Compatibility Studies of Polyacrylamide/Nanoclay/Copper oxide Nanocomposites on the Fluidic Physical Properties for Improvement of Inkjet Printability

Neetika Singh, Hari Madhav, Paramjit Singh, and Gautam Jaiswar
Department of Chemistry, Dr. B. R. Ambedkar University, Agra- 282 002, India
*Email: gaiswar@gmail.com

Abstract

Water-borne ink, an industrially important ink based on the polycrylates, in that polycrylamides imparts specific properties to the inks. Some properties of inks such as glossy or hardness is also adjust by varying the polymers, so in the present studies, nanocomposites of Polyacrylamide/Nanoclay/copper oxide nanoparticles were synthesized. The Nanoclay and Nanoparticles were varied to 0.5, 1 and 2% with respect to monomer of acrylamide and the effect on physical properties of ink such as, density, viscosity, surface tension, drying and smudging were observed to see the performance of it on polymer nanocomposites mixed in ink. The final product were characterized by UV-Vis and FTIR spectroscopy to see the presence of individual component of nanocomposites. It was found that the solution with polymer nanocomposites shows, improved in the physical properties with variation of 2% with respect to ink solution. Finally the biological activities were performed to see the effect of it on the ink solution.

Keywords: Copper oxide nanoparticles, Inkjet Ink, Nanoclay, Polyacrylamide, Survismeter.

1. Introduction

Ink occupy an integral and versatile position in our daily life. On the basis of different types and uses, researchers defined ink in various ways but in simplest description, ink is a liquid or semi-liquid material used for writing, printing, or drawing. In the chemist’s point of view, the ink is a colloidal system of fine pigments particles which are dispersed in a solvent [1]. There are mainly four elements of ink i.e. colorant, vehicle, solvent, and additives [2]. The first man made ink dates back to 4,500 years in Egypt, which consisted of a mixture of animal or vegetable charcoal (lampblack) and glue [3, 4].

On the basis of colorant, the ink is basically divided in two parts i.e. dye based ink and pigment based ink. Some of the printing inks are: Quick-Set Ink, Heat-Set Ink, Moisture-Set Ink, Radiation-Curing Ink, High-Gloss Ink, Metallic Ink, Magnetic Ink, Florescents Ink, and Scuff-Resistant Ink [5].

In solvent-borne inks, the main polymers are based on nitrocellulose but in water-borne ink the main polymers are based on polycrylates. Many of the homopolymers or copolymers of polycrylates were widely used in water-borne inks such as polyurethanes, polycrylamide and polyesters are useful in imparting specific properties of inks. Some properties of inks such as glossy or hardness is also adjust by polymers. The final properties of inks are depends on the reactivity of ink components with polymers. For e.g. the applicability and colour strength of ink is affected when polymer-surfactants interaction detract from fine properties such as dispersion stability [6-8].

Nanoclay is used to improve the ink properties such as avoiding pigment sedimentation, to provide good colour distribution, to obtained desired film thickness, reduction in misting, etc. [9]. The nanoparticles are Au, Ag, Cu, TiO₂, Fe₂O₃, etc. which were used to improve various properties of inkjet ink. Gold, silver and Magnetic nanoparticles can be easily screen printed on to various type of paper with the nanoparticles being so small that they seep into the paper’s pores [10, 11].

So, in the present research work, an attempt were made to synthesis polymer nanocomposites of PAM/Nanoclay/CuO nanoparticles and were treated with Inkjet printer ink cyan, magenta and yellow to see the effect on density, viscosity, surface tension, drying, smudging and antibacterial activity.

2 Experimental Details

2.1 MATERIALS USED

Acrylamide was purchased from Alfa Aesar, Germany. BPO, Ceric Ammonium Nitrate, HNO₃, HCl and Glacial acetic acid were obtained from Merck India. Acetone and NaOH were obtained from Fisher Scientific, India. Ethanol was purchased from Changshu Yangyuan Chemical, China. Double distilled water was purchased from Veb Research Laboratory, India. Cupric acetate was obtained from S. D. Fine-Chem. Ltd. India. Nanoclay (alkyl quaternary ammonium bentonite) was requested from Esan Ezczacıbaşi Endüstriel Ham Maddeler San. Ve Tic. A.Ş, İstanbul, Turkey. Inkjet ink was obtained from Pro-Dot, Datalink Industrial Corporation, India. Desmat Glossy Paper was obtained from, Rational Business Corporation Pvt. Ltd., India. All chemicals and materials are used as they received and stored in a cool place.

2.2 CHARACTERIZATION

2.2.1 Density

The density of ink was calculated at 20°C by density bottle using the following expression [12],

$$\rho = \frac{\text{wt. of the liquid}}{\text{wt. of equal volume of water}} \times \text{Density of water at } t^\circ C$$

2.2.2 Viscosity

The ink viscosity was measured by survismeter, which is patented instrument for viscosity, surface tension and interfacial tension measurements and invented by Prof. Man Singh [13], and calculated from the conventional formula-

$$\eta = \frac{\mu}{\gamma t} \times \eta_t$$

Where $\eta$ and $\eta_t$ are the viscosities, $t$ and $t_0$ are the flow times, and $\mu$ and $\rho$ are the densities of the measured and reference liquids at the given temperature, respectively.

2.2.3 Surface Tension

The ink surface tension were also measured by the same Survismeter and surface tension coefficient is calculated using the standard formula.

$$\gamma = \frac{\eta_t \rho}{\eta \rho_t} \times \gamma_t$$

Where, $\gamma$, $\gamma_t$ = surface tension of sample and reference, $\eta$, $\eta_t$ = number of drops of sample and reference, $\rho$, $\rho_t$ = density of sample and reference [13].

2.2.4 Drying
The test was performed on Desmat Glossy Paper at temperature 25° C. In this test, the pattern of prepared ink samples were marked on glossy paper with the help of drawing brush and the drying time was noted with the help of stopwatch.

2.2.5 Smudging

The test was performed on Desmat Glossy Paper at temperature 25° C. In this test, the pattern of prepared ink samples were marked on glossy paper with the help of drawing brush and smudged the ink with the help of hand thumb after interval of 3 sec.

2.2.6 UV-Vis Spectroscopy

UV-Vis absorption spectra of polymer nanocomposite mixed ink samples were obtained using a LABINDIA 3000+ Double beam spectrophotometer. The scan range was from 300.00 to 1100.00 nm.

2.2.7 FTIR Spectroscopy

The FTIR spectra of ink samples were obtained by the instrument Bruker Alfa FT-IR/FT-IR (ATR Mode) with ZnSe crystal.

2.2.8 Antimicrobial Test

The antimicrobial activity of the polymer nanocomposites modified ink was tested against E. coli bacteria using by disc diffusion method. Nutrient agar plates were prepared, sterilized and solidified. After solidification, bacterial cultures were swabbed on the Petridish. The pure CuO nanoparticles, pure magenta, cyan, yellow ink and the sample code PNCM6, PNCC9 and PNCY9 were placed in the E. coli bacterial cultured nutrient agar plate and kept for incubation at 37 °C for 24 hrs. to see the effect of polymer nanocomposites modified ink against bacteria.

2.3 SYNTHESIS

2.3.1 Synthesis of CuO Nanoparticles

Nanoparticles of CuO were prepared by previously reported Sol-Gel method [14]. 0.2 M cupric acetate solution was taken in a cleaned round bottom flask. 1 ml of glacial acetic acid was added to above aqueous solution and heated at 100°C with constant stirring on magnetic stirrer. Solution of 8 M NaOH was added drop wise to above solution and heated till pH 7 is obtained and the colour of solution immediately changed from blue to black. The large amount of black precipitate of CuO nanoparticles were formed immediately which was collected. The precipitate was centrifuged and washed 3-4 times with deionized water and dried in air for 24 h.

2.3.2 Preparation of PAM/Nanoclay/CuO Nanocomposites

The solution of nanoclay was added drop wise in aqueous solution of acrylamide. Both initiator BPO and appropriate solution of ceric ammonium nitrate in 1N nitric acid (HNO3) were added and heated at 70°C with continuous stirring to complete polymerization. After 30 min, the sonicated CuO nanoparticles were added spherically and slowly mixed in this polymerized solution. The prepared polymer nanocomposite was vigorously stirred for 4-5 hours to from viscous solution. The solution was taken in petridish and precipitated in access of acetone in acidic medium. This synthetic process was repeated for the variation studies of nanoclay and nanoparticles, which was provide in table 1.

2.3.3 Preparation of Ink samples with Polymer Nanocomposites

The different sets of ink were prepared by mixing of polymer nanocomposites in three different main colour CMY ink. The ink samples were prepared by varying the different concentration of polymer nanocomposites in ink. Each polymer nanocomposites mixed with ink in variation of 0.5%, 1% and 2% in 30 ml of ink respectively. The detailed mixing for the formation of final polymer nanocomposites in inks is shown in table 2.

Table 1 Mixing Concentration of AAm/CuO/Nanoclay

| Sample Code | Acrylamide (AAm) (gm.) | Nanoclay (gm.) | CuO (gm.) |
|-------------|-----------------------|----------------|-----------|
| PNC         | 2                     | 0.0            | 0.0       |
| PNC51       | 2                     | 0.1            | 0.02      |
| PNC52       | 2                     | 0.1            | 0.04      |
| PNC54       | 2                     | 0.1            | 0.08      |
| PNC101      | 2                     | 0.2            | 0.02      |
| PNC102      | 2                     | 0.2            | 0.04      |
| PNC104      | 2                     | 0.2            | 0.08      |
| PNC201      | 2                     | 0.4            | 0.02      |
| PNC202      | 2                     | 0.4            | 0.04      |
| PNC204      | 2                     | 0.4            | 0.08      |

The properties of prepared ink samples were studied on the basis of following physical parameters such as; Density, viscosity, surface tension, drying, smudging.

3 Results and Discussions

3.1 Effect of Polymer Nanocomposites on Density of Ink

Density has traditionally been used as the primary means to control the printing process. It has been widely held that it correlates well with the amount of colorant that is put on the paper over a limited range of ink film thicknesses [15]. After adding synthesized polymer nanocomposites in inks, the minor difference was observed in density of mixed polymer nanocomposites inks and pure inks, and it was observed that, the density was increased as comparison to the pure ink. The data of density was given in the table 3. After adding polymer nanocomposites in ink, the different graphs of density data were observed with different variations.

Graphical representation of magenta ink in figure 1 shows that, the density of pure

©JFIPS, India

http://www.jfips.com/
magenta ink was 1.053. After adding the polymer nanocomposites PNC52 and PNC54 in the variation of 0.5%, 1% and 2% with respect to the ink, it was observed that the density increases for each variation as compare to that of pure ink. It was observed that in all the samples, the density got increases at every steps.

**Table 3 Experimental Density Data of Ink Samples**

| Colour of Ink | Density of Pure Ink (gm./cm³) | Sample Code | % of Polymer Nanocomposites in Ink | Density of Ink mixed with PNCs (gm./cm³) |
|---------------|-------------------------------|-------------|-----------------------------------|-----------------------------------------|
| Magenta       | 1.053                         | PNC52       | 0.5                               | 1.055                                   |
|               |                               |             | 1                                 | 1.059                                   |
|               |                               |             | 2                                 | 1.066                                   |
|               | PNC54                         | 0.5         | 1                                 | 1.064                                   |
|               |                               |             | 1                                 | 1.068                                   |
|               |                               |             | 2                                 | 1.083                                   |
| Cyan          | 1.037                         | PNC101      | 0.5                               | 1.040                                   |
|               |                               |             | 1                                 | 1.043                                   |
|               |                               |             | 2                                 | 1.046                                   |
|               | PNC102                        | 0.5         | 1                                 | 1.076                                   |
|               |                               |             | 1                                 | 1.083                                   |
|               |                               |             | 2                                 | 1.095                                   |
|               | PNC104                        | 0.5         | 1                                 | 1.040                                   |
|               |                               |             | 1                                 | 1.044                                   |
|               |                               |             | 2                                 | 1.050                                   |
| Yellow        | 1.044                         | PNC201      | 0.5                               | 1.047                                   |
|               |                               |             | 1                                 | 1.052                                   |
|               |                               |             | 2                                 | 1.056                                   |
|               | PNC202                        | 0.5         | 1                                 | 1.050                                   |
|               |                               |             | 1                                 | 1.058                                   |
|               |                               |             | 2                                 | 1.063                                   |
|               | PNC204                        | 0.5         | 1                                 | 1.015                                   |
|               |                               |             | 1                                 | 1.057                                   |
|               |                               |             | 2                                 | 1.062                                   |

**Fig. 1 Density Curves of Magenta Ink Samples**

Graphical representation of cyan ink in figure 2 shows that, the density of pure yellow ink was 1.044. After adding the polymer nanocomposites PNC101 and PNC202 in the variation of 0.5%, 1% and 2% with respect to the ink, it was observed that the density got increases at every steps but after adding polymer nanocomposite PNC204 in the variation of 0.5%, 1% and 2%, the density decreased in first step and increased in last two steps.

**Fig. 2 Density Curves of Cyan Ink Samples**

Graphical representation of yellow ink in figure 3 shows that, the density of pure yellow ink was 1.044. After adding the polymer nanocomposites PNC201 and PNC202 in the variation of 0.5%, 1% and 2% with respect to the ink, it was observed that the density got increases at every steps but after adding polymer nanocomposite PNC204 in the variation of 0.5%, 1% and 2%, the density decreased in first step and increased in last two steps.

**Fig. 3 Density Curves of Yellow Ink Samples**

### 3.2 Effect of Polymer Nanocomposites on Viscosity of Ink

The viscosity of ink strongly affects, how it behave on the press and is ultimately transferred to the sheet. The properties of the ink’s viscosity can have several effects on ink absorption, colour strength and drying [16]. The experimental viscosity data of ink samples was calculated by using above standard formula and reported in the table 4.

**Table 4 Experimental Viscosity Data of Ink Samples**

| Colour of Ink | Viscosity of Pure Ink (mPa) | Sample Code | % of Polymer Nanocomposites in Ink | Viscosity of PNCs in Ink (mPa) |
|---------------|-----------------------------|-------------|-----------------------------------|-------------------------------|
| Magenta       | 2.450                       | PNC52       | 0.5                               | 2.353                         |
|               |                              |             | 1                                 | 2.452                         |
|               |                              |             | 2                                 | 2.675                         |
|               |                              |             | 0.5                               | 2.796                         |
|               |                              |             | 1                                 | 3.589                         |
|               |                              |             | 2                                 | 4.923                         |
| Cyan          | 2.157                       | PNC101      | 0.5                               | 2.174                         |
|               |                              |             | 1                                 | 2.483                         |
|               |                              |             | 2                                 | 2.976                         |
|               |                              |             | 0.5                               | 2.897                         |

©JFIPS, India http://www.jfips.com/
After adding polymer nanocomposites in ink, the following graphs of viscosity data were observed with different variations. Graphical representation of magenta ink in figure 4 shows that, the viscosity of pure magenta ink was 2.450. After adding polymer nanocomposite PNC52 in the variation of 0.5%, 1% and 2% with respect to the ink, it was observed that the viscosity got decreases in first step and got increases in remaining two steps but After adding the polymer nanocomposite PNC54 in the variation of 0.5%, 1% and 2%, it was observed that the viscosity got increases at every steps.

Graphical representation of cyan ink in figure 5 shows that, the viscosity of pure cyan ink was 30.295. After adding the polymer nanocomposites PNC101 and PNC102 in the variation of 0.5%, 1% and 2% with respect to the ink, it was observed that the viscosity got increases at every steps but after adding the polymer nanocomposites PNC104 in the variation of 0.5%, 1% and 2%, it was observed that the viscosity decreases in variation of first step but got increases in the last two steps as compare to that of pure ink.

Graphical representation of yellow ink in figure 6 shows that, the viscosity of pure yellow ink was 1.169. After adding the polymer nanocomposites PNC201 and PNC202 in the variation of 0.5%, 1% and 2% with respect to the ink, it was observed that the viscosity got increases in every step but After adding the polymer nanocomposites PNC204 in the variation of 0.5%, 1% and 2%, it was observed that the viscosity decreases with variation in first step but got increases in the last two steps as compare to that of pure ink.

### Table 5: Experimental Surface Tension Data of Ink Samples

| Colour of Ink | Surface Tension of Pure Ink (dyne/cm) | Sample Code | % of Polymer Nanocomposite in Ink | Surface Tension of Ink Mixed with PNCs (dyne/cm) |
|---------------|---------------------------------------|-------------|----------------------------------|-----------------------------------------------|
| Magenta       | 32.574                                | PNC52       | 0.5                              | 32.264                                        |
|               |                                       | 1           |                                  | 32.703                                        |
|               |                                       | 2           |                                  | 32.474                                        |
|               |                                       | PNC54       | 0.5                              | 32.419                                        |
|               |                                       | 1           |                                  | 30.603                                        |
|               |                                       | 2           |                                  | 27.348                                        |
| Cyan          | 30.295                                | PNC101      | 0.5                              | 29.176                                        |
|               |                                       | 1           |                                  | 28.982                                        |
|               |                                       | 2           |                                  | 28.643                                        |
|               |                                       | PNC102      | 0.5                              | 29.267                                        |
Surface tension is an important physical property of inks, which was determining ink meniscus recovery and drop formation from the print head nozzle. For example, a low surface tension can result in excessive nozzle faceplate wetting leading to poor ink ejection, thereby affecting jet reliability. On the other hand, a high surface tension can lead to insufficient faceplate wetting, which may compromise droplet formation and ejection [18]. The experimental surface tension data of ink samples was calculated by using above standard formula and given in the table.

After adding polymer nanocomposites in ink, the following graphs of surface tension data were observed with different variations. Graphical representation of magenta ink in figure 7 shows that, the surface tension of pure magenta ink was 32.574. After adding the polymer nanocomposites PNC52 in the variation of 0.5%, 1% and 2% with respect to ink, it was observed that the surface tension increased in case of 0.5% variation and decreased in the remaining two steps.

Graphical representation of cyan ink in figure 8 shows that, the surface tension of pure cyan ink was 30.295. After adding the polymer nanocomposites PNC101 and PNC102 in the variation of 0.5%, 1% and 2% with respect to ink, it was observed that the surface tension decreased at every step, but after adding polymer nanocomposites PNC104 in the variation of 0.5%, 1% and 2%, the surface tension increased in case of 0.5% variation and decreased in the remaining two steps.

Graphical representation of yellow ink in figure 9 shows that, the surface tension of pure yellow ink was 37.859. After adding the polymer nanocomposites PNC201 and PNC202 in the variation of 0.5%, 1% and 2% with respect to ink, it was observed that the surface tension decreased at every step, but after adding polymer nanocomposites PNC204 in the variation of 0.5%, 1% and 2%, it was observed that the surface tension got decreases in case of 0.5% variation but increased in remaining two steps but in all steps, the surface tension remains lower as compared to the pure yellow ink. But at last after adding polymer nanocomposite PNC204 in the variation of 0.5%, 1% and 2%, it was observed that the surface tension increased in case of 0.5% variation which was higher as compared to the pure ink, than decreased in 1% and 2% variations.

### Table 5: Surface Tension of Ink Samples

| Ink Color | Surface Tension (°) |
|-----------|---------------------|
| Magenta   | 32.574              |
| Cyan      | 30.295              |
| Yellow    | 37.859              |

### Graphical Representation

**Fig. 7** Surface tension Curve of Magenta Ink Samples

**Fig. 8** Surface tension Curves of Cyan Ink Samples

**Fig. 9** Surface tension Curve of Yellow Ink Samples

### 3.4 Effect of Polymer Nanocomposites on Drying Properties of Ink

Fig. 10 Presentation of Drying Test
Drying is one of the most important parameters of printing ink. In our study, the drying test was performed on the Desmat glossy paper which was shown in figure 10. In drying patterns, it was observed that, the pure magenta ink was dried on the paper in 3 min 6 sec, cyan ink was dried on the paper in 2 min 4 sec, and the pure yellow ink dried on the paper in 2 min 6 sec. The drying test shows that the maximum drying time was 10 min 1 sec for sample code PNC102 with variation of 2% and the minimum drying time was 1 min 5 sec for sample code PNC102 with variation of 1%. Drying time for each ink sample was given in table 6.

Table 6 Experimental Drying Time for Ink Samples

| Code of Sample | Observation time | Code of Sample | Observation time |
|---------------|-----------------|---------------|-----------------|
| PNC52 (0.5%)  | 2 min 3 sec     | PNC104 (2%)   | 3 min 8 sec     |
| PNC52 (1%)    | 2 min 4 sec     | PNC201 (0.5%) | 3 min 8 sec     |
| PNC52 (2%)    | 2 min 7 sec     | PNC201 (1%)   | 3 min          |
| PNC54 (0.5%)  | 6 min 5 sec     | PNC201 (2%)   | 3 min 6 sec     |
| PNC54 (1%)    | 5 min 4 sec     | PNC202 (0.5%) | 3 min 3 sec     |
| PNC54 (2%)    | 4 min 4 sec     | PNC202 (1%)   | 2 min 9 sec     |
| PNC101 (0.5%) | 3 min 3 sec     | PNC202 (2%)   | 1 min 9 sec     |
| PNC101 (1%)   | 2 min 7 sec     | PNC204 (0.5%) | 2 min 4 sec     |
| PNC101 (2%)   | 2 min 7 sec     | PNC204 (1%)   | 1 min 6 sec     |
| PNC102 (0.5%) | 1 min 9 sec     | PNC204 (2%)   | 3 min 7 sec     |
| PNC102 (1%)   | 1 min 5 sec     | Magenta       | 3 min 6 sec     |
| PNC102 (2%)   | 10 min 1 sec    | Cyan          | 2 min 4 sec     |
| PNC104 (0.5%) | 2 min 4 sec     | Yellow        | 2 min 6 sec     |
| PNC104 (1%)   | 3 min          |               |                 |

3.5 Effect of Polymer Nanocomposites on Smudging Properties of Ink

Smudging is also one of the most important factors of printing ink. The stability of ink on paper after printing depends upon how much ink is stable against smudging. In our present studies, the smudging test was performed on the Desmat glossy paper which was shown in figure 11. From the smudging patterns, it was observed that, the pure magenta ink was smudged on the paper but pure cyan ink do not smudge on the paper similarly, the pure yellow ink smudged on the paper.

It was observed in all the samples, the smudging was maximum in 1% variation of PNC54 sample. The highest smudging may be attributed due to presence of polymer nanocomposite PNC54 in 2% variation which was found least in the least smudging samples. Smudging time for each ink sample was given in table 7.

Table 7 Experimental Smudging Time for Each Ink Sample

| Code of Sample | Observation | Code of Sample | Observation |
|---------------|-------------|---------------|-------------|
| PNC52 (0.5%)  | LS          | PNC104 (2%)   | S           |
| PNC52 (1%)    | S           | PNC201 (0.5%) | LS          |
| PNC52 (2%)    | LS          | PNC201 (1%)   | LS          |
| PNC54 (0.5%)  | LS          | PNC201 (2%)   | LS          |
| PNC54 (1%)    | MS          | PNC202 (0.5%) | NS          |
| PNC54 (2%)    | S           | PNC202 (1%)   | NS          |
| PNC101 (0.5%) | LS          | PNC202 (0.5%) | LS          |
| PNC101 (1%)   | NS          | PNC202 (1%)   | NS          |
| PNC101 (2%)   | NS          | PNC204 (0.5%) | LS          |
| PNC102 (0.5%) | NS          | PNC204 (1%)   | LS          |
| PNC102 (1%)   | NS          | PNC204 (2%)   | S           |
| PNC102 (2%)   | NS          | Magenta       | S           |
| PNC104 (0.5%) | S           | Cyan          | LS          |
| PNC104 (1%)   | LS          | Yellow        | LS          |

S = Smudged, LS = Less Smudged, MS = More Smudged, NS = No Smudged

3.6 UV-Vis Spectroscopy of Ink

Data of UV-visible spectroscopy of various ink samples is shown in table 8.

Table 8 UV-Visible Data of Various Ink Samples

| Sr. No. | Sample Code | Wavelength (nm) | Absorbance |
|---------|-------------|-----------------|------------|
| 1       | PNC201 (0.5%) | 429             | 0.064      |
| 2       | PNC201 (1%)  | 427,425         | 0.059      |
| 3       | PNC201 (2%)  | 430             | 0.065      |
| 4       | PNC202 (0.5%) | 408             | 0.118      |

Fig. 11 Presentation of Smudging Test
It was observed from table 8 and UV spectrums (figure 12) that, the highest absorption is seen in 0.5% variation of PNC104 in figure 13 and lowest in 1% variation of PNC201 in figure 14, which may be due to the contribution of polyacrylamide/nanoclay/CuO nanocomposite. The shift towards higher wavelength was seen in different variations of PNC101, PNC104 was due to the cyan ink, which absorb at higher wavelength. The spectra also shows that the UV-visible absorbance is due to the contributory effects of all the components not by the individual components.

### 3.7 FTIR Spectroscopy

In most of our samples studied, the following FTIR data is seen, which is shown in the table 9.

| Wavenumber (cm⁻¹) | Molecular motion         |
|-------------------|--------------------------|
| 3277              | N-H sym. str             |
| 2913              | C-H asym. str            |
| 2854              | C-H str.                 |
| 1743              | Carbonyl group           |
| 1547              | N-H bending              |
nanoparticles were synthesized from cupric acetate by using sol-gel method. The synthesized polymer nanocomposites were applied to enhance the properties of inkjet ink. Polymer nanocomposites were mixed in inkjet ink in different variations i.e. 0.5%, 1% and 2% with respect to ink and fluid physical properties of ink such as density, viscosity, surface tension, drying, smudging etc. were studied. In present study, after adding the polymer nanocomposites in ink it was observed in most of the samples that, the density of ink was slightly increased. Viscosity is also important parameter of ink. High viscosity of ink increases dot sharpness and sometimes causes the ink to dry inside the cell, resulting in cell clogging. Low viscous ink took more time in drying and flow on substrate while viscous ink got dried in less time, did not flow on substrate and gives better print quality. We observed in most of the samples that, viscosity of ink increased which might improve the print quality and also improve the flow properties of ink in printing. After adding the polymer nanocomposites in ink samples, it was observed in most of the samples that, the surface tension of ink was slightly decreased. Due this slightly decreased surface tension, the printing of ink may be smoother and the clotting of nozzles of print cartridge may be reduce. The low surface tension will also improve the flow properties of ink on substrate. During using of ink material, ink drying and smudging are also considered to be a very important function. After the ink has been applied to the surface to be printed, it must bind there to ensure it stays. After mixing the polymer nanocomposites in ink, it have seen that these properties were improved. The UV-Vis spectra result shows that polymer nanocomposites mixed with ink samples absorbed mostly in the visible region. The FTIR results of polymer nanocomposites mixed ink samples shows that, the polyaerylamide polymer nanocomposites were present in all ink samples. The results of in-vitro anti-bacterial screening of ink samples and CuO nanoparticles against bacteria E. coli exhibited that, the bacterial culture has least effect on the ink samples and CuO nanoparticles.

Acknowledgement

The authors acknowledge Department of Chemistry, Dr. B. R. Ambedkar University, Agra, India for providing facilities to conduct this research work. We are highly thankful to Prof. Man Singh, Department of Chemistry, Central University of Gujarat for providing us Survismeter to our Department. We also wish to acknowledge DST-FIST, India for providing FTIR and UV-Visible Spectroscopy to the Department through which we performed our analysis.

References

[1] Ink chemistry, The Royal Society of Chemistry, London. http://www.rsc.org/chemistryworld/Issues/2003/March/inkchemistry.asp (accessed June 08, 2016).
[2] Kobrilinsky, L. Forensic Chemistry Handbook; Johns Wiley & sons: New Jersey, 2011.
[3] Risio, S. D.; Yan, N. Macromol. Rapid. Comm. 2007, 28, 1934-1940.
[4] Michel, B.; Bernard, A.; Bitesh, A.; Dalamache, E.; Geissla, M.; Junchery, D.; Renaut, J. P.; Rothizer, H.; Schmid, H.; Schmidt, P.; Stutz, R. Journal of Research & Development. 2001, 45, 697-719
[5] Kipphahn, H. Handbook of print media: Technologies and Production Methods; Springer- Verlag Berlin Heidelberg: New York, 2001.
[6] Izdebska, J.; Thomas, S. Printing on Polymers: Fundamental and Applications; William Andrew: U.S.A., 2016.
[7] Acton, Q. A. Issues in Materials and Manufacturing Research, 2013 ed.; ScholarlyEditions: Atlanta, 2013.
[8] Gans, B. J.; Duineveld, P. C.; Schubert, U. S. Adv. Mater. 2004, 16, 203-213.
[9] Patel, H. A.; Somani, R. S.; Bajaj, H. C.; Jasra, R. V. Bull. Matr. Sci. 2006, 29, 135-145.
[10] Kamyszyny, A.; Magdassi, S. Small. 2014, 10, 3515-3535.
[11] Lesyk, R.; Petrovska, H.; Krauchek, O.; Babitski, Y.; Kotlyarchuk, B. Nanomaterials for Ink-Jet Printed Electronic. In Proceeding of the Second FP7 Conference and Third International Summer School Nanotechnology: From Fundamental Research to Innovations, 2015, doi:10.1007/978-3-319-18543-9_31.
[12] Yadav, J. B. Advanced Practical Physical Chemistry, 13th ed.; Krishna-Prakashan (P): Meerut, 2011.

3.8 Antimicrobial Activity of Ink Polymer Nanocomposites

It was observed from FTIR data of prepared ink samples that, the absorption bands at 3277 and 1547 cm\(^{-1}\) were due to symmetrical stretching of NH\(_2\). Absorption bands at 2913 and 1461 cm\(^{-1}\) were observed due to symmetric stretching of CH\(_2\). Absorption bands at 2854, 1424 and 1326 cm\(^{-1}\) were observed due to stretching of CH. The presence of absorption band at 1743 cm\(^{-1}\) confirmed the C=O group in ink samples. Absorption bands at 1156 and 1102 cm\(^{-1}\) were observed due to C=C bending. The presence of these absorption bands in ink samples confirm the presence of polyaerylamide nanocomposites. The observed FTIR data of polyaerylamide was closely related to the observed data of Freddi [19].

![Fig. 15 FTIR Spectra of 1% PNC201](image)

3.8 Antimicrobial Activity of Ink Polymer Nanocomposites

3.8 Antimicrobial Activity of Ink Polymer Nanocomposites

Fig. 15 FTIR Spectra of 1% PNC201

Fig. 16 Presentation of Antimicrobial Test, (a) On First Day, (b) After 48 Hrs

Printing paper are prone to microbial attacks, so to see the effect of antibacterial, the in-vitro anti-bacterial screening of samples of Ink were tested against bacteria E. coli. The result exhibit that the bacterial culture has least effect on the ink samples and CuO nanoparticles which was confirmed from figure 16.

4 Conclusion

In the present research work, nanocomposites of polyaerylamide, nanoclay and CuO nanoparticles have been prepared by solution mixing technique in different loadings of nanoclay and CuO nanoparticles. For the nanocomposites, CuO nanoparticles were synthesized from cupric acetate by using sol-gel method. The synthesized polymer nanocomposites were applied to enhance the properties of inkjet ink. Polymer nanocomposites were mixed in inkjet ink in different variations i.e. 0.5%, 1% and 2% with respect to ink and fluid physical properties of ink such as density, viscosity, surface tension, drying, smudging etc. were studied. In present study, after adding the polymer nanocomposites in ink it was observed in most of the samples that, the density of ink was slightly increased. Viscosity is also important parameter of ink. High viscosity of ink increases dot sharpness and sometimes causes the ink to dry inside the cell, resulting in cell clogging. Low viscous ink took more time in drying and flow on substrate while viscous ink got dried in less time, did not flow on substrate and gives better print quality. We observed in most of the samples that, viscosity of ink increased which might improve the print quality and also improve the flow properties of ink in printing. After adding the polymer nanocomposites in ink samples, it was observed in most of the samples that, the surface tension of ink was slightly decreased. Due this slightly decreased surface tension, the printing of ink may be smoother and the clotting of nozzles of print cartridge may be reduce. The low surface tension will also improve the flow properties of ink on substrate. During using of ink material, ink drying and smudging are also considered to be a very important function. After the ink has been applied to the surface to be printed, it must bind there to ensure it stays. After mixing the polymer nanocomposites in ink, it have seen that these properties were improved. The UV-Vis spectra result shows that polymer nanocomposites mixed with ink samples absorbed mostly in the visible region. The FTIR results of polymer nanocomposites mixed ink samples shows that, the polyaerylamide polymer nanocomposites were present in all ink samples. The results of in-vitro anti-bacterial screening of ink samples and CuO nanoparticles against bacteria E. coli exhibited that, the bacterial culture has least effect on the ink samples and CuO nanoparticles.
[13] Singh, M. Surf. Interface Anal. 2008, 40, 1344–1349.

[14] Aparna, Y.; Rao, K. V. E.; Subbarao, P. S. Synthesis and Characterization of CuO Nano Particles by Novel Sol-Gel Method. In International Proceeding of Chemical. Biological and Environmental Engineering, 2012, doi: 10.7763/IPCBEE.

[15] Density & Dot Gain, Salmon Creek Publishing, U.S. http://www.flexoglobal.com/flexomag/08-July/flexomag-ploumidis (accessed July 13, 2016).

[16] For your print information: Ink Viscosity, Graphic Art Magazine, Canada. http://graphicartsmag.com/articles/2011/02/for-your-print-information-ink-viscosity (accessed July 13, 2016).

[17] Suganuma, K. Introduction to Printed Electronics; Springer: New York, 2014.

[18] Printing Inks & Adhesives, Kibron Inc, Finland. http://www.kibron.com/solutions/printing-inks-a-adhesives (accessed July 13, 2016).

[19] Freddi, G.; Tsukada, M.; Beretta, S. J. Appl. Polym. Sci. 1999, 71, 1563-1571.