EFFECTIVENESS OF THE NEW FORMULATION OF GNP/SA HYBRID CONDUCTIVE INK ON TORSION/ BENDING CYCLIC LOADING

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "Effectiveness of The New Formulation of GNP/SA Hybrid Conductive Ink on Torsion/Bending Cyclic Loading" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :...

Name : Hazril Hisham Bin Hussin

Date : 24 September 2024

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineeering.

Signature : ....

Supervisor Name : Assoc. Prof. Ir. Ts. Dr. Mohd Azli Bin Salim

Date : September 25, 2024

DEDICATION

To my beloved mother, father and most importantly my beloved wife.

ABSTRACT

In a dynamic era characterized by the integration of innovation and technology, hybrid conductive ink has emerged as a powerful catalyst in the production of flexible electronic devices. It also opens up new opportunities to advance electronic printing technology. However, there are challenges in realizing it, namely in terms of formulating a suitable ink material for that purpose. Materials such as graphene nanoplatelets (GNP), which are carbon-based, become fillers in polymer composites together with silver flakes (Ag), planning a good combination with silver acetate (SA) to produce a new formulation of conductive hybrid ink. This research aims to study the characteristics and uses of GNP hybrid conductive ink when mixed with organic solvents and cured at 250°C. Several aspects have been studied as a research goal in terms of formulating a new GNP hybrid conductive ink formulation and further, comparing the characteristics of the new conductive ink formulation against the mechanical, electrical and morphological properties of the flexible substrate. The optimal formulation process of the hybrid conductive ink is important in ensuring its level of resistivity during cyclic testing using the Two-Point-Probe measurement technique. The evaluation of electrical and mechanical conductivity is started by carrying out a cyclic test on the sample and comparing it to the baseline, which is not subjected to the test. After the cyclic tests of torsion and bending are conducted, shear stress tests are also conducted to determine the mechanical properties. The reliability of the new formulation of conductive ink was also evaluated. After the cyclic and baseline tests, a comparative analysis of the GNP hybrid revealed no significant changes in the tested sample's resistivity. The total average resistivity of the sample was 1.99E-05 Ω.m at baseline, and the lowest average for torsion was 2.02E-05 Ω.m and for bending, 2.41E-05 Ω.m. The higher shear stress values (MPa) for samples cured at 5 hours indicate a better result with an average of 57.36 MPa. The findings in this research show that the hybrid formulation of GNP in conductive ink can improve its electrical conductivity performance with an average improvement of 42.58% for both torsion and bending tests. This provides valuable insights, and pave the way for future improvements in conductive ink formulations that can be utilized in various flexible electronic applications.

KEBERKESANAN FORMULASI BAHARU DAKWAT KONDUKTIF HIBRID GNP/SA TERHADAP BEBANAN KITARAN KILASAN/LENTURAN

ABSTRAK

Dalam era dinamik yang dicirikan oleh penyepaduan inovasi dan teknologi, dakwat konduktif hibrid telah muncul sebagai pemangkin berkuasa dalam pengeluaran peranti elektronik yang fleksibel. Ia juga membuka peluang baharu untuk memajukan teknologi percetakan elektronik. Namun begitu, terdapat cabaran dalam merealisasikannya iaitu dari segi formulasi bahan dakwat yang sesuai bagi tujuan tersebut. Bahan seperti graphene nanoplatelets (GNP), yang berasaskan karbon, menjadi pengisi dalam komposit polimer bersama serpihan perak (Ag), merencanakan kombinasi yang baik dengan perak asetat (SA) untuk menghasilkan rumusan baharu dakwat hibrid konduktif. Penyelidikan ini bertujuan untuk mengkaji beberapa ciri dan kegunaan dakwat konduktif hibrid GNP apabila dicampur dengan pelarut organik dan diawet pada suhu 250°C. Beberapa aspek telah dikaji sebagai matlamat kajian dari segi merumuskan formulasi dakwat konduktif hibrid GNP baharu dan seterusnya, membandingkan ciri-ciri rumusan baharu dakwat konduktif terhadap sifat mekanikal, elektrikal dan morfologi substrat fleksibel. Proses perumusan optimum dakwat konduktif hibrid adalah penting dalam memastikan tahap kerintangannya semasa ujian kitaran menggunakan teknik pengukuran kuar dua titik. Penilaian kekonduksian elektrik dan mekanikal dimulakan dengan menjalankan ujian kitaran pada sampel dan membandingkannya dengan garis dasar, yang tidak tertakluk kepada ujian. Selepas ujian kitaran kilasan dan lenturan dijalankan, ujian tegasan ricih juga dijalankan untuk menentukan sifat mekanikal. Kebolehpercayaan formulasi baru dakwat konduktif juga dinilai. Selepas ujian kitaran dan garis dasar, analisis perbandingan hibrid GNP mendedahkan tiada perubahan ketara dalam kerintangan sampel yang diuji. Jumlah kerintangan purata sampel ialah 1.99E-05 Ω.m pada garis dasar, dan purata terendah untuk kilasan ialah 2.02E-05 Ω.m dan untuk lenturan, 2.41E-05 Ω.m. Nilai tegasan ricih (MPa) yang lebih tinggi untuk sampel yang diawetkan pada 5 jam menunjukkan keputusan yang lebih baik dengan purata 57.36 MPa. Penemuan dalam penyelidikan ini menunjukkan bahawa formulasi hibrid GNP dalam dakwat konduktif boleh meningkatkan prestasi kekonduksian elektriknya, dengan purata peningkatan sebanyak 42.58% untuk kedua-dua ujian kilasan dan lenturan. Ini memberikan pandangan yang berharga, dan membuka jalan untuk penambahbaikan masa depan dalam formulasi dakwat konduktif yang boleh digunakan dalam pelbagai aplikasi elektronik yang fleksibel.

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LIST OF ABBREVIATIONS

RFID	Radio frequency identification
PCB	Printed circuit boards
GNP	Graphene nanoplatelets
Au	Aurum (Gold)
Pt	Platinum
AgNPs	Silver nanoparticles
CNT	Carbon nanotube
CPs	Conductive polymers
Cu	Copper
Ag	Silver
Al	Aluminium
SA	Silver acetate
PE	Printed electronics
DMF	Dimethylformamide
NMP	N-methyl-2-pyrrolidone
SEM	Scanning Electron Microscopy
EDX	Energy Dispersive X-ray

IACS	International Annealed Copper Standard
PTF	Polymer thick films
Zn	Zinc
CVD	Chemical vapor deposition
3D	Three-dimensional
CFD	Computational fluid dynamics
PEDOT:PSS	Poly (3,4-ethylenedioxythiophene)-poly (styrenesulfonate)
DoD	Drop-on-demand
PET	Polyethylene terephthalate
AgNW	Silver nanowires
SCI	Stretchable conductive ink
PD	Palladium
Sn	Tin
CB	Carbon black
RPM	Revolutions per minute
SE	Secondary electron
IoT	Internet of things
Gr-Ag	Graphene - silver
GNP-Ag	Graphene nanoplatelets and silver

xGnP H-5	GNP powder
wt.%	Weight percentage
R_m	Material resistance
UTM	Universal Testing Machine

LIST OF SYMBOLS

Ω·m	Ohm meter
%	Percentage
kΩ/sq	kiloohms per square
$	Dollar
°C	Degree Celsius
Ω·cm	Ohm centimeter
µm	Micrometer
µΩ·cm	Microohm centimeter
R, Ω	Resistance
V	Voltmeter
I	Current source to the sample
MΩ	Megaohm
V_s	Voltage source
I_m	Current measure
ρ	Volume of resistivity
A	Cross-sectional area
L	Length
F	Force
ℓ	Length of the specimen
w	Width of conductive ink
t	Thickness of conductive ink

x	Zoom ratio of the lens
E	Young’s modulus
τ	Shear stress
σ	Stress