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Influence of sugarcane bagasse fibres from the rind and pith on selected properties of bio-composite material

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Abstract

The use of composites made from lignocellulosic fibres is gaining popularity these days since they are eco-friendly, cost-effective, and could potentially replace synthetic plastics. The purpose of the research was to find the fibres from sugarcane bagasse that might be used as a composite material. Various physical and mechanical properties of the fibres were examined after they were removed as outer rind and inner pith. The raw rind had a density of around 720kg/m^3, which was higher than the inner pith fibres. At the same time, the water absorption properties of outer rind and inner pith composites were investigated. The results suggest that the rind absorbed more water than the pith composites, with a 14-15% increase. Based on the findings, it was determined that sugarcane bagasse fibres were ideal for reinforcing bio-composites.

Keywords: Bio-composites, cost-effective, density, eco-friendly, mechanical properties

1. Introduction

The use of lignocellulosic materials in reinforcement applications to replace polymeric composites has been growing in recent years. This is because of various properties of natural fibres like low density, bio-degradability, less expensive, and renewable has increased their importance towards automobile industries, insulators, acoustic sectors [1]. The most appealing features of green composites are that they are entirely degradable, environmentally benign, and long-lasting [2]. On the way, sugarcane bagasse is the residual material obtained after crushing and extraction of juice from the sugarcane stalk. This has been left in the ground which causes landfills and disposal issues. The major portion of this waste has been used in the fuel generation system in the boilers and also in the paper and pulp industry. As these materials are composed of cellulose, hemicellulose, and lignin, creates the interest to explore the potential of these materials in various applications. The sugarcane stalk is mainly composed of the harder component in the outer called rind which has lengthy fibres which are arranged randomly that are bonded together by hemicellulose and lignin. The inner soft component called pith is made up of small fibres and mostly consists of sucrose [3]. Bagasse contains roughly 55 percent cellulose, hemicellulose, lignin, and ash, with cellulose, hemicellulose, lignin, and ash concentrations of 17%, 25%, and 1%, respectively [4]. Many researchers have worked on the characterization of natural fibres obtained from agricultural biomass. Few works have been reported on the effective use of bagasse in reinforcement. S.C Lee has studied the effect of inner pith and outer rind on the properties of the composites made from these two constituents [3]. In this study, an attempt has been made to characterize the fibres from the outer rind and inner pith in terms of physical, mechanical, water absorption properties.

2. Materials and Methods

2.1 Materials

The sugarcane bagasse was obtained from the ICAR-Sugarcane Breeding Institute, Coimbatore, Tamil Nadu, India. The bagasse has undergone a retting process for 2 days in water followed by drying in a hot air oven at 80C for 72hours. Then it was separated into the outer rind and inner pith manually. The Epoxy LY 556 is an epoxy resin used for binding and HY 951 is an anhydride hardener used for the composite preparation.

2.2 Preparation of composites

The outer rind and inner pith fibres were mixed separately with the epoxy resin and hardener in the ratio of 70% fibres and 30% resin. The mixture was then made into the mold by compression molding method with the dimensions of 23* 23cm. The thickness of the composite was about 5mm [5].

2.3 Test methods

2.3.1 Density of fibres

The ratio of specimen mass to specimen bulk volume was calculated as the bulk density of the samples. The volume of the standard cylinder was measured and the mass change before and after loading of the fibres was noted and the bulk density was calculated for both outer rind and inner pith samples. The bulk density (ρ_t, g/cm^3)was calculated as:

$$\rho_t = m/V \qquad (1)$$

The sample porosity was determined from the measured bulk density and true density values using the formula,

$$\varepsilon = (1 - \rho_{b/}\, \rho_{t)} \qquad (2)$$

Where,
ε- Porosity of the sample, (outer rind and inner pith)
ρ_b – bulk density, g/cm^3
ρ_t – true density, g/cm^3

2.3.2 Optical properties

The optical properties of fibres and composite samples of fibres were determined using a Hunter lab colorimeter (M/S Hunter Associates Laboratory Inc, Reston, Virginia; Model: Mini-scan EZ 4500 L, Hunter lab) at the Central Institute of Agricultural Engineering (CIAE) in Coimbatore.

2.3.3 Mechanical properties

2.3.3.1 Single fiber tensile test

The single fiber test was carried out for the fibres in the Universal testing machine (Model UNITEK 3410) by following the ASTM D3822-07 method. The sample gauge length was about 50mm and the crosshead speed was about 20mm/s.

The bending strength of the rind and pith composites was analyzed in the Universal testing machine. The length of the sample gauge was around 20 cm and the speed of the crosshead was around 2microseconds. Fig 1 shows the sample holded between the load cell for the bending test of the composites.

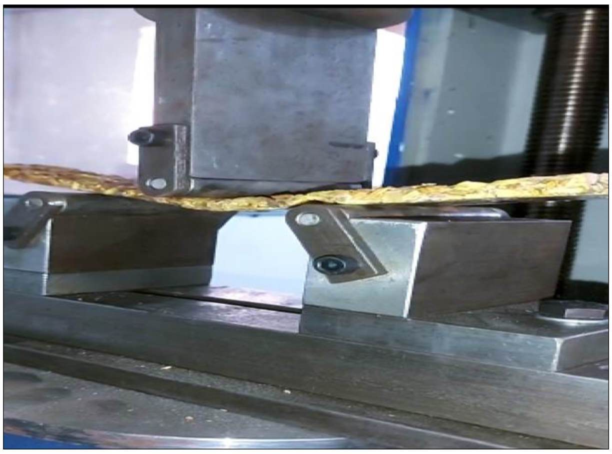

Fig 1: Sample placed between the load cells in the UTM for bending strength

The tensile stress and the bending strength of the fibres and composites were calculated from equation (3)

$$\sigma = \frac{F}{A} \qquad (3)$$

Where,
σ denotes the tensile stress and bending strength in MPa
F is the maximum peak load in kN
A refers to the cross-sectional area of the fibres and composites

2.3.4 Water absorption pattern of composites

The samples were conditioned in a hot air oven at 50°C for 48 hours before the experiment. The samples were immersed in the water at the regular time intervals of 24hours and the experiment was conducted for 8 days at a water bath with a constant temperature of 80°C. The difference in the mass of the samples from the initial day to the final day which is expressed as the percentage of original mass gives the water absorption behavior of the composites.

3. Results and Discussion

3.1 Density of the fibres: The natural fibres are lignocellulose materials as these are different in size and thickness for both the outer rind and inner pith. These are usually made up of a bundle of the individual cell. The bulk density of the outer rind was higher (720 to 763 kg/m^3) when compared with the inner pith (320 to 335 kg/m^3). The pith component consists of numerous hollow cavities known as lumen. The presence of the lumen will decrease the bulk density and it can be used in acoustic insulator applications [6]. Similar behavior was analyzed by S.C. Lee and he has concluded that the pith has spongy shaped smaller-sized fibres. The rind consists of a smaller amount of lumen with many finer cellulosic fibres compared with the inner pith [7].

It has been found that the porosity of the inner pith sample was more to the value of 0.984 approximately, 98.4% compared to the outer rind. This is maybe due to the porosity of the inner pith increasing when the bulk density of the sample decreases. The porosity of the inner pith was more because of the presence of the void spaces. As bagasse and bagasse ash have low densities, it can be inferred that the highest proportion of bagasse and bagasse ash will further increase porosity [8]. Table.1 shows the comparison of bulk density and porosity of the outer rind and inner pith fibres.

Table 1: Engineering properties of sugarcane bagasse fibres

S. No	Engineering properties	Outer rind fibres	Inner pith fibres
1.	Bulk density, kg/m^3	720.25	320.12
2.	True density, kg/m^3	4.64	5.33
3.	Porosity, %	98.42	99.25

3.2 Optical properties of fibres and composites

The optical properties of the outer rind and inner pith fibres and composites are summarized in Table 2. For the fibres, the L* value of the inner pith was lower at the value of 60.43 when compared with the outer rind and it shows the L* value shifted towards the blackish region. The a* value shows that the color of the fibres samples was positive (Reddish). Similarly, the b* value was towards the blue turned positive and confirms that the fibres are yellowish in nature.

For the composites, the L* value was similar for both the composites and it was about 48.72 for rind composites and 50.25 for pith composites. The a* values show that the composites are in the reddish region and the values are 7.89 and 10.53 for both rind and pith composites. The b* value was between 27.53 to 35.04 for both the composites and these values shows that the composites are in the yellow region. Fig.2 shows the optical properties of the inner pith and outer rind fibres and composites

Table 2: L*,a* and b* values of sugarcane bagasse fibres and composites

Samples	L*	a*	b*
Outer rind fibres	71.94±2.01	5.08±1.70	21.37±2.23
Inner pith fibres	60.23±1.03	9.16±2.43	23.29±1.10
Rind composites	48.72±3.02	8.03±1.20	27.53±2.09
Pith composites	50.25±2.33	10.53±3.21	35.05±2.34

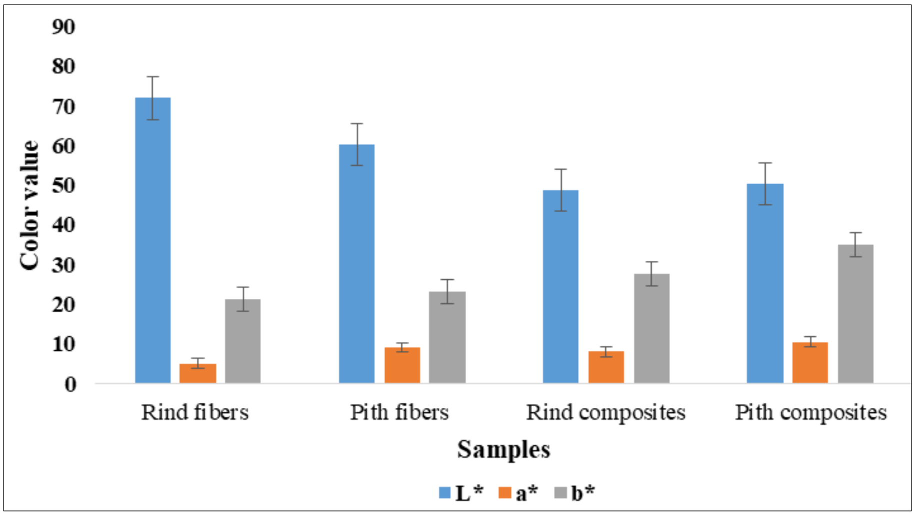

Fig 2: L*, a* and b* values of the sugarcane bagasse fibres and composites

3.3 Single fiber tensile test

Table 3 summarises the results of a single fiber tensile test of the outer rind and inner pith fibres. In comparison with the inner pith, the tensile stress was more for the outer rind (85.15934 MPa). The presence of the pore spaces has reduced the tensile strength of the inner pith fibres. A similar trend was observed for all the tensile properties for elongation at break (4.24%) when compared to the inner pith (1.9%) According to P. Manimaran *et al*. (2017), the increased tensile strength is mostly due to a larger fraction of highly polymerized and linearly orientated cellulose in the fibres [9]. A similar observation was observed by Vilay *et al*. (2008) in bagasse fibres with a tensile strength of about 96.24 MPa [10]. Fibrillation has led to an equal distribution of load over the fiber length due to the finer packing of cellulose chains [11].

Due to the existence of void spaces in the outer rind, it was found from the findings that the force needed for the elongation was minimum. The minimum force suggested that the tensile strength of the outer rind was small since no treatment was done to increase its stability. The various tensile properties of fibres were shown in Fig.3

Table 3: Mechanical properties of outer rind and inner pith fibres of sugarcane bagasse

S. No	Mechanical properties	Outer rind fibres	Inner pith fibres
1.	Tensile strength (Mpa)	8.68±1.23	2.194±1.56
2.	Young's Modulus (Gpa)	2.00±2.12	1.195±2.20
3.	Elongation at break (%)	4.24±1.89	1.823±3.12
4.	Cross sectional area mm^2	2.98±2.24	4.711±1.29

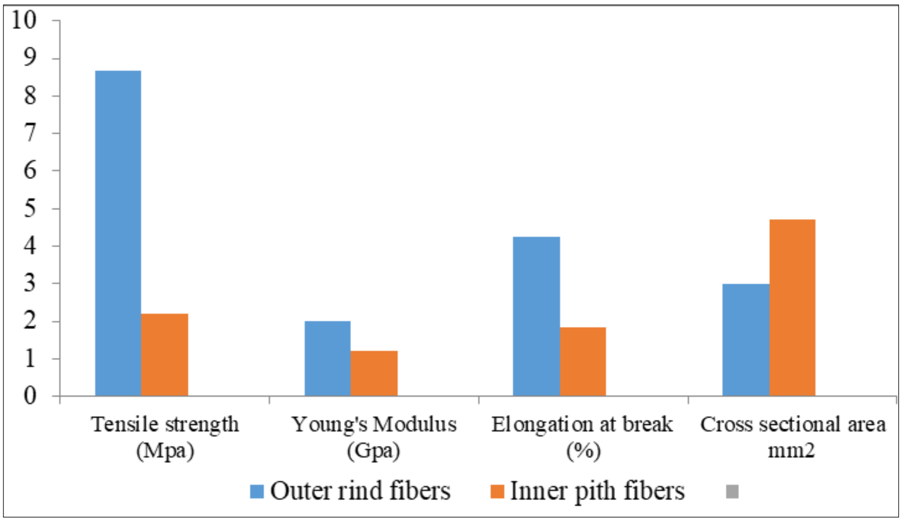

Fig 3: Mechanical properties of the bagasse fibres

3.4 Bending strength of the composites

The bending strength of the inner pith bagasse-based Composite was higher compared to outer rind bagasse fibres composites are because epoxy resins and hardeners improve the properties of surface fiber adhesives through fibrillation**.** As compared to the raw rind fiber, it has been found that the necessary bending force is reasonably higher. This may be because the intermolecular space between the rind materials was smaller since the epoxy resin was well bound to the fiber material and made the composite rigid [12]. The bending stress was found to be higher for the pith composites with a value of 9.397 MPa when compared with the rind composites (4.828MPa). The results of the bending properties of the composites were shown in Table 4

Table 4: Bending strength of the rind and pith composites

S. No	Mechanical properties	Rind Composites	Pith Composites
1.	Maximum load (kg)	10.45±2.23	20.34±3.89
2.	Stress in kN/mm^2	0.53±0.89	1.03±0.62
3.	Bending strength in MPa	4.82±1.40	9.39±2.12

3.5 Water absorption pattern of composites

Fig.4 shows the pattern of the water uptake of the inner pith and outer rind composites. As the water absorption process begins, it rises sharply, then levelled off for some time before it approaches equilibrium. All the parameters i.e., fiber orientation, fiber loading, fiber permeability, fiber loading, temperature, and fiber loading in fibrous composites affect the water absorption [13]. The resin must have occupied the lumen spaces and reduced the water uptake of the fibres. Due to their hydrophilic chemical composition and porous structure, natural fiber reinforced composites are highly sensitive to humidity, causing natural fibres to swell, leading to interfacial de-bonding between natural fibres and polymer matrix, and deterioration of mechanical properties [14, 15]. A bagasse fiber's cell wall is initially saturated with water, and then void spaces are occupied by water. This facilitates water sorption into composites systems because pith comprises bigger lumens and has spongy characteristics. Meanwhile, in the composite system, using the pith fiber causes the water sorption to be reduced [3].

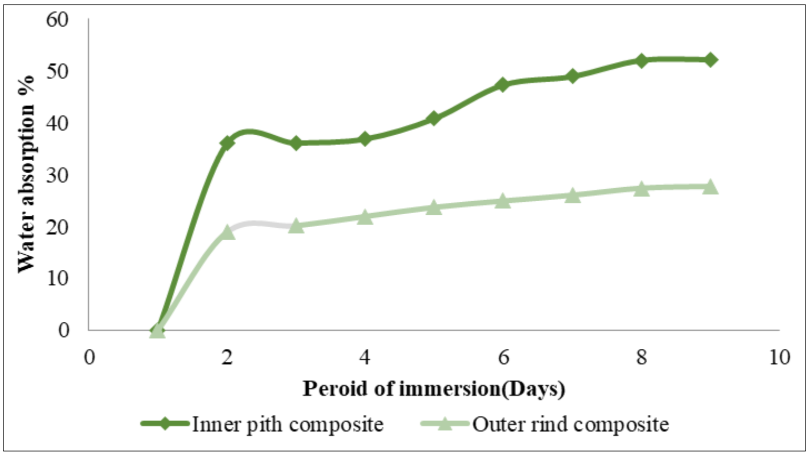

Fig 4: Water absorption behaviour of pith and rind composites

3.6 Modelling for water absorption behaviour

From the Fig.5, it was observed that the from the four mentioned models, Cubic model is a best fit which is similar with the water absorption pattern of the outer rind composites with R^2 value of 0.924.

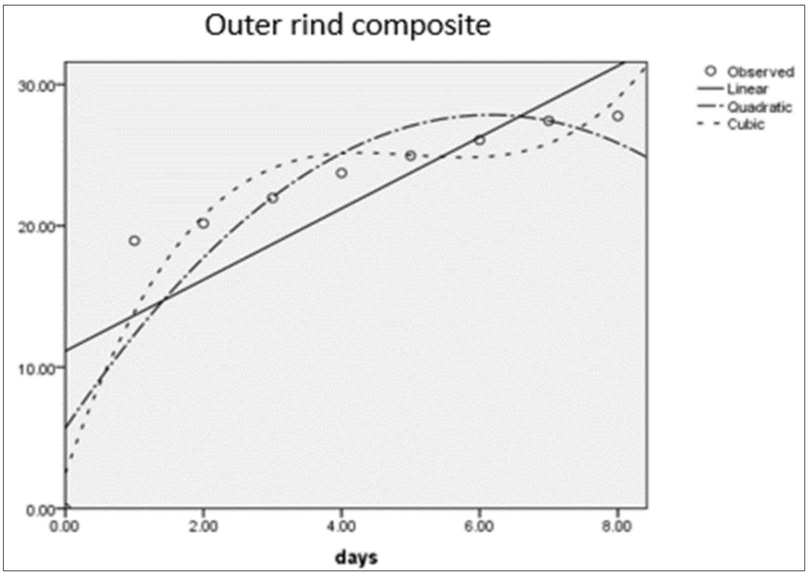

Fig 5: Different models of water absorption behaviour of Outer rind composites

In case of inner pith composites, different models has been adopted to check the water absorption behaviour of the inner pith composites. From the R^2 value (0.885), it was observed that the cubic model was a best fit for the inner pith composites.

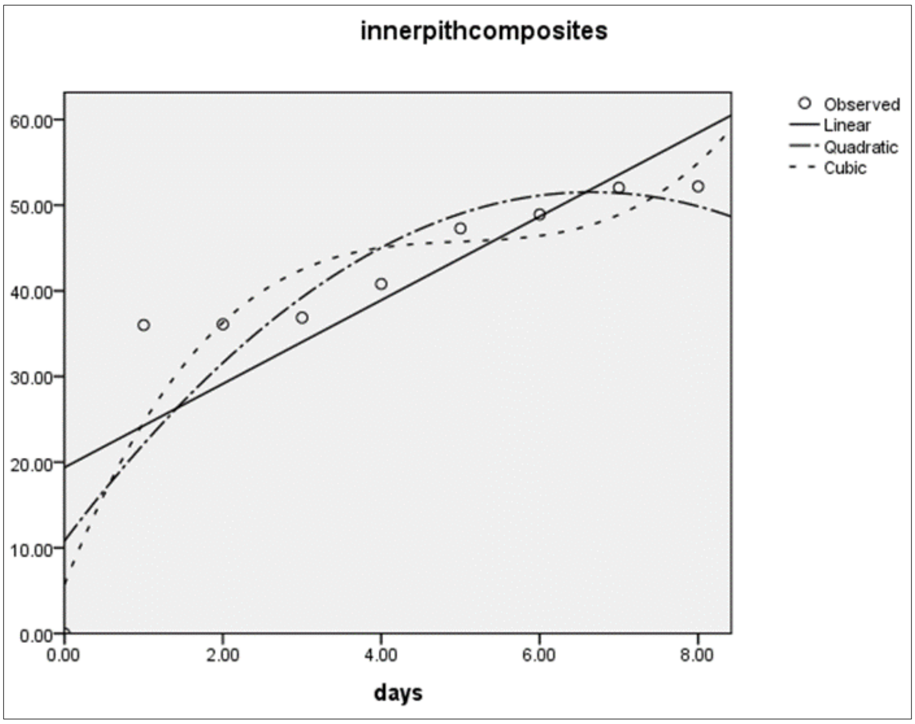

Fig 6: Different models of water absorption behaviour of Inner pith composites

4. Conclusion

The mechanical properties of composite systems are generally influenced by the microstructure of pith and rind components. When compared to inner pith fibres, the tensile characteristics and bending strength of rind fiber-reinforced composites improved. The best results were from rind fiber composites, which had higher tensile and yield stress as well as less water absorption. These fibres have been reported to be beneficial in the production of structures due to their characteristics and dimensional stability. These natural fibres can be used to strengthen composites and as a replacement for plastic crates due to their high absorption rate.

As a result of the characterization of this study, the outer rind and inner pith fibres from the sugarcane bagasse can be adopted as a lightweight material, acoustic material, and a piezoelectric medium.

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6. References

1. Luz SMd, Goncalves AR, Del'Arco Jr A. Mechanical behavior and microstructural analysis of sugarcane bagasse fibres reinforced polypropylene composites. Composites Part A: applied science and manufacturing 2007;38(6):1455-61.
2. Balaji A, Karthikeyan B, Swaminathan J. Comparative mechanical, thermal, and morphological study of untreated and NaOH-treated bagasse fiber-reinforced cardanol green composites. Advanced Composites and Hybrid Materials 2019;2(1):125-32.
3. Lee S, Mariatti M. The effect of bagasse fibres obtained (from rind and pith component) on the properties of unsaturated polyester composites. Materials Letters 2008;62(15):2253-6.
4. Hoareau W, Trindade WG, Siegmund B, Castellan A, Frollini E. Sugar cane bagasse and curaua lignins oxidized by chlorine dioxide and reacted with furfuryl alcohol: characterization and stability. Polymer Degradation and Stability 2004;86(3):567-76.
5. Shinoj S, Visvanathan R, Panigrahi S. Towards industrial utilization of oil palm fibre: Physical and dielectric characterization of linear low density polyethylene composites and comparison with other fibre sources. Biosystems engineering 2010;106(4):378-88.
6. Alshammari BA, Alotaibi MD, Alothman OY, Sanjay M, Kian LK, Almutairi Z *et al.* A new study on characterization and properties of natural fibres obtained from olive tree (*Olea europaea* L.) residues. Journal of Polymers and the Environment 2019;27(11):2334-40.
7. Rasul M, Rudolph V, Carsky M. Physical properties of bagasse. Fuel 1999;78(8):905-10.
8. Janbuala S, Eambua M, Satayavibul A, Nethan W. Effect of bagasse and bagasse ash levels on properties of pottery products. Heliyon 2018;4(9):e00814.
9. Manimaran P, Prithiviraj M, Saravanakumar S, Arthanarieswaran V, Senthamaraikannan P. Physicochemical, tensile, and thermal characterization of new natural cellulosic fibres from the stems of Sida cordifolia. Journal of Natural Fibres 2018;15(6):860-9.
10. Vilay V, Mariatti M, Taib RM, Todo M. Effect of fiber surface treatment and fiber loading on the properties of bagasse fiber–reinforced unsaturated polyester composites. Composites Science and Technology 2008;68(3-4):631-8.
11. Abdullah S, Zuhudi N, Anuar N, Isa M, editors. Mechanical and thermal characterization of alkali treated kenaf fibres. IOP Conference Series: Materials Science and Engineering: IOP Publishing 2018.
12. Sood M, Dwivedi G. Effect of fiber treatment on flexural properties of natural fiber reinforced composites: A review. Egyptian journal of petroleum 2018;27(4):775-83.

13. Sreekala M, Kumaran M, Thomas S. Water sorption in oil palm fiber reinforced phenol formaldehyde composites. Composites Part A: Applied science and manufacturing 2002;33(6):763-77.
14. Bodur MS, Englund K, Bakkal M. Water absorption behavior and kinetics of glass fiber/waste cotton fabric hybrid composites. Journal of Applied Polymer Science 2017;134(47):45506.
15. López CC, Lefebvre X, Brusselle-Dupend N, Klopffer M-H, Cangémi L, Castagnet S *et al*. Effect of porosity and hydrostatic pressure on water absorption in a semicrystalline fluoropolymer. Journal of materials science 2016;51(8):3750-61.