/10 yarn blend of indigenous fibers and polyester. Results obtained from different trials for tensile strength testing was close to each other which confirmed that the fibers was plasma-treated uniformly.

IV. CONCLUSIONS

Plasma-treated yarns made of indigenous fiber from water hyacinth and pineapple in 10/10/80 blend (water hyacinth/pineapple/polyester) have comparable characteristics to pure polyester. The produced yarns made from combination of oxygen and argon (at 10:10 ration) plasma-treated indigenous fibers were comparable to yarns made of pure polyester and untreated indigenous fibers based on FTIR analysis with increased in hydrophilicity confirmed thru Raman spectroscopy. The AFM analysis had shown increased in roughness of yarns which also indicates increased in hydrophilicity. Through Weibull distribution, it was also determined that the tensile strength of the yarns increased with argon plasma treatment as compared to untreated and polyester yarns. Therefore, with plasma treatment, the hydrophilicity of the water hyacinth and pineapple indigenous fibers increased such that the produced yarns with 10:10:80 blend of treated water hyacinth, pineapple fibers, and untreated polyester fiber showed significant increase in hydrophilicity property at most using oxygen gas.

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