



# Copper Phthalocyanine- Perylene-3,4,9,10-tetracarboxylic dianhydride Supercapacitors

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Perylene-3,4,9,10-tetracarboxylic dianhydride (PTCDA) and copper phthalocyanine (CuPC) were used to fabricate a supercapacitor. The present study reports the electrical properties of a supercapacitor based on PTCDA and CuPC. The active electrode, electrolyte, current electrodes used for the supercapacitors are p-type and n-type organic semiconductors, copper chloride and Al-Cu metal electrodes, respectively. Black carbon was added to active electrodes PTCDA and CuPC. The current-voltage and power-voltage characteristics of the prepared PTCDA and CuPC based supercapacitors were performed using Fytronix 9200 IV-CV analyzer. The  $I_{sc}$ ,  $V_{oc}$ , and  $P_{max}$  values for the Al/CuPC/PTCDA/Cu supercapacitors were 1.28 mA, 0.12 V, and 0.038 mW, respectively. Among the prepared supercapacitors, the supercapacitor with the CuPC ratio: BC=90:10 exhibited the highest electrical performance between all supercapacitors. It is evaluated that the organic semiconductor can be used for supercapacitor applications.

**Keywords:** Supercapacitors, PTCDA, CuPC

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## 1. Introduction

A supercapacitor (SC) (or ultracapacitor) differs from an ordinary capacitor in two important ways: its plates effectively have a much bigger area and the distance between them is much smaller, because the separator between them works in a different way to a conventional dielectric. Also electrochemical capacitor that has a very high power density as compared to common capacitors, about 100 times greater. Compared with the battery, the SC or Ultracapacitor is a high-density energy source or storage with huge capacitance for a short time span. SC have a high power density than the same rated battery. Although there are different kinds of batteries in the market, for example, lithium-ion, polymer, lead-acid batteries have different power density, from 1000 Wh per kg to 2000 Wh per kg.

The electrode materials contribute to the storage performance of a SC and can be divided into three categories: double layer capacitors that act electrostatically, pseudo-capacitors that act electrochemically, and hybrid capacitors that utilize both.

SC are a high-density energy source with high energy storage capacity, long shelf life, and quick charging capabilities making them ideal for applications in hybrid vehicles, portable devices, and energy harvesting.

Capacitors and batteries are similar in the sense that they can both store electrical power and then release it when needed. The big difference is that capacitors store power as an electrostatic field, while batteries use a chemical reaction to store and later release power.

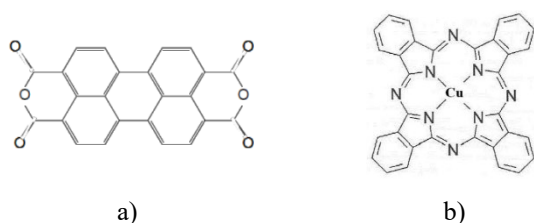
Copper phthalocyanine (CuPc), ( $Cu_{32}H_{16}CuN_8$ ) also called phthalocyanine blue, phthal blue and many other names, is

a bright, crystalline, synthetic blue pigment from the group of phthalocyanine dyes. It is a p-type organic semiconductor.

Perylenetetracarboxylic dianhydride (PTCDA) is an organic dye molecule and an organic n type semiconductor.

## 2. Experimental

The present study has been fabricated new organic SC using p and n- type organic semiconductors such as CuPC and PTCDA. CuPC and PTCDA organics used in the study were used as they are without any purification. The chemical structure of CuPC and Pentacene is given in figure 1. In order to improve the electrical properties of CuPC and Pentacene, composite materials of CuPC and Pentacene were prepared by adding different proportions of black carbon (BC) to CuPC and Pentacene.



**Fig. 1. Chemical structure of a) PTCDA and b) CuPC**

Firstly, PTCDA and CuPC based composites have been prepared by slurry method and electrical performance of the supercapacitors have been investigated by current-voltage and power-voltage characteristics.

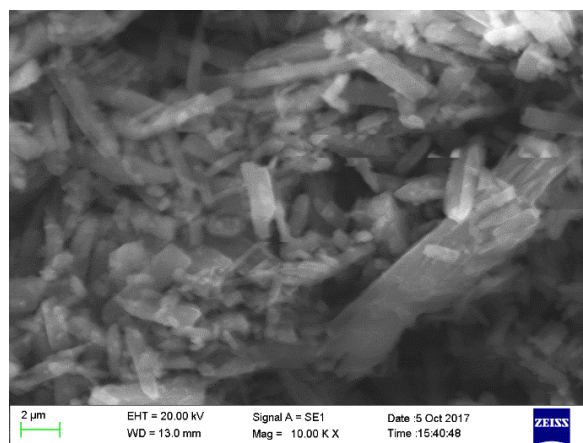
Also in order to electrical performance of the supercapacitors, the organic semiconductors were filled with the black carbon. For this, the total mass of the matrix material is taken at the appropriate value, CuPC: BC and PTCDA: BC are homogeneously dispersed in NMP (N-methylpyrrolidone) in weight ratios of 100:0, 90:10, 80:20 and 70:30, then at 100 °C. Composite materials were produced by drying.

## 3. Results and Discussion

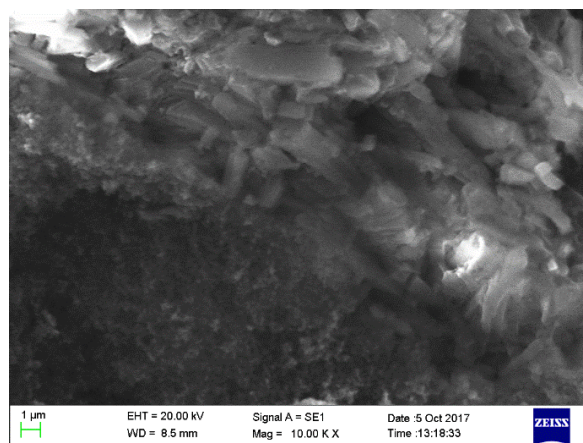
### 3.1. Determination of the SEM images CuPC and PTCDA pellets

SEM image of the organic semiconductor prepared in pellet form for SEM measurements is given in Figure 2- Figure 6. It is formed with a homogeneous and uniform distribution, as seen from the SEM picture of PTCDA in In Fig 2. As seen in the Fig 3., rod-shaped particles were formed in the structure of CuPC. Rod structures have different size. SEM images of the materials produced after BC doping are given in Fig 3., Fig 4. and Fig 5. As seen in Figure 4. composite structures consist of any new particles. BC particles appear to interact with CuPC. The rod structures in the composite

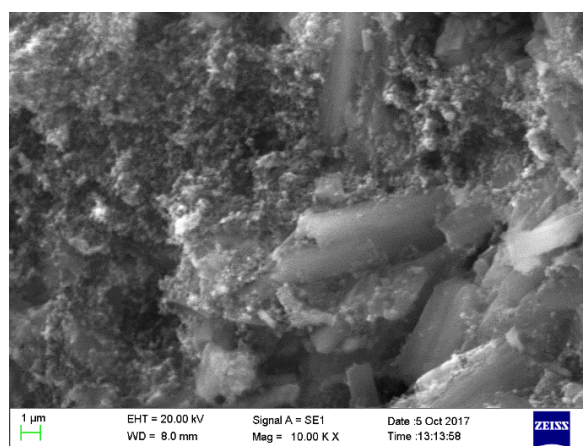
disappeared and the composite showed an uneven distribution.



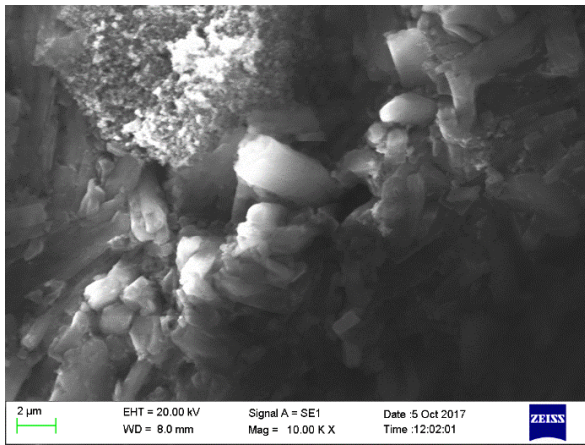
**Fig.2. SEM image of the CuPC pellet**



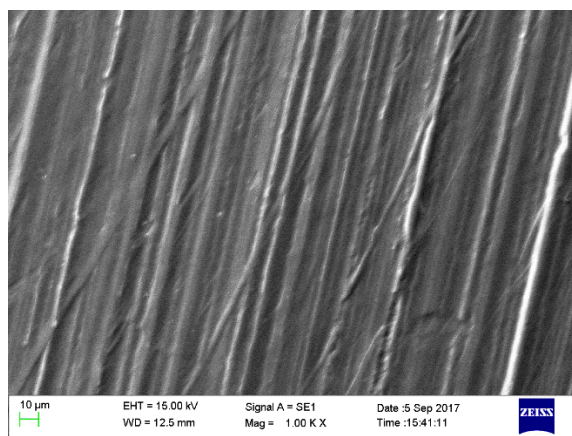
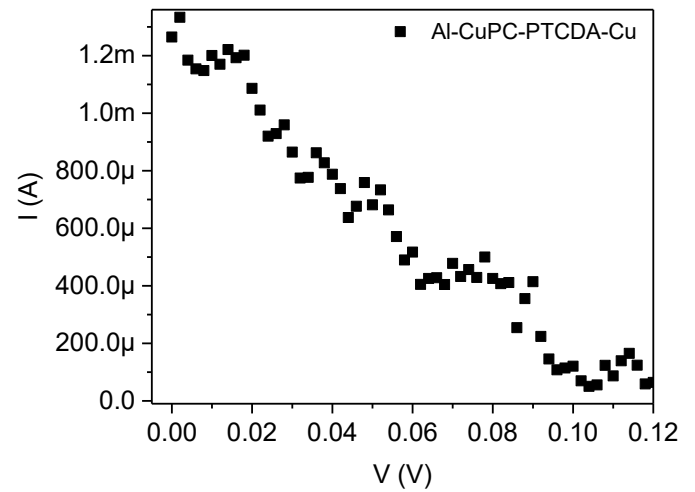
**Fig.3. SEM image of the %90 CuPC %10 BC pellet**



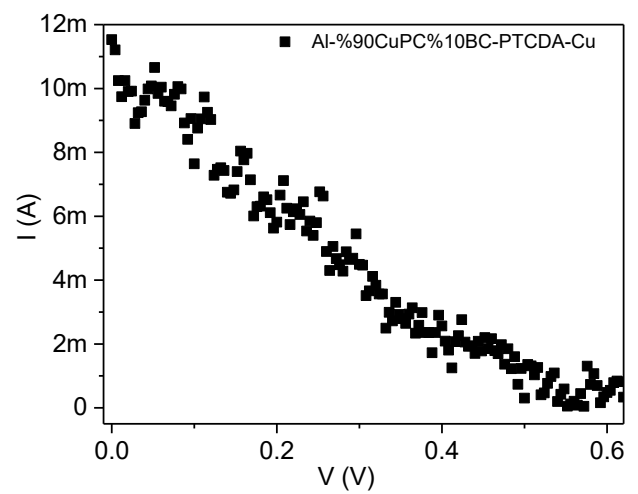
**Fig.4. SEM image of the %80 CuPC %20 pellet**



**Fig.5.** SEM image of the %70 CuPC %30 BC pellet



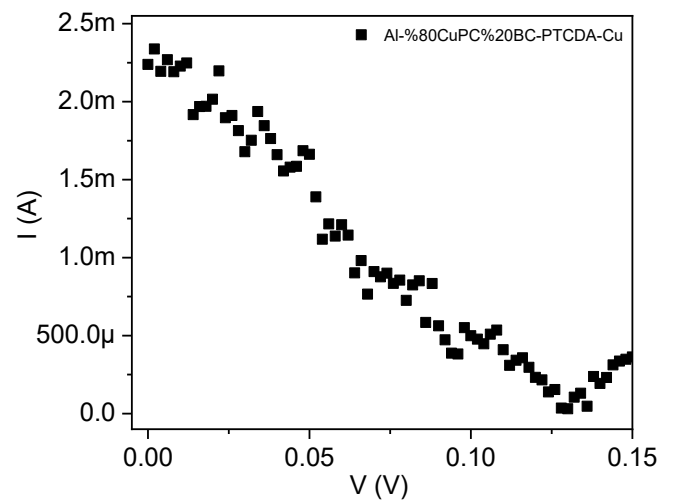
**Fig. 6.** SEM image of the PTCDA pellet



### 3.2. Determination of I-V and P-V Characteristics of Al/CuPc/PTCDA/Cu supercapacitors

In Figure 7. and Figure 8. I-V and P-V curves of Al/CuPc/PTCDA/Cu supercapacitors are given.  $I_{sc}$ ,  $V_{oc}$ ,  $P_{max}$  values of Al/ CuPc/ PTCDA /Cu battery were found as 1.28 mA, 0.12 V and 0.038 mW, respectively.

Then, new supercapacitors were prepared by doping BC to CuPC. CuPC:BC=90:10 battery gave the highest power among the produced supercapacitors. The maximum power of the SC was found to be 1.58 mW.



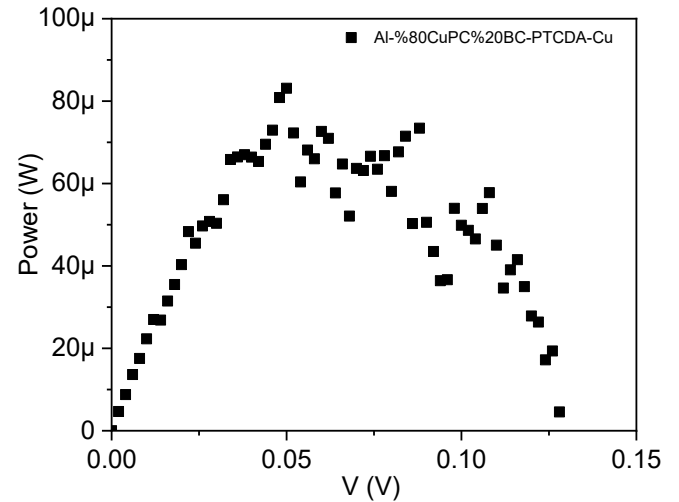
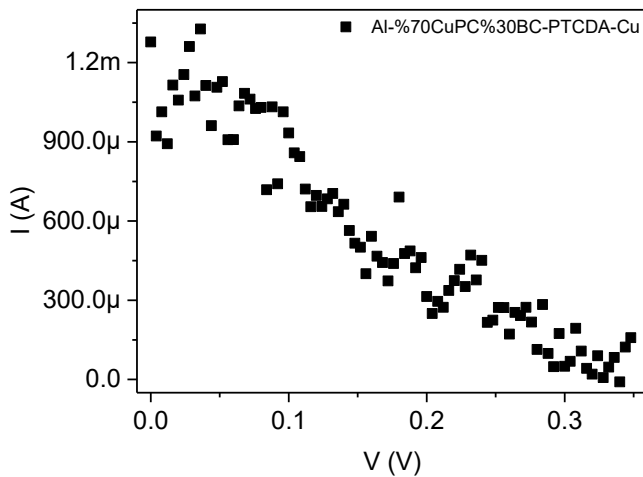


Fig. 7. Current-voltage plots of supercapacitors

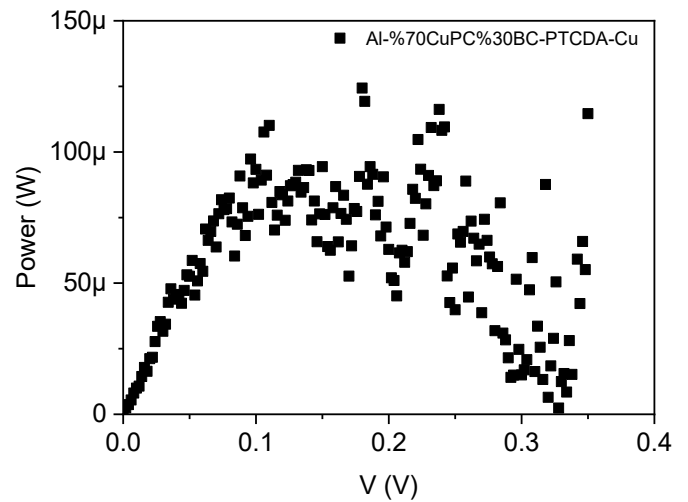
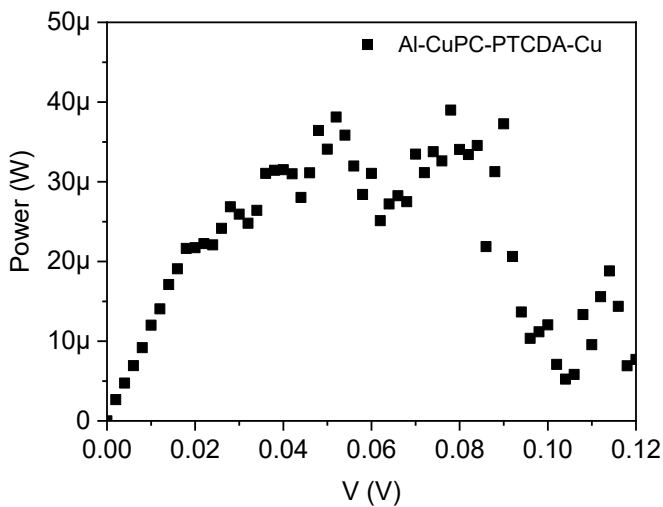
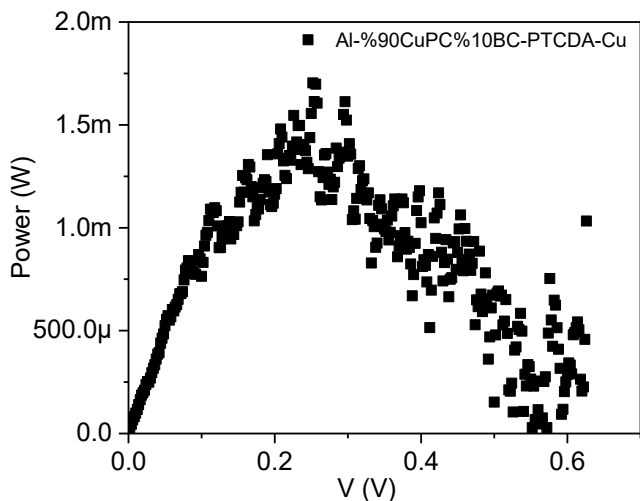


Fig. 8. Power-voltage plots of supercapacitors



Comparing organic composite supercapacitors with undoped CuPC, BC additive supercapacitors have significantly improved electrical performance. Although the increase in battery power does not show a regular increase, BC doped CuPC supercapacitors have higher power values than CuPC supercapacitors.

#### 4. Conclusion

In this study, a new supercapacitor design with p-type organic semiconductor-electrolyte-n-type semiconductor structure has been made. This structure, which is not in the literature, was designed for the first time and the first SC were produced in this regard. In the production of SC, p-type and n-type organic semiconductor materials with stable structure at room temperature are used. In order to increase the electrical performance of the produced supercapacitor, their electrical conductivity was investigated by doping organic materials. CuPC as p-type semiconductor material and PTCDA as n-type material were used. The effect of BC doping on CuPC organic semiconductor on SC performance

was investigated. It has been determined that 90% CuPC 10% BC-PTCDA supercapacitor has the highest power value from the produced 90% CuPC 10% BC, 80% CuPC 20% BC, 70% CuPC 30% BC composites. Super capacitors produced according to the results obtained can be used in low power dissipative electronic circuits.

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