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Experimental Investigation on Analysis of Alkaline Treated Natural Fibers Reinforced Hybrid Composites

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Abstract--- For a variety of possible uses, natural fibers are essential reinforcement in polymer matrix composites. They therefore have a greater impact on a nation's socioeconomic development. Automakers and material scientists are being forced to take into account the biological meaning of their items during handling, reusing, and removal because of the consistently rising interest for supportable and eco-accommodating items. Thus, there is a ton of interest in utilizing natural fibers to create biodegradable and sustainable composites. Natural fiber's wide range of accessibility can lessen the strain on agriculture and forests. Utilizing a variety of raw materials simultaneously will support maintaining nature's ecological balance. Regularly, 30-40% of the waste materials created by horticulture and woodland items can likewise be used in esteem added handling. Due to their inexhaustibility, biodegradability, recyclability, eco-amicability, light weight, worked on unambiguous strength, great protection from effect and erosion, overflow, simplicity of handling, and cost-adequacy, regular fiber supported composites have made a significant introduction to the automotive industry over the past ten years. The transportation industry has prompted the use of natural fiber reinforced composites in a variety of applications due to their cost-effectiveness and weight reduction, making them superior substitutes for petroleum/synthetic fibers.

Keywords--- Natural Fibers, Raw Materials, Agriculture Sources, Petroleum, Synthetic Fibers.

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I. Introduction

In order to work on the item and fulfill client expectations, fiber-reinforced composites are used to examine their mechanical and actual properties. These properties include cost effectiveness, high production rate, and ease of fabrication. Fibers serve as reinforcement or filler in fiber-reinforced composites, while polymers serve as a matrix. The fibers can be bio/natural, like plant, mineral, or animal fibers, or petroleum/synthetic, like aramid, boron, carbon, glass, and Kevlar fibers. Because of their superior mechanical performance and lightweight nature, engineered fiber built up polymer composites are broadly used in high strength applications like automotive, aviation, and marine. Except for glass fibers, these fibers are expensive, non-recyclable, non-biodegradable, hazardous to health, require a lot of energy to produce, and are not environmentally friendly. (Kumar et al., 2022). Because they are lightweight and have superior mechanical performance, synthetic fiber reinforced polymer composites are widely used in high strength applications like automotive, aviation, and marine. Except for glass fibers, these fibers are expensive, non-recyclable, non-biodegradable, hazardous to health, require a lot of energy to produce, and are not environmentally friendly.

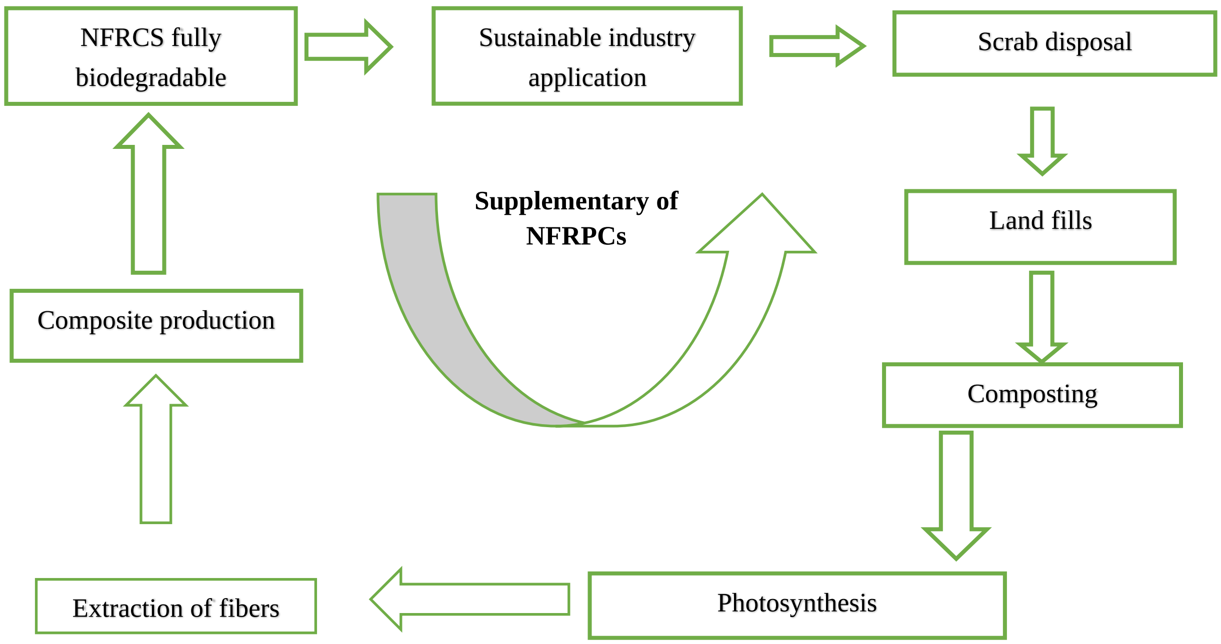

Figure 1: Natural Fibers Reinforced Composites

The importance of creating materials that can replace petroleum-based materials has been made clear by material engineers in figure 1. As a result, the need for the profitable application of bio-based materials in various engineering fields has grown in recent years. Natural fibers and other bio-based materials are sustainable and environmentally friendly. They are found in large quantities in nature and offer several benefits, including low density, biodegradability, recyclability, renewability, high specific strength, superior fatigue strength, improved resistance to wear and corrosion, and reduced cost. Natural fiber reinforced composites made from biopolymers and renewable plant fibers would be extremely important to the composites industry as a way to address the oil production crisis as well as the growing environmental threat. The advancement of composites reinforced with natural fibers has expanded their use in a number of engineering domains. Contrasted with glass fiber, which presently makes up most of auto composites, normal filaments can possibly diminish vehicle weight by up to 40% net vehicle weight. Minerals, plants, and animals are the sources of bio/natural fibers. Feathers, wool, and silk are instances of normal filaments got from creatures (Bekele et al., 2023). Among the types of natural fibers derived from plant seeds, leaves, fruits, grass, roots, and stems is plant fiber.

II. Chemical Composition of Natural Fibers

Tensile strength, specific modulus, density, and electrical resistivity are all dependent on the chemical makeup and structure of the fiber. Cellulose's hydrophilic nature, which includes alcoholic hydroxyl groups, affects the hydrophobic matrix's interface zone with the fiber.

With 80% of crystalline regions (higher packing density) widely circulated all through the fiber and lesser request indistinct locales with lower pressing thickness, cellulose is an exceptionally crystalline structure. In contrast to linear cellulose, hemicellulose is composed of highly branched polysaccharide polymers, such as galactose, glucose, xylose, and mannose, as well as a cluster of polysaccharides that are joined to the cellulose after gelatin is taken out. It has a level of polymerization 10-1000 times lower than cellulose and contains different sorts of sugar units. As polymers of phenyl-propane units, lignin is formless, profoundly mind boggling, generally fragrant, and insoluble in most of solvents (Pokhriyal et al., 2024). It fills in as a defensive hindrance for the cellulose and hardens the fiber cell walls welcomed on by the lignification cycle. Lignin fills in as an underlying scaffolding part in plants. Polysaccharides like cellulose and hemicellulose are quick to frame in plant cell walls, and lignin fills in the holes between the fibers of the polysaccharides to cement them together. The term "pectin" refers to a group of heteropolysachrides that give plants flexibility. The last component of fibers are waxes, which are composed of various alcohols. Figure 2 illustrates how the chemical makeup of natural fibers affects their mechanical, warm, and actual qualities. The most important factor influencing the toughness of natural fibers is the microfibrillar angle (MFA). Regular fiber built up composites' durability expanded with the MFA, peaking between 15 and 20 degrees.

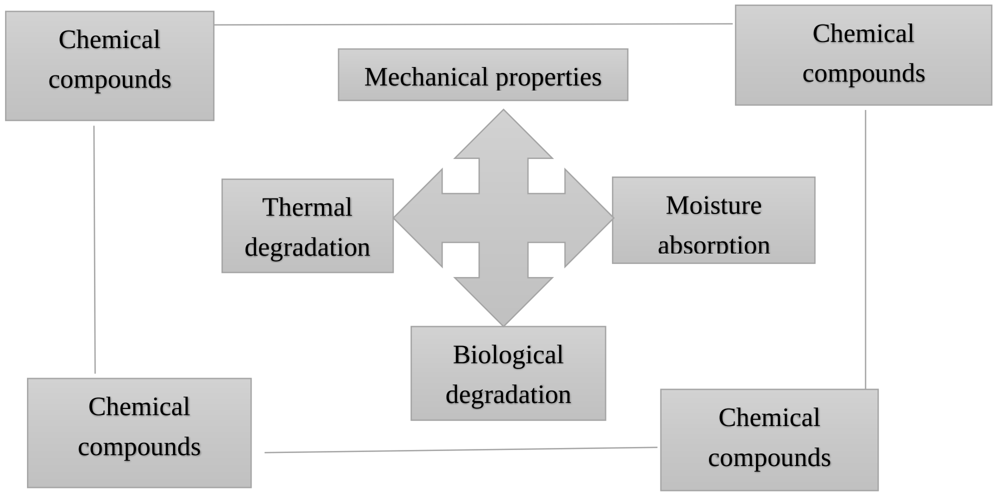

Figure 2: Influence of Chemical Composition of Natural Fibers on Physical, Mechanical and Thermal Properties

III. Chemical Treatment of Natural Fibers

The drawback of using cellulosic natural fibers as reinforcement is that they are incompatible with thermoset or thermoplastic polymers due to their hydrophilic nature. This outcomes in a feeble connection between the fiber and the framework on the grounds that the polymer lattice is hydrophobic. Regardless, legitimate substance treatment ought to be utilized to build the interfacial strength between the normal fiber and the oil-based grid (Binu Kumar et al., 2022). To move the applied pressure to filaments from the network, it is critical to foster a superior interphase for better composites with regards to execution. One technique for natural fibers to increase the adherence of the hydrophilic fibers to the hydrophobic matrix is chemical treatment. Because it reduces the measure of hydroxyl bunches on the fiber surface and builds the fiber's unpleasantness and protection from water retention, it fortifies the interfacial connection between the filaments and the polymer framework by expanding the successful fiber surface region and perspective proportion. The kind of reagent, temperature, fixation, and treatment term all influence the result of synthetic treatment. Basic, benzoylation, acrylation, peroxide, silane, potassium permanganate, dewaxing, maleated coupling specialist, stearic corrosive, join copolymerization, acetylation, and isocyanate treatment are among the various chemical treatments for various natural fibers.

IV. Ceramics Filled Natural Fibers Reinforced Composites

Picking the right fiber, framework, and filler is fundamental for working on the composite's characteristics. While fillers further develop security, solidness, protection from scraped area and intensity, coefficient of warm extension, and strength, filaments invigorate the polymer grid and work on the mechanical execution of composites. In regular fiber built up composites, ceramic fillers are frequently used to improve performance beyond what would be achievable with only the reinforcement and resin components alone. In addition to enhancing mechanical performance, ceramic fillers can aid with stiffness, shrinkage, water resistance, cost reduction, and dimensional stability. In recent years, there has been a greater focus on the incorporation of ceramic fillers into polymer matrix composites for structural, automotive, aerospace, and building applications. There is a lot of interest in how the weight percentage, shape, and size of filler particles affect the mechanical and actual qualities of polymer grid composites. Consequently, a lot of researchers have concentrated on composites reinforced with natural fibers and ceramics (Bhagat et al., 2024).

To change the unrefined components into the completed item without making any deformities, proper assembling methods ought to be utilized. The size and state of the end result, the properties of the support and framework, the natural substance handling boundaries like handling temperature, strain, and restoring time, creation time, and assembling cost are the main considerations for design and manufacturing experts when choosing the best manufacturing techniques to create fiber-reinforced composites. Fiber-reinforced composites have generally been made using a variety of techniques, including automated tape laying, filament winding, resin transfer molding, pultrusion, vacuum bag molding, compression molding, injection molding, spray-up, and hand layup. The requirement for specialized molds, which raises manufacturing costs and restricts the final part's formability, is a common problem with all conventional methods. As a result, creating detailed and customized parts becomes costly and time-consuming. The development of additive manufacturing for fiber reinforced composites has been sparked by the requirement for low expenses, simple plan customization, robotized creation, more limited lead times, less waste, and insignificant deformities. Since it can possibly improve, alter, and differentiate the properties of nonexclusive materials by adding fortifications, added substance assembling of composites has drawn in exceptional consideration. With the capacity to alter fiber volume portion and fiber direction to make practically evaluated composites, additive manufacturing has the potential to become a leading technology in the composites sector. Low density fiber reinforced composites made using additive manufacturing have gained popularity in a number of industries during the past few decades. For fiber-reinforced composites, using additive manufacturing techniques offers a significant chance to reduce weight and improve strength. Depending on how similar they are, different-shaped fibers can be combined with different polymer matrices to create stronger, more improved mechanical qualities. Throughout the course of recent years, endeavors have been made to develop short fiber reinforced composites with improved strength for use in additive manufacturing processes. In order to enable printed parts with better mechanical properties, recent research trends are focused on creating innovative fiber reinforced composites, such as continuous fibers, and innovative additive manufacturing process modifications. Fiber-reinforced additively manufactured components are a good alternative to more costly components made of ferrous or nonferrous metals because they can be used to produce pilot parts with fewer part numbers. Figure 3 depicts a schematic of the fiber reinforced additive manufacturing process.

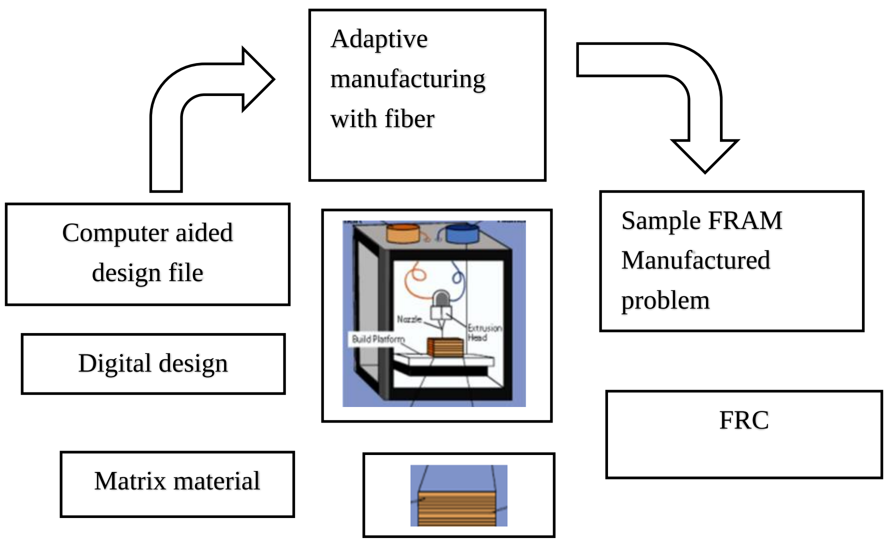

Figure 3: Schematic Representation of Fiber Reinforced Additive Manufacturing Process

The most generally utilized added substance fabricating procedure is melded testimony displaying, which makes three-dimensional (3D) products by directionally oriented extrusion with a tiny extrusion die that is between 0.5 and 2 mm in diameter. Researchers studying composite materials most frequently use FDM because of its cost-effectiveness, efficiency, and ease of fabrication. The part is constructed layer by layer, just like in other additive manufacturing processes, but FDM is distinguished by the constant extrusion and deposition of material that has been heated above its melt temperature (Cavalcanti et al., 2019). When a polymer filament is used as feedstock, it pushes the molten material through the liquefier like a piston. Thermoplastic polymers are the primary material used in FDM and related processes to create 3D-printed objects, although ceramics, metals.

V. Environmental And Industrial Impact of Natural Fibers Reinforced Composites

Every automobile product should be recyclable and disposable in accordance with environmental regulations and the significance of disposal in nations such as the US, Europe, the UK, and Japan. Just 5% of scrapped cars can be burned or dumped in a landfill. According to a survey based on multiple sources, approximately 20 lakh vehicles in the UK become obsolete each year. Even though 75–80% of an end-of-life vehicle's weight is recycled, automakers are under a lot of pressure to make new products more recyclable. The only way to prevent landfill pollution is through recycling. Car manufacturers are therefore making a lot of effort to change the materials used in their vehicles in order to reduce their weight. Due to stringent regulations and laws pertaining to automotive EOL requirements in Europe and Asia, automakers are also required to take into account the environmental impact of the vehicle's end of life (EOL), including the production of raw materials, product manufacturing, usage, and disposal. In such an endeavor, natural fiber reinforced composites that result in a 50% weight reduction and a 30% cost savings can be very accommodating. Roughly 23% of global CO2 emissions come from the transportation sector, which includes cars, planes, trains, and ships. (Sahu & Gupta, 2020). In figure 4 displays the Extraction Process of Banana Fiber.

Figure 4: Extraction Process of Banana Fiber

One of the efficient and environmentally responsible ways to increase the interfacial strength between hydrophilic filaments and the hydrophobic lattice is to apply an alkaline or mercerization treatment. The sodium hydroxide (NaOH) reagent is used in alkaline treatment to alter the natural fibers' cellulosic sub-atomic construction. The direction of the thickly pressed translucent cellulose request is changed in this treatment by shaping undefined regions where cellulose micromolecules are isolated and the spaces are loaded up with water particles. (Nachippan et al., 2021). In figure 5 displays the Alkaline Treatment Procedures.

Figure 5: Alkaline Treatment Procedures

Following the effect test, the actual properties of the composite material were inspected utilizing a SEM (JEOL JSM-6480LV). Silver glue is utilized to mount composite examples on nails. Before the photomicrographs are taken, a slim layer of platinum is vacuum-dissipated onto the examples to expand their conductivity. In figure 6 displays the FTIR Spectra of Treated NFRC below.

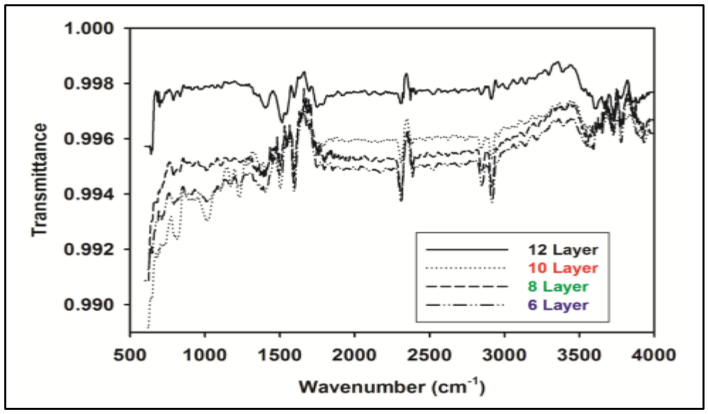

Figure 6: FTIR Spectra of Treated NFRC

According to the FTIR analysis, the alkaline treatment improved the mechanical properties of the composite overwhelmingly of the lignin and hemicellulose from the fibers. Additionally, it was discovered that a concentration of NaOH greater than 5% harmed the fiber surface, leading to poor matrix-fiber adhesion that reduced the mechanical qualities of composites. In figure 7 displays the FTIR Spectra of Treated Ramie and Jute Fibers Reinforced Composites.

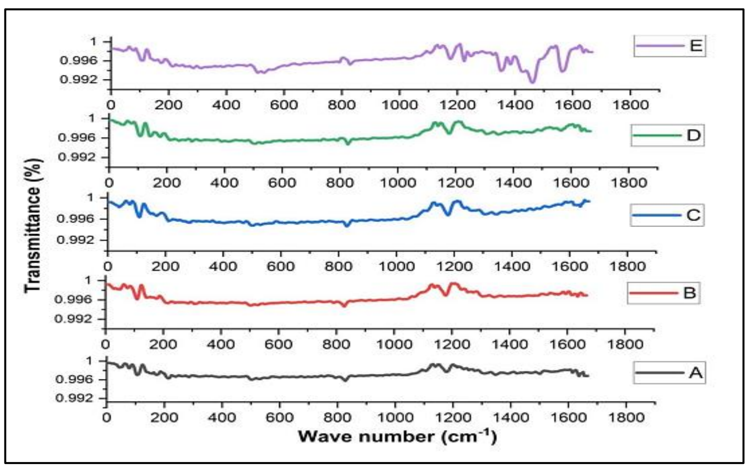

Figure 7: FTIR Spectra of Treated Ramie and Jute Fibers Reinforced Composites

Because the water/ethanol mixture solution removes hemicellulose, lignin, and pectin, the alkaline treatment significantly alters the surface of the ramie and jute fibers. A soluble layer created on the ramie and jute filaments' surface because of the basic gatherings being considered. This peculiarity shows that most of the hydroxyl and ester bunches in cellulose, hemicellulose, and lignin filaments have been lost.

VI. Conclusions

For a variety of possible uses, natural fibers are essential reinforcement in polymer matrix composites. They therefore have a greater impact on a nation's socioeconomic development. Automakers and material scientists are being forced to take into account the environmental meaning of their items during handling, reusing, and removal due to the steadily rising demand for sustainable and eco-friendly products. As a result, there is a lot of interest in using natural fibers to create biodegradable and sustainable composites. Due to recycling concerns and the materials' non-biodegradability, polymer matrix composites reinforced with petroleum-based fibers and composed of thermoset/thermoplastic polymers limit the final product's environmental friendliness. Composites that provide a feasible outcome are created by incorporating bio/normal strands into to some extent or totally biodegradable polymers.

Research on amplifying the utilization of regular strands like areca, ramie, snake grass, flax, kenaf, hemp, bamboo, sisal, pineapple, jute, luffa cylindrica, and others is progressing. The transportation area, which requires recyclability, unrivaled extravagance and driving execution, upgraded wellbeing measures, eco-friendliness, and lower CO2 discharges, is the primary industrial sector where these fibers have found numerous applications. Thus, it is essential for the transportation sector to use low-density and biodegradable materials. The utilization of normal filaments and their composites is additionally expected by these variables as well as different impacts like accessibility, cost adequacy, rigid ecological guidelines, worldwide market, presentation of new items, and the requirement for manageable nature.

References

[1] Kumar, R. S., Muralidharan, N., & Sathyamurthy, R. (2022). Optimization of alkali treatment process parameters for kenaf fiber: experiments design. *Journal of Natural Fibers*, *19*(11), 4276-4285. https://doi.org/10.1080/15440478.2020.1856276

[2] Bekele, A. E., Lemu, H. G., & Jiru, M. G. (2023). Study of the effects of alkali treatment and fiber orientation on mechanical properties of enset/sisal polymer hybrid composite. *Journal of composites science*, *7*(1), 37. https://doi.org/10.3390/jcs7010037

[3] Pokhriyal, M., Rakesh, P. K., Rangappa, S. M., & Siengchin, S. (2024). Effect of alkali treatment on novel natural fiber extracted from Himalayacalamus falconeri culms for polymer composite applications. *Biomass Conversion and Biorefinery*, *14*(16), 18481-18497. https://doi.org/10.1007/s13399-023-03843-4

[4] Binu Kumar, V. J., Bensam Raj, J., Karuppasamy, R., & Thanigaivelan, R. (2022). Influence of chemical treatment and moisture absorption on tensile behavior of neem/banana fibers reinforced hybrid composites: an experimental investigation. *Journal of Natural Fibers*, *19*(8), 3051-3062. https://doi.org/10.1080/15440478.2020.1838995

[5] Bhagat, M. S., Jadhav, V. D., Kulkarni, S. K., Satishkumar, P., & Saminathan, R. (2024). Comparative analysis of alkali-treated natural fibres for improved interfacial adhesion in composite materials. *Interactions*, *245*(1), 206. https://doi.org/10.1007/s10751-024-02041-6

[6] Cavalcanti, D. K., Banea, M. D., Neto, J. D. S. S., Lima, R. A. A., da Silva, L. F., & Carbas, R. J. (2019). Mechanical characterization of intralaminar natural fibre-reinforced hybrid composites. *Composites Part B: Engineering*, *175*, 107149. https://doi.org/10.1016/j.compositesb.2019.107149

[7] Sahu, P., & Gupta, M. K. (2020). A review on the properties of natural fibres and its bio-composites: Effect of alkali treatment. *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, *234*(1), 198-217. https://doi.org/10.1177/1464420719875163

[8] Nachippan, N. M., Alphonse, M., Raja, V. B., Shasidhar, S., Teja, G. V., & Reddy, R. H. (2021). Experimental investigation of hemp fiber hybrid composite material for automotive application. *Materials Today: Proceedings*, *44*, 3666-3672. https://doi.org/10.1016/j.matpr.2020.10.798