Amorphous Carbon Nanotube-MoS2 Nanohybrids : A New Material in the Application of Battery, Supercapacitor and Field-emission Display Devices

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**Abstract:** The discovery of graphene make the researcher interested towards the other two-dimensional material which has quite similar properties like graphene. Among them, MoS2 nanosheets has extraordinary optoelectronic and physical properties. It has several applications in developing battery, sensor, optoelectronic device etc. On the other hand, amorphous carbon nanotube can be synthesized by using a low temperature chemical process. Due to the ease processing of amorphous carbon nanotube (ACNT), good optoelectronic and physical property based nanomaterial with amorphous carbon nanotube, can be a good replacement of crystalline carbon nanotube in numerous applications. Here in this paper, amorphous carbon nanotube-MoS2 nanohybrids were prepared by hydrothermal method. Beside this, ACNT has been synthesized by using a low temperature chemical process. The as prepared samples (ACNT and ACNT\_MoS2 nanohybrids) were characterized by using field emission scanning electron microscopy, X-ray diffraction method, high resolution transmission electron microscope and fourier transformed infrared spectroscopy method.

**Keywords:** amorphous carbon nanotube, MoS2 nanosheets, nanohybrids, hydrothermal method, battery, supercapacitor, field – emission display devices.

**1. Introduction**

Instead of graphene, the beautiful physical and opoelectronic property of two dimensional molybdenum di sulphide(MoS2) can be a good replacement in many applications such as electromagnetic wave absorber, supercapacitor, field-emission display devices and catalysis. Two dimensional MoS2 is a direct band gap material with band gap of 1.8 eV whereas bulk MoS2 is a indirect band gap material with band gap of 1.23 eV. Due to its direct band gap characteristics, it is hugely applicable in optoelectronic devices. Now a days, MoS2 nanosheets are also used in developing transistors and diode. Moreover, excellent high mobility, ON/OFF ratio, sensitivity makes MoS2 nanosheets as useful in fabricating field effect transistors and phototransistors. However, the researchers and scientist have discovered several methods like mechanical exfoliation, liquid phase exfoliation, chemical vapour deposition etc for synthesis of MoS2 nanosheets. On the other hand, unlike crystalline carbon nanotube, amorphous carbon nanotube can be prepared by a low temperature(2250C) process. Due to the presence of several dangling bond in amorphous carbon nanotube, it is easily react with other nanomaterial to form into nanohybrids. Instead of crystalline carbon nanotube, this nanohybrids can be applicable in numerous applications. Though ACNT-MoS2 nanohybrids can be developed by using liquid phase method, eco-friendly method and hydrothermal method. In eco-friendly method, bulk MoS2, ultra tide detergent and amorphous carbon nanotube are used as main material. In this method, a 10 g amount of bulk MoS2 are first stirred in a 50 ml of di-water (at 600C temperature) and an amount of 20 g detergent (Ultra Tide) for a fixed time and measured 400 rpm, followed by sonication using a solid probe sonicator for 3 hrs. After that, 2 g of ACNT is poured into that solutions and stirred for 30 minutes with 400 rpm. Finally the samples are filtered and washed with di-water and ethanol repeatedly. Lastly the samples are kept in an oven with a temperature of 500C for 10 hrs. In, liquid phase method, for synthesis of ACNT-MoS2 nanohybrids, MoS2 powder is used as precursor and isopropanol are used as solvent. A measured quantity of MoS2 powder is taken in a beaker which is contained previous mentioned solvent. This beaker is kept in a ultrasonicator for 30mins and then as prepared ACNT is poured into this solutions. Finally the mixed solutions are ultrasonicated for more 10 minutes. After that the samples are washed with distilled water and absolute ethanol for several time and filtered by a filter paper.

Here in this paper, amorphous carbon nanotube has been synthesized by using pre mentioned low temperature process. ACNT-MoS2 nanohybrids has been prepared by using less complicated hydrothermal method. Finally the as prepared ACNT and ACNT\_MoS2 nanohybrids were characterized by field emission scanning electron microscope, X-ray diffraction, HRTEM, FT-IR method.

**2. Materials and Method**

For the preparation of amorphous carbon nanotube, Ferrocene ((C5H5)2Fe, Merck), ammonium chloride (NH4Cl) and hydrochloric acid (HCl) are the main material used in this process. For synthesis of amorphous CNT, first ferrocene and ammonium chloride were taken in 1:2 weight ratio. Then weighted material placed in a mortar and grinded very well. After that, the mixture were placed in a quartz beaker and kept it in an oven with 2250C for 30 minutes. Then the black product was washed with DI-water and dilute HCL repeteadly for removing the impurity present in amorphous CNT. Then final product was kept in an oven with 600C for 24 hrs.

Hexaammonium heptamolybdate tetrahydrate and thiourea were used as main material in hydrothermal method. In this procedure, 1.24 g of hexaammonium heptamolybdate tetrahydrate and 2.28 g of thiourea were dissolved in 50ml deionized water under vigorous stirring for 50 min to form a homogeneous solutions. Then this solutions were transferred into a teflon-lined stainless steel  autoclave and closed securely. Next solutions containing autoclave heated with a temperature 2000C for a fixed 20h time. Furthermore the final solutions were cooled down normally and centrifuged for producing powder like sample. Samples were washed with distilled water and absolute ethanol for several time. Finally this samples were dried in vacuum at 600C for 18 h.

**3. Characterizations**

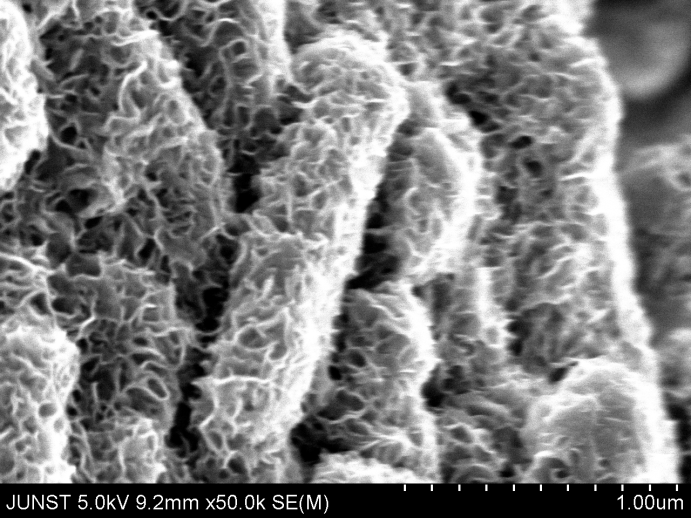
Amorphous carbon nanotube and as prepared ACNT-MoS2 nanohybrids were characterized by using field emission scanning electron microscope, X-ray diffraction (XRD, Bruker). FE-SEM is used for the surface analysis and X-ray diffraction method is used for determining the material property of as produced samples. High resolution transmission electron microscopy (HRTEM, JEOL-JEM 2100) is used for surface analysis of eco-friendly synthesized nanohybrids. Different bond measurement were done by FT-IR (Shimadzu FTIR-8400S) instrument.

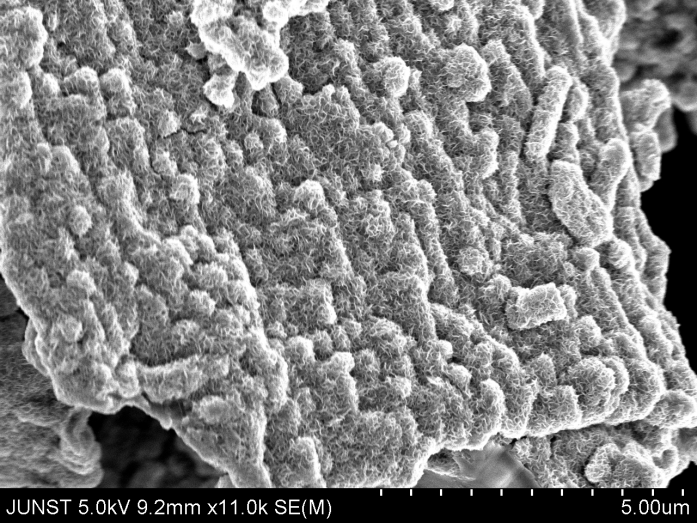
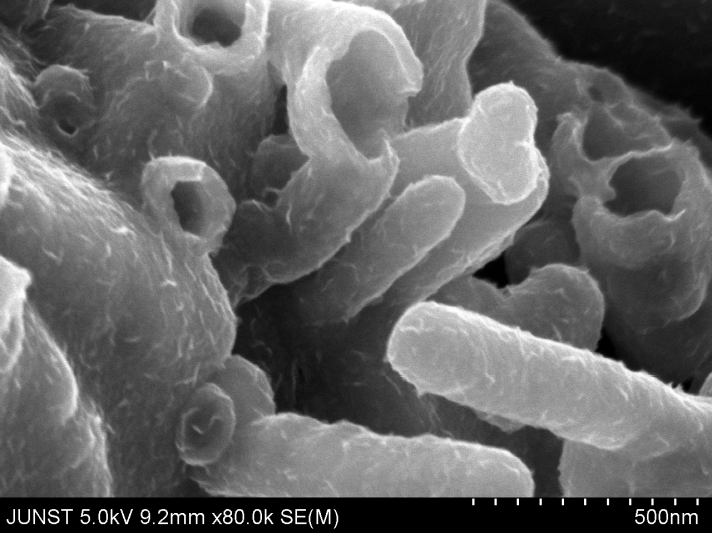
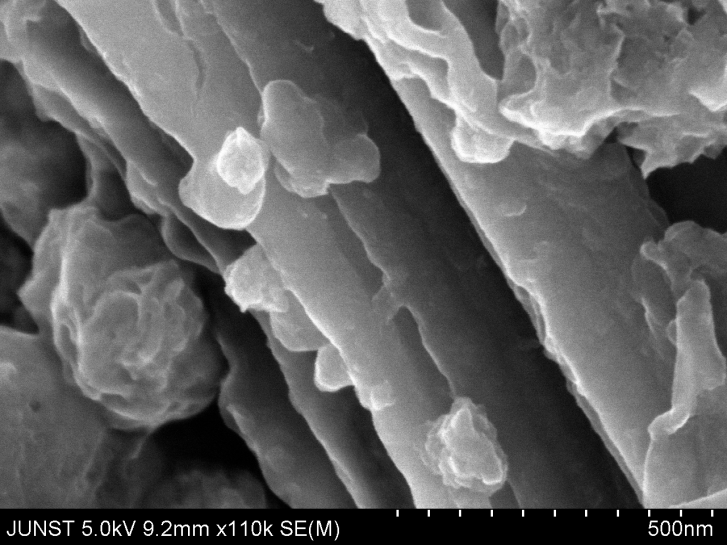
**4. Results and Discussions**

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**(a)**

Figure 1: FESEM image of amorphous carbon nanotube.

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**(b)**

**(a)**

Figure 2: FESEM image of liquid phase synthesized ACNT-MoS2 nanohybrids.

**MoS2 nanosheets**

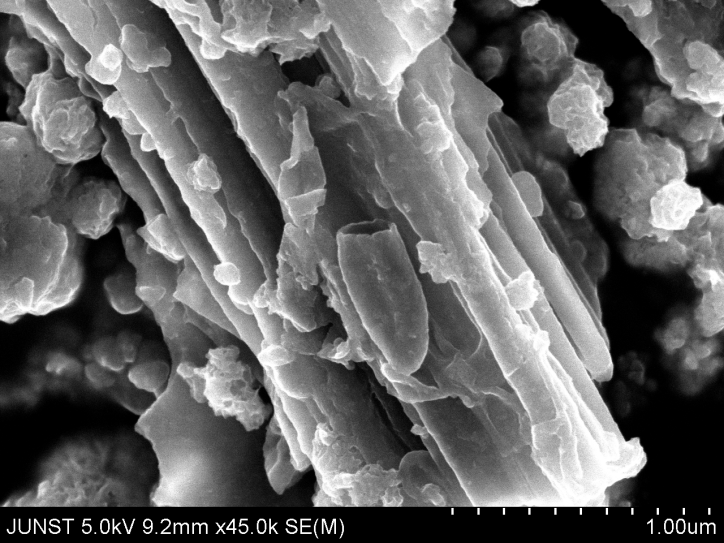
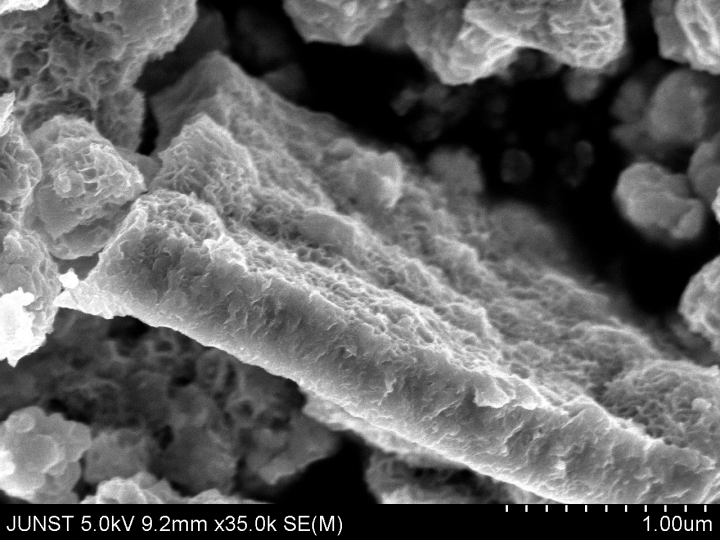
**Amorphous Carbon Nanotube**

**(b)**

**(a)**

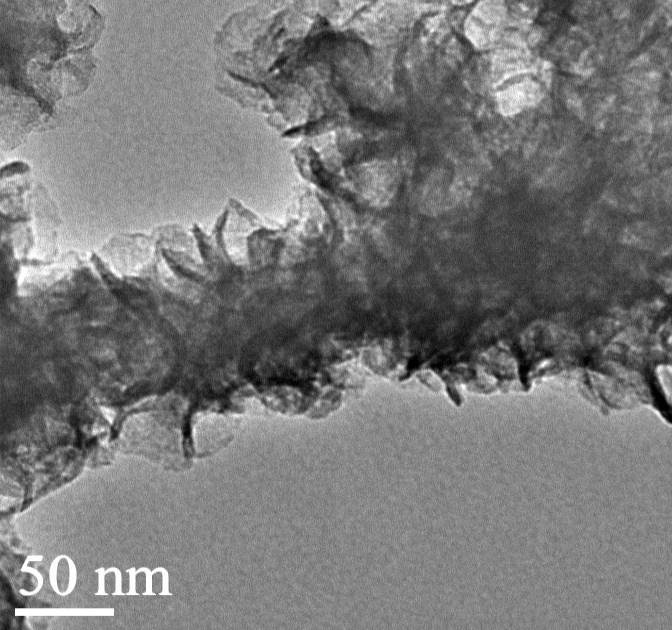
**110**

**(a)**

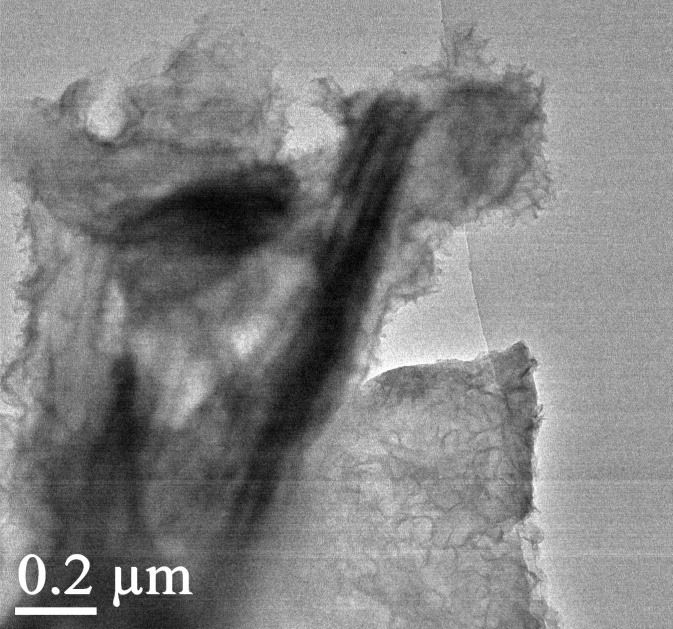


**(d)**

**(c)**

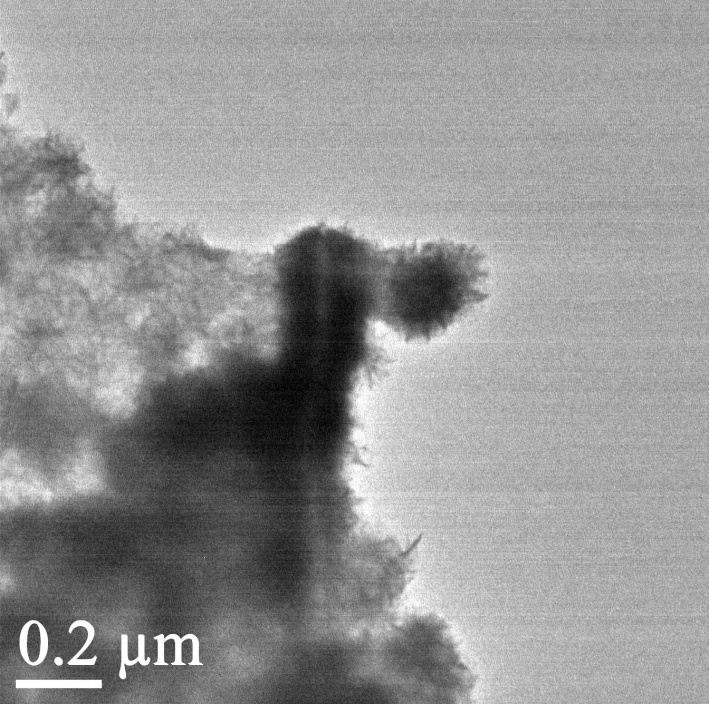
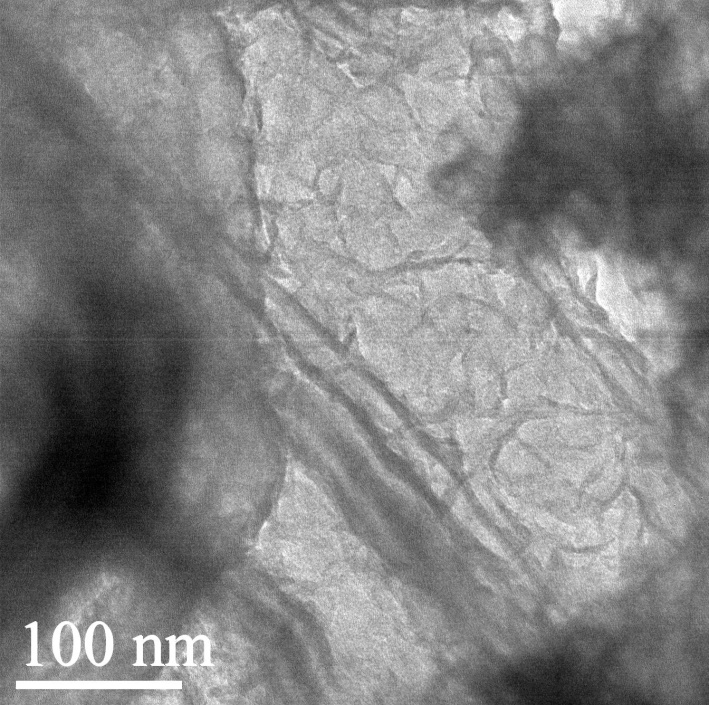


**(e)**



**(e)**

**(f)**



**(h)**

**(g)**

Figure 3: (a, b, c and d) FESEM, (e, f, g, h) HRTEM image of eco-friendly produced ACNT\_MoS2 nanohybrids.

Figure 1 (a and b) are showing the FE-SEM image of amorphous carbon nanotube. From FE-SEM image it is clearly observed the formation of amorphous carbon nanotube. From there, It is proved that the surface of carbon nanotube are amorphous in nature. Figure 2 (a and b) are showing the FE-SEM image of liquid phase synthesized ACNT-MoS2 nanohybrids. Amorphous carbon nanotube are wrapped by MoS2 nanosheets. XRD pattern taken using Cu Kα radiation (wavelength λ = 0.15418 nm) with normal θ-2θ scanning in the range between 5 - 650. One peak around 26.50 is occurred for the (002) plane of 2 dimensional graphitic phase of carbon. From XRD pattern, it is observed that the carbon nanotube is amorphous in structure. In figure 2, (100) and (110) peak arises due to the incorporation of MoS2 nanosheets in amorphous carbon nanotube. In eco-friendly produced nanohybrids, Surface analysis of ACNT-MoS2 nanohybrids were done from FE-SEM and HRTEM image. FE-SEM image reveals the formation of MoS2 nanosheets with amorphous carbon nanotube. High resolution transmission electron microscopy image shows the clear vision of ACNT-MoS2 samples.All planes i.e. (002), (100), (102) and (110) are corresponding to the MoS2 nanosheets. Graphitic carbon plane of amorphous carbon nanotube was suppressed by MoS2 nanosheets.

**(b)**

**(a)**



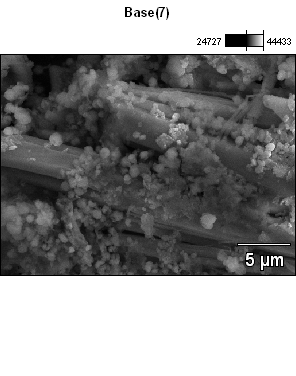


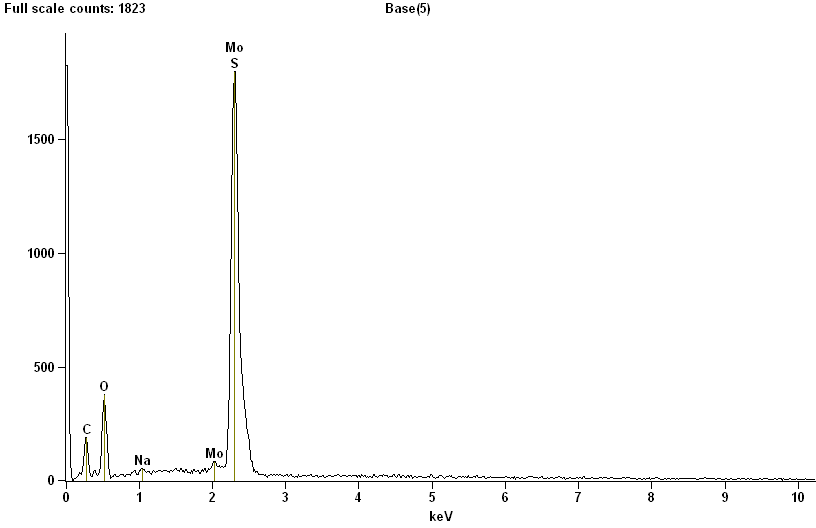
**(d)**

**(c)**



Figure 4: (a) XRD pattern of amorphous carbon nanotube, (b) liquid phase synthesized ACNT-MoS2 nanohybrids, (c and d) XRD and FT-IR pattern of eco-friendly synthesized ACNT-MoS2 nanohybrids.





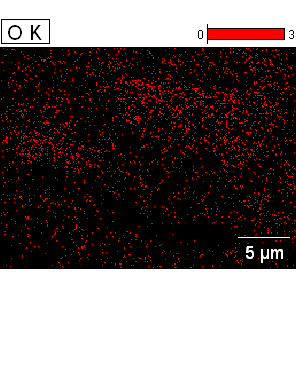
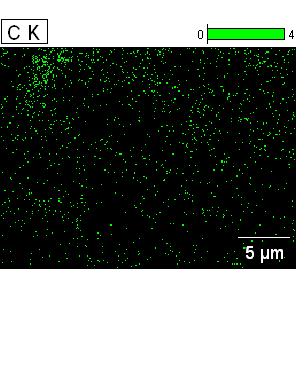
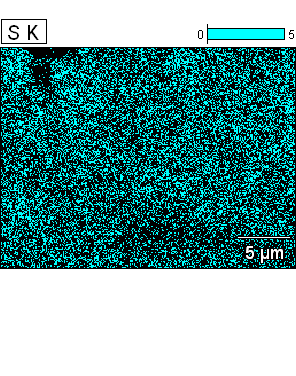
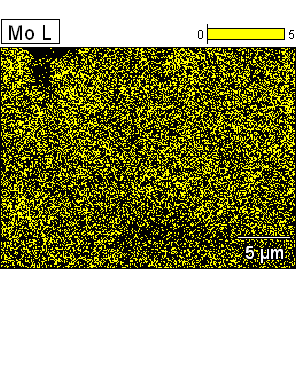
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Figure 2: EDX spectra of eco-friendly produced ACNT-MoS2 sample with corresponding elemental mapping.

**Table 1: Compositional analysis of eco-friendly produced ACNT-MoS2 sample from EDX study.**

Elemental line atom %

C K 47.91

O K 29.81

S K 14.74

Mo L 7.24

Total 100

**4. Conclusions**

Here in this paper, a simple hydrothermal method has been used for synthesis of amorphous carbon nanotube-MoS2 nanohybrids. Amorphous carbon nanotube were prepared separately by a low temperature chemical process. FE-SEM and HRTEM image proves the formation of ACNT-MoS2 nanohybrids. From there, it is also observed that the quality of samples are good in comparable with other methods of ACNT-MoS2 nanohybrids preparation. The method which has used here for synthesis of ACNT-MoS2 nanohybrids are very simple. Here amorphous carbon nanotube which was previously prepared by a low temperature chemical process are used here. In paper industry, huge amount of dye (generally toxic) and water is used. This nanohybrids can be used as toxic dye removal material in paper industry. From FE-SEM image, it is visualize that the quality of ACNT-MoS2 nanohybrids are very much good. This nanohybrids are quite interesting for developing anode material of lithium- ion battery, supercapacitor application and field emission devices.

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