A Review of Process Parameters and Morphology of HTS YBCO by Electrospinning Technique

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Abstract— Various homogeneous aqueous solutions of high-temperature superconductor $YBa_2Cu_3O_{7-\delta}$ (HTS YBCO) have been prepared successfully during the last years. These HTS YBCO were synthesized using sol-gel accompanied with an electrospinning technique using plenty polymers and having varieties of concentration ratio. The polymeric solution and amorphous precursor were used to create an atomic level interaction between different salts to prepare HTS YBCO. This review focuses on the basic parameters utilizing in electrospinning process and their effects on the diameter morphologies of HTS YBCO nanostructures. The results showed that increasing applied voltage, polymer concentration ratio in the precursor solution, flow rate injection, viscosity, and the jet or needle diameter systematically enhanced the diameter of the nanostructure.

Keywords— Electrospinning; HTS YBCO; Morphology; Process parameter

1. INTRODUCTION

High-temperature superconductor $YBa_2Cu_3O_{7-\delta}$ (HTS YBCO) was first observed by Chu and his group in 1987 [1, 2]. The HTS YBCO prepared via solid-state reaction method with a transition temperature above 94 K. This breakthrough promises many applications because of the high transition temperature of superconductor at above 77 K (boiling temperature of liquid nitrogen) [2]. The solid state reaction method is a relatively longer process to prepare HTS YBCO from metallic oxide [3]. On the other hand sol-gel method appears to be the first candidate, which was used to mix the metallic oxide on an atomic level and form precursor homogeneous solution in a short time [2, 4]. Lastly, HTS YBCO has been well studied using sol-gel with electrospinning techniques [5]. The HTS YBCO among other ceramic 1:2:3 material superconductors have many properties that make it more popular, because of its outstanding properties, like high transition temperature, current density, magnetic field and chemical stability and easy to fabricate from metal oxides, acetate and nitrite [6, 7]. Moreover, it is components are non-toxic, non-volatile and less anisotropic, capable of having single phase and relatively low cost [8, 9].

The first studied of ceramic with nanostructure by electrospinning technique was published in 2002 [10]. After that more than 25 kinds of ceramic nanostructure have been prepared. This work offers a brief review on HTS YBCO nanostructured morphologies, which synthesized by using a combination of conventional sol-gel and electrospinning technique. The researchers presented the use of multi-polymeric concentration ratio, as well as different polymers and different procedures of heat treatments with electrospinning process to produce different morphologies of HTS YBCO superconductor [5, 9].

This paper was composed of five sections: the first part presented an introduction to a general overview. The experimental approach of the electric field that is typically used in electrospinning process was introduced, followed by the polymer concentrations and its vital role exploitable in electrospinning as assistant applied to create nanostructure. Besides, many researchers reported that to collect thin diameter of nanofibers, nanowires, and nanotube there were two ways, one by controlling their electrospinning parameters and the second by managing the composite concentration of the polymer and precursor solutions. The relationship between the precursor and polymer concentration was presented. The injection flow rate is one of the most affected conditions with viscosity was introduced. The final section has introduced the size of the jet and its relation with needle diameter.

This review also included the studies of HTS YBCO nanostructure for the period from the year 2006 to 2015. The researchers' used different procedures to fabricate the various morphologies of HTS YBCO with unique dimension and shapes via electrospinning technique. The reported studies showed details information about using many polymers like polyvinyl alcohol (PVA), poly (acrylic acid) (PAAC) and poly (vinyl pyrrolidone) (PVP) [5, 9, 11]. The academics studied the structure and the properties of the HTS YBCO prepared by using metallic acetate or nitrite as a starting material with a multi-concentration ratio of the polymer solution. This study highlights the best results of the researchers' work, which synthesizes and fabricates optimal size and continuous morphology for the nanostructure of HTS YBCO by using the electrospinning-sol-gel technique.

2. ELECTROSPINNING PROCESS

Electrospinning process has been studied successfully to fabricate different morphologies of HTS YBCO, which has attracted much attention by researchers and widely studied to produce nanowires as well as nanofibres [5, 9]. Figure 1 shows research had done with using electrospinning and sol-gel to prepare different structures. The electrospinning process consists of four setups, the high voltage power supplier, spinneret, syringe pump and collector. The electrospinning can be defined as an electric field applied between a tip nozzle and the collector. Normally the high voltage was used to generate a gaunt charged jet solution from the droplet at the tip of the needle; the drop began to stretch to form a monofilament. The monofilament leaves the drop when the electric field strength increase and the electrostatic repulsive force overcomes the surface tension [12, 13]. The polymers with sol-gel composite solutions were used as a solution aid to tune the viscosity, controlling of nanowires diameter, support formation of nanostructures and to verify collected nanowires at the initial time [5]. Commonly, HTS YBCO nanostructures are made by the electrospinning of sol-gel metallic acetate precursors in the presence of a specific ratio of polymer followed by calcination at higher temperatures to burn out the polymer and collect the pure structure of HTS YBCO [9]. Electrospinning technique is a simple, cheap, easy, and controlled parameters, which plays a vital role in the fabrication of nanowires and other nanostructured materials [10]. The first time electrospinning was patented in 1934, the invention had been forgotten and did not claim as an electrospinning technique and exploited as nanotechnology [11, 12, 14]. More than 80 years electrospinning appear the first candidate to use overall the nanostructure researches. The electrospinning technique opened up the amazing possibility to explore some additional intriguing physical properties at the nanoscale. The electrospinning process is relatively simple, inexpensive, easy, scalable, straightforward and versatile bottom-up approach, which achieves the nanostructure with different morphologies [10, 12].

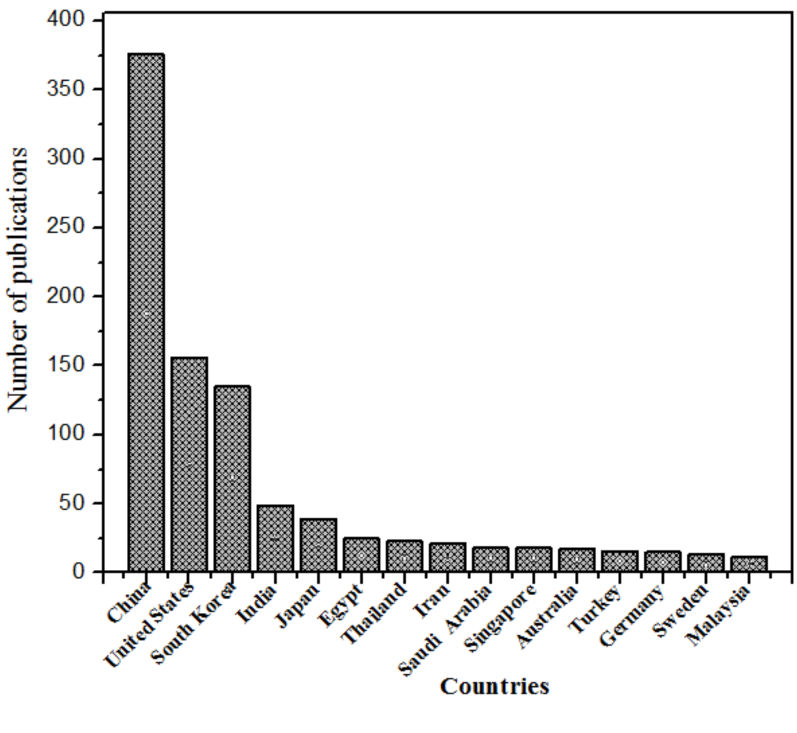

Figure 1: Number of publications by 15 countries. The data was taken from Scopus, December 2015, keywords "electrospinning and sol-gel".

3. NANOSTRUCTURE

The one dimension nanostructure is one of nanotechnology aspects, over the last decade having more attractive attentions due to the unique properties and the significance rapidly applications [11, 13]. A large number of reported research has been published in this area, so many methods have introduced the preparation and fabrication of HTS YBCO nanostructures. Structures like fibers, wires, tube, tape, particles, and flowers with one dimension nanostructure have been prepared [15]. Electrospinning technique allows for further manipulation on the atomic structure scale; it can change the atomic structure to an amazing construction with nano scale than that other technique. Morphology like fibers, wires, tape, tube, and flowers was achieved only with electrospinning technique [16].

Most of the studies in nanostructures by electrospinning up to now have been reported their fabrication and methodology with some of missing research information steps. Although, few studies have indicated the experimental details and analysis. Anyway, aside from the recent studies, the electrospinning process was that the procedure that has followed by some of the heat treatments, which was used essentially to remove out the polymer solvent and collected the desired single crystal nanostructures [16]. Those begun with sol-gel of the precursor solution contain polymers. The electrospinning technique from the point view of many authors considers the unique experimental that attract the attention to the Nano production [11, 16]. The simplest and controlled fabrication of nanostructured making the electrospinning process to be in the front of other technologies in the field of nanotechnology [10, 16].

4. THE STUDIES AND MORPHOLOGY OF HTS YBCO NANOSTRUCTURES

HTS YBCO nanostructure has been studies of the ten last year's by electrospinning the sol-gel solution of YBCO. The results show three kinds of morphologies like nanofibers (NFs), nanotubes (NTs) and nanowires (NWs). This paper presents the process parameters, and the procedures follow to fabricate HTS YBCO nanostructures and their results.

A. Nanofibres

In 2006, Cui *et al* [17] report the early work prepared and characterized the HTS YBCO nanofibers. The nanofibres were prepared from a metal acetate of Y, Ba, and Cu with stoichiometric ratio 1:2:3. Using a combination of sol-gel aqueous solution of PVA (Mw = 78000) with electrospinning, the viscosity of the solution was controlled by evaporating the solvent and made condensation for the reaction. The optimum viscosity used for electrospinning was from 300 to 500 cp. The results found that the diameter of nanofibers increased rapidly by increasing the applied voltage, viscosity, and the flow rate. The optimal ratio between the [metal acetate] and [PVA] is equal to 5, and the electrospinning parameters setup was tabulated in Table 1. The nanofibres diameter obtained was about 870 nm and decreases to 540 nm after the heat treatment, because of the decomposition of the polymer component from the fibers. Although nanofibers were obtained with long length and continue, the diameter is large about the other articles, because of the use of high voltage, flow rate, short distance and the large inner needle diameter of electrospinning solution. However, the nanofibres of HTS YBCO have been achieved, the single phase structure. It was successfully fabricated and characterized with high transition temperature 92 K. The phase structure, and morphology of HTS YBCO nanofibres was depend strongly on the heat treatment process Table 2, shows the electrospinning parameters that followed to fabricate the nanostructured shapes of HTS YBCO over the last ten years.

B. Pyrolyzing Nanofibres

Greenberg *et al.*, in 2008 [9] synthesized the HTS YBCO nanofibres using metallic nitrite salts of Y, Ba, and Cu under the stoichiometric composition of 1:2:3 with poly (acrylic acid) (PAAc) (M_w = 450,000) via electrospinning and sol-gel of the aqueous polymeric solution. The precursor solution was controlled by the mass ratio of 2:1 between 5% aqueous solutions of (PAAc) and 5% of (Y, Ba, and Cu)-Nitrite. The viscosity of the aqueous polymer solution was 52 cp and by adding metal nitrites, its ion concentration increased and therefore, the conductivity and partial charge of the aqueous solution increased and became denser. For more detailed information, see Table 1 and 2. The solution of electrospun and the result fibers was pyrolyzed using the tube furnace with complex heat treatments as illustrated in [9]. The nanofibres gained with small dimensions with a diameter between 50 and 100 nanometers and ten micrometers in length. The small aspects of the nanofibers due to the thermal decomposition of the PAAc during the heat treatment and the small quantities of (Y, Ba, Cu)-nitrite in the precursor electrospun solution. Greenberg *et al.* tried to investigate the fabrication of shapeable of HTS YBCO and study the structure of nanofibers produced by electrospinning of PAAc/metal nitrite precursor solution followed by the multi-heat treatment. The production of large scale, continuous nanofibers still challenges and need more attention. Electrospinning was the scalable technique composed from several approaches parameters that control the dimension of the nanostructure via manipulation of these factors [16]. These unique features make the electrospinning technique the versatile, controlled, scalable and industrial.

Table1: The procedures to synthesize YBCO superconductor with different morphologies.

Polymer	Polymer Ratio	Solvent	Precursor	Calcination Temperature	Structure	Viscosity (cp)	Diameter (nm)	Ref.
PVA	5%	Propionic acid, 2-hydroxy isobutyric acid	Y, Ba, and Cu acetate	450 ºC	YBa_2Cu_3O NFs	300-500	540	[17]
PAAc	10%	deionized water	Y, Ba , and Cu nitrate	450 ºC	YBa_2Cu_3O NFs	52	50-100	[9]
PVA	10%	Deionized water	Y, Ba , and Cu acetate	500 ºC	YBa_2Cu_3O NFs	….	300-800	[8]
PVA	10%	Deionized water	Y, Ba, and Cu acetate doped boron	600 ºC	YBa_2Cu_3O+Bo NFs	…..	200-500	[8]
PVP	18%	ethanol and acetic acid	Y, Ba , and Cu acetate	900 ºC	YBa_2Cu_3O NTs	…..	110-150	[11]
PVP	4%	Methanol, propionic acid, and acetic acid	Y, Ba, and Cu acetate	450 ºC	YBa_2Cu_3O NWs	75 50	120-550 50-80	[5]

Table 2: The electrospinning factors used to fabricate the HTS YBCO

Polymer	Applied voltage (KV)	Tip collector distance (cm)	Flow rate (ml/h)	Needle diameter (mm)	Structure	Diameter (nm)	Ref
PVA	24-28	10-18	1-3	0.83	YBa_2Cu_3O NFs	540	[9]
PAAc	~20	18	1-3	0.5	YBa_2Cu_3O NFs	50-100	[19]
PVA	15	15	1	0.8	YBa_2Cu_3O NFs	300-800	[8]
PVA	15	15	1	0.8	YBa_2Cu_3O+Bo NFs	200-500	[8]
PVP	19.2	12	3	0.5	YBa_2Cu_3O NTs	110-150	[18]
PVP	21	16	0.8	0.3	YBa_2Cu_3O NWs	120-550 50-80	[5]

C. Nanofibres HTS YBCO Contains Boron

Keyed *et al*. [18] showed that the transition temperature enhanced significantly when 5% of Boron was mixed with the high superconducting material. U. Ibrahim et al. [8] in 2010 synthesize and characterized the HTS YBCO nanofibers doped Boron from Y, Ba, and Cu acetate mixed according to the stoichiometric ratio 1:2:3. The aqueous solution was used with PVA (M_w = 720,000), weight ratio 10%, the solutions were prepared first set as a free boron and 1% of boric acid was added to the second solution to prepare the second set boron doped solution. Then the solutions electrospun and the result fibers subjected to heat treatment to burn out the polymer and collect the HTS YBCO free boron and boron doped fibers. The results showed the free boron fiber diameter between 300 and 800 nanometers, while the doped boron fiber diameter was around 200 and 500 nanometers. The results are consistent with the Cui *et al.* [17] and the fibers doped boron are usually more stable, conductive, lower size and high transition temperature. Table 1 and 2 showed the solutions and electrospinning parameters, U. Ibrahim et al. used a high flow rate as well as the significant size jet solution. These two components lead to increase the fiber diameter by compared this result with Greenberg *et al.* [9] and Edgar et al. [5] work, the fiber diameters goes down to 50 nanometers. Thus the lowest fiber diameter can be achieved by using relatively high applied voltage, less flow rate injection and small needle diameter, also, to using the high polymer molecular weight like PVP poly (vinyl pyrrolidone) (Mw = 1300000).

D. Nanotubes

In 2013, S. Zhenjiang *et al.* [11] successfully fabricated the HTS YBCO nanotube by a unique electrospinning and sol-gel techniques. The precursor solution was made from the polymer PVP (Mw = 1300000), 18% weight ratio and Y, Ba, and Cu acetate according to the stoichiometric ratio 1:2:3. The polymer PVP was used with a high concentration ratio, which leads to increase the viscosity of the precursor solution. Therefore, S. Zhenjiang *et al.* experiment was with a high viscosity sol-gel solution, high applied voltage, small inner diameter (i.e. small jet solution) and high flow rate. The result showed the new morphology of HTS YBCO called nanotubes with relatively small inner diameters and thin walls, see Table 1 and 2. The nanotubes of HTS YBCO was annealed in an oxygen atmosphere for the high temperature at 900 ºC and the nanotube obtained with a diameter from 110 to 150 nanometers with a wall thickness of from 30 to 40 nanometre. The HTS YBCO nanotubes show high critical temperature with the broader transition, unlike the standard block YBCO. The new structure of HTS YBCO nanotubes, nanofibres, and lastly nanowires must have individual features differ from thin films and block samples, promising a significant application [19, 20].

E. Nanowires

On June 2014 Edgar et al. [5] reported the new progress in preparing HTS YBCO nanowires. The nanowires were prepared via manipulation of the concentration ratio of the precursor solution and polymer using sol-gel and electrospinning technique. The precursor solution was contained of Y, Ba and Cu acetate mixed according to the chemical atomic ratio 1:2:3 and the polymer (PVP) poly (vinyl pyrrolidone) (Mw = 1300000). The HTS YBCO nanowires prepared through two concentration solutions, the first one mixed the metal acetate to a polymer with ratio 5:1, while the second mixed according to ratio 1:1. However, the polymer ratio was different in use relative to metal acetate, because it was used to control the viscosity. The viscosity of the solutions was adjusted by adding different quantities of solvent, then the viscosity of the first solution was 75 cp and 50 cp for the second solution. The results showed two kinds of nanowires, the randomly and alignment nanowires, the nanowires diameter with high viscosity 75 cp was from 300 to 600 nanometers, while the lower viscosity 50 cp between 150 and 350 nanometers see Table 1 and 2. This result was accepted by literature review, where high viscosity leads to thicker diameter [10, 21]. The second heat treatments result with single phase structure as well as high critical transition temperature near 92 K and the lowest diameter.

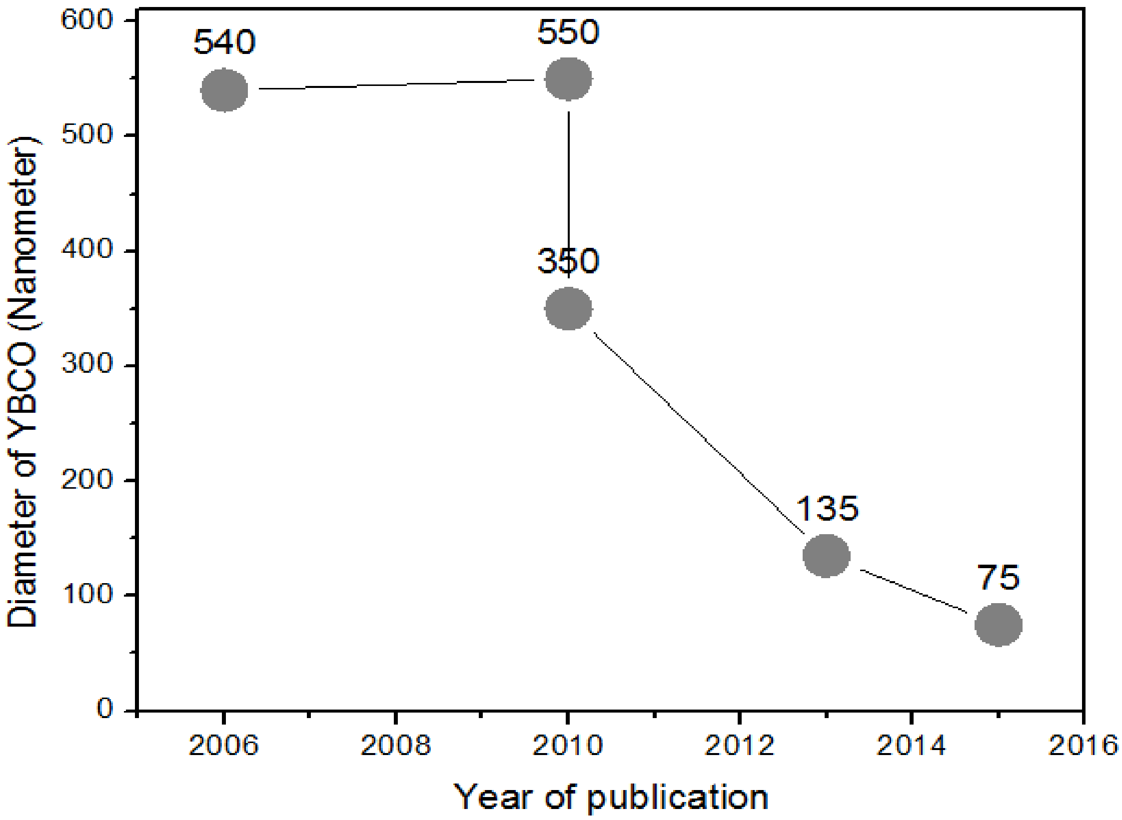

Figure 2: The nanostructure diameter of HTS YBCO vs. the years of publication, the data was taken from Scopus, December 2015, keywords “electrospinning and YBCO”.

4. THE EXPERIMENTAL APPROACH

In general, the nanostructure of HTS YBCO could be obtained via three controlled procedures of parameters. First of all the solution properties (conductivity, viscosity and surface tension) and the solution parameters seems to be the basic one, that is playing the important role in forming the nanostructure by sol-gel with electrospinning technique [10, 22]. The use of polymers as well as precursor solvent, which affected the morphologies of the produced nanostructures. The polymer concentration ratio, molecular weight of polymers, the solvent quality, and precursor concentration in comparison with polymer ratio are examples of the basic solution parameters [12]. Secondly, the electrospinning parameters like the applied voltage, tip collector distance, (motion and size) of the collector, needle gauge, and flow rate injection are the essential parameters. The ambient conditions like temperature, humidity and air velocity inside the chamber of the electrospinning unit are the third affected on the fabricated nanostructures. These parameters were used to control and manipulation of nanostructured morphologies [12, 22, 23].

Table 3: The variation of fiber diameter with many parameters

Parameters		**The influence**	**Fiber diameter description**
Solution parameters	Viscosity	High	Increase
		Low	Decrease
	Conductivity	High	Increase
		Low	Decrease
	Surface tension	High	Decrease
		Low	Increase
	Polymer concentration	High	Increase
		Low	Decrease
	Molecular weight	High	Decrease
		Low	Increase
E-Spinning parameters	Electric potential	High	Increase
		Low	Decrease
	Tip collector distance	High	Decrease
		Low	Increase
	Flow rate	High	Increase
		Low	Decrease
	Needle diameter (jet size)	Big	Increase
		Small	Decrease
	Motion and size collector	Fast	Decrease
		Slow	Increase
Ambient parameters	Humidity	High	Increase
		Low	Decrease
	Temperature	High	Increase
		Low	Decrease
	Air velocity	Fast	Increase
		Slow	Decrease

A. Electric field approach

The electric field plays a major role in the fabrication and designing the desired morphologies of HTS YBCO. The diameter of nanostructures versus the year of fabrication is presented in Figure 2 [5, 8, 9, 11, 17]. The strength of the electric field imposes the solution to be like a cone called Taylor cone and the molecules in solution begun to elongate and stretch under the repulsive forces between charges jets. The electric field acted on the tip of the solution and made it like capacitors, the solution charged to different polarities and became ready to separate from the top of cone [23-25]. When the repulsive forces overcome the surface tension and viscosity the jet goes directly to the collector. The strength of the electric field desired to generate the jets and form the nanostructure depends on how much the conductivity, viscosity and surface tension (i.e. solvent properties) of the solution [12, 22]. The high electric field and high viscose solution lead to an increase in the average diameter of nanostructures like nanofibers and nanowires [5, 9, 26]. Table 2, "Figure 2" shows the high applied voltage results in large fiber diameter that were fabricated by Cui *et al.* [17]. The nanostructure diameter depends strongly on the procedure of solution properties and electrospinning parameters [26-29]. Table 1 and 2 illustrate the variation in nanostructure diameter according to the applied voltage besides the solution properties [5, 8, 9, 11, 17].

B. Polymer concentration parameters

In 1993 Doshi et al. [30] published the first report about the fabrication of fibers from polymers by electrospinning. The polymer fibers have been produced with different shapes, cross sections, and morphologies. The electrospinning technique was used the polymer fibers on the industrial application of various polymers. The fiber diameter depends strongly on the polymer concentration, for example, it has been reported when the polyvinyl acetate (PVAc) concentration increased in the spinning solution (sol-gel), the diameter of the electrospun fibers increased due to increasing the viscosity [26, 30, 31]. The polymer concentration that was used in the spinning solution must be defined from the molecular weight and the ratio of polymers in the solution. Therefore, the polymer concentration is influenced by the solution parameters, such as the molecular weight, solvent quality, solution viscosity, solution conductivity, dielectric constant and surface tension [12, 25, 26, 31]. The polymer concentration ratio plays a significant role in the spinning solution properties. Thus it is controlling the viscosity of the solution, tune the diameter or the size of nanostructure shape [10, 12, 22, 31]. Table 1, shows the sum of HTS YBCO work to fabricate different nanostructure morphology via a combination of sol-gel and electrospinning techniques, it is clear that some of the workers increased the polymer concentration ratio. The high concentration ratio of polymers in the spinning solution increases the viscosity and results in thicker nanostructure [17]. On the contrary, the low concentration ratio of the polymers leads to decrease the viscosity and results in thinner nanostructure diameter [5], see Table 2.

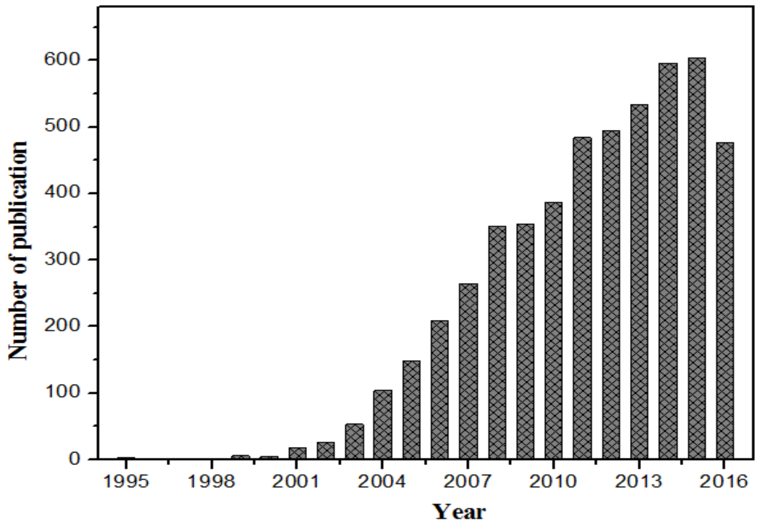

Figure 3: Number of polymer fibers publication fabricated by electrospinning vs. the year of publication, the data was taken from Scopus, December 2015, keywords “electrospinning and polymer fibers”.

C. Composite concentration approaches

The relation between precursor and polymer is complicated, and it is solved by doing more experiments. Yu Jin et al. [32] in 2009 study the effect of the weight ratio of poly (vinyl alcohol) (PVA) to the composite concentration, the applied voltage and the relative content of the polymer and composite. The result was fabricated nanostructures looking like the necklace structure. The structure was obtained by controlling the three quantities of polymer, composite, and the solvent. The composite concentration was affected by the amount of polymer and solvent, thus the three components mentioned before determined the electrospun nanostructure [25, 26, 32, 33]. Table 4 shows the polymer to the YBCO precursor ratio; it is evident from the first row, the high ratio of the precursor YBCO about the polymer PVA results in high viscosity and thick fiber diameter [17]. Greenberg *et al.* (2008) [9], mentioned in the detailed research experiment, the ratio of the polymer to the YBCO precursor solution is equal to 2:1, this means that the result is spinning precursor was made by adding one part of YBCO precursor to two parts of polymer PAAc. The result was low viscosity and thin diameter [9], see Table 4. A typical YBCO precursor concentration ratio relative to polymer was made by S. Zhenjiang et al. [8], the results shows the nanotube structure of HTS YBCO with the small cross section. Edgar et al. [5] prepare two spinning precursor solution by adding two different ratios of precursor to the same ratio of polymer, see Table-4. The solvent was adjusted to tune the low viscosity in the two solutions around 75 cp and 50 cp, the results showed different nanostructure diameters, Table 4. These results are expected to be consistent with the literature review [25, 29, 31, 32].

Table 4: The nanostructure diameter of the HTS YBCO and its concentration with polymer

Polymer	Polymer Ratio	Polymer: Precursor Ratio	Structure	Viscosity (cp)	Diameter (nm)	Ref.
PVA	5%	1:5	YBa_2Cu_3O NFs	300-500	540	[9]
PAAc	10%	2:1	YBa_2Cu_3O NFs	52	50-100	[19]
PVA	10%	....	YBa_2Cu_3O NFs	….	300-800	[8]
PVA	10%	….	YBa_2Cu_3O+Bo NFs	…..	200-500	[8]
PVP	18%	8:5	YBa_2Cu_3O NTs	…..	110-150	[18]
PVP	4%	1:1 1:5	YBa_2Cu_3O NWs	75 50	120-550 50-80	[5]

D. The injection flows rate

The morphology of HTS YBCO nanostructures is governed by the speed of flow rate injection and applied voltage. Khalil et al. [29] study the fabrication of copper nanowires via electrospinning, the precursor contains copper acetate and poly (vinyl) alcohol. The results found that the morphology of the copper nanowires was sensitive to the injection flow rate speed and the applied voltage. The experiment showed that the high flow rate must be associated high applied voltage. At lower flow rate with optimum applied voltage it produced nanowire with thinner diameter. In contrast, at a higher flow rate, the thicker jet leads with optimum voltage to produced nanowires with thicker diameters. Any disproportion between the flow rate injections and applied voltage leads to form the beads or broken the nanowires [22, 24, 29, 31]. Table 2, shows the electrospinning process parameter to fabricate different nanostructure of HTS YBCO. Cui *et al.* [17] fabricate HTS YBCO nanofibres with high flow rate and high applied voltage relative to the other workers; the results appear typically with a thicker nanofibers diameter relative to other researchers. The high flow rate injection could provide a thicker jet that will produce smooth and uniform nanostructures if the applied voltage increased to the ideal value, in this case, the ideal voltage will balance the forces of surface tension and viscosity. Moreover, if the applied voltage increased more than the typical value, the beads will be formed, and the non-uniform structure will be produced. Anyway the production of the nanostructure with uniform morphology is useful in potential application due to their unique properties [12, 16, 22, 25, 29].

E. Size jet approaches

The small size of the needle inner diameter leads to release a small amount of drop charged jet and thus any increased applied voltage caused to increase the stretch at the tip of Taylor cone. The electrospinning society has been focused on the liquid jets properties of that would be emitted from the Taylor cone when the diameter of jet controlled by small radius of the needle. The charged jet density will be increased on account a small area caused strongly stretched jet charge solution, consequently the results would be in a small nanostructure diameter [12, 25, 33]. Remarkable work reported by Edgar et al. [5] see Table 2; the author fabricates the HTS YBCO nanowires with two concentration ratio of precursor about the polymer PVP, Table 4. The needle inner diameter was 0.3 mm, the spinning solution viscosity was tuned by adding more solvent to obtain different viscosity 75 cp and 50 cp. The electrospinning results in various nanowire diametric depend on the viscosity of the spinning solution for more detailed refers to [5]. The research results explored that the fiber diameter could be controlled significantly by the spinning solution properties, especially the viscosity and electrospinning parameters such as the applied voltage and flow rate injection [31, 33].

5. CONCLUSION

This paper highlights the extensive efforts in preparing and fabrication of multi nanostructures shape from HTS YBCO by using electrospinning and sol-gel techniques. This review made a comparison between the results and procedures that were used via electrospinning and sol-gel to prepare the nanostructure HTS YBCO. The results showed the diameter of nanostructure depends strongly on the solution properties, typically the viscosity and the electrospinning parameters include the applied voltage and the flow rate injection. Besides these efforts, the research articles reported about preparing other nanostructures materials. The detailed research information about control the diameter of the nanostructures and their results was consistent with the HTS YBCO research results, the procedures and their effect parameters on the nanostructure diameter almost same trend. The concern around the electrospinning process parameters and the solution properties already has the key factor in any desired morphology. This study expected to benefit the reader quickly have a good background in the essential principles and experimental idea pre-experience.

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