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ABSTRACT

Dielectric barrier discharge (DBD) under atmospheric pressure can be generated in a simple and economical way without complicated vacuum system and it has found many uses ranging from the industry to medicine. This work presents the characteristics of a filamentary dielectric barrier discharge jet (DBD jet) in Ar, N_2 and Ar:N_2 (47%:53%) mixture. The jet was designed based on DBD configuration which consisted of a hemispherical powered electrode, grounded end plate with nozzle and a glass test tube as the insulator. The discharge was ignited between the electrodes and gas flow across the discharge and through the 1.0 mm nozzle then formed the jet. This configuration resulted in constriction of the gas flow and the DBD was subjected to pressures above atmospheric pressure.

The ignition of the jet was investigated for different kinds of gases. The ignition voltage for Ar was the lowest. The highest number of current filaments was obtained from Ar discharge while N_2 discharge registered the least even though at higher ignition voltage. Influence of operating parameters (applied high voltage, gas flow rate, gap width) on the electrical characteristics (charge transferred, energy deposited and power dissipated between the electrodes) of the DBD jet for Ar, N_2 and Ar:N_2 was studied experimentally based on the *Q-V* Lissajous method. The measured mean power dissipated was less than 7 W for all the gases employed, yielding an efficiency <19%. The dielectric capacitance, C_d deduced from *Q-V* Lissajous plot decreased at higher gas flow rate for the gases employed in this study except in Ar discharge, in which C_d remained constant.

The physical structure of the plasma jets was qualitatively analyzed from the digital images and correlated to the electrical characteristics of the DBD jet. Ar, N_2 and Ar:N_2 jets grew longer and wider with increase in gas flow rate. At the applied voltage of

14.2 kV and flow rate of 12.5 LPM, Ar jet length expanded up to 6.2 mm in open air whereas the width grew from 0.4 mm at 1.8 LPM to 1.4 mm at 12.5 LPM. These were the optimum conditions to obtain a 'good' jet (in terms of dimension and luminosity) in the present setup. The net charges transported in the plasma jets were measured by placing a copper disc to intercept the jet stream. The charges transported out of the nozzle were higher in N_2 jet than Ar jet.

The optical diagnostic of DBD jet had been employed by using a spectrometer where line intensities from the jet in Ar and N_2 were observed and chemically active species of the jet were determined. The chemically active species (O, OH, N) transported through the jet are useful for surface treatment. Surface treatment was carried out for Ar and N_2 discharges at various treatment times (15 s, 30 s, 60 s, 90 s, and 120 s). It was found that treated Mylar film by N_2 and Ar plasma jets demonstrated ability to enhance surface wettability. The ageing effect on the Mylar film treated for 120 s showed that the sample did not fully recover to the untreated state even after 50 days of ageing.

ABSTRAK

Sistem nyahcas penghalang dielektrik (DBD) di bawah tekanan atmosfera boleh dijana dengan cara yang mudah dan ekonomi tanpa sistem vakum yang rumit serta mempunyai pelbagai kegunaan dalam lingkungan industri sehingga perubatan. Projek ini membentangkan ciri-ciri nyahcas penghalang dielektrik jet (DBD jet) beroperasi di bawah Ar, N_2 dan campuran gas Ar:N_2 (47%:53%). Jet ini telah direka berdasarkan konfigurasi DBD yang terdiri daripada hemisfera elektrod, plat yang dibumikan dengan muncung serta tiub kaca sebagai penebat. Nyahcas dihidupkan di antara elektrod dan gas dibenarkan mengalir ke dalam nyahcas dan mengalir keluar melalui muncung yang bersaiz 1.0 mm. Jet dibentuk seterusnya. Konfigurasi ini mengakibatkan penyempitan dalam aliran gas dan DBD mengalami tekanan melebihi tekanan atmosfera.

Pencucuhan jet telah dikaji untuk pelbagai jenis gas. Voltan pencucuh bagi gas Ar adalah terendah. Bilangan filamen yang tertinggi telah diperolehi daripada jet Ar manakala jet N_2 mencatatkan bilangan yang terendah walaupun voltan pencucuh yang dikenakan lebih tinggi. Pengaruh parameter yang beroperasi (voltan kuasa tinggi, kadar aliran gas, jurang antara elektrod) ke atas ciri-ciri elektrik (caj dipindahkan, tenaga disimpan dan kuasa yang dilesapkan antara elektrod) untuk jet DBD dalam gas Ar, N_2 dan Ar:N_2 telah dikaji berdasarkan kaedah Lissajous Q-V. Kuasa yang dilesapkan didapati kurang daripada 7 W untuk semua gas yang digunakan dan menghasilkan kecekapan <19%. Kemuatan, C_d diperoleh dari plot Lissajous Q-V menurun pada kadar aliran gas yang lebih tinggi bagi gas yang digunakan dalam kajian ini kecuali dalam nyahcas Ar, C_d berada dalam tahap yang malar.

Struktur fizikal jet plasma telah dianalisis secara kualitatif dari imej berdigital dan dihubungkaitkan dengan ciri-ciri elektrik jet DBD. Jet Ar, N_2 dan Ar:N_2 berkembang lebih panjang dan lebih lebar dengan peningkatan kadar aliran gas. Pada voltan

sebanyak 14.2 kV dan kadar aliran gas sebanyak 12.5 LPM, panjang jet Ar berkembang sehingga 6.2 mm di udara manakala lebar meningkat daripada 0.4 mm pada 1.8 LPM kepada 1.4 mm pada 12.5 LPM. Ini adalah keadaan optimum untuk memperolehi jet yang 'baik' (dari segi dimensi dan kilauan) dalam persediaan ini. Caj bersih diangkut dalam jet plasma diukur dengan meletakkan cakera kuprum untuk memintas aliran jet. Caj yang dibawa keluar dari muncung adalah lebih tinggi dalam jet N_2 daripada jet Ar .

Diagnostik optik untuk jet DBD ini telah diuji dengan menggunakan spektrometer di mana keamatan garis spektrum dari jet Ar dan N_2 telah diperhatikan dan spesies aktif yang terdapat pada jet ini telah ditentukan. Spesies aktif (O, OH, N) yang diangkut melalui jet adalah berguna untuk rawatan permukaan. Rawatan permukaan telah dijalankan untuk Ar dan N_2 pada masa rawatan yang berlainan (15 s, 30 s, 60 s, 90 s, dan 120 s). Didapati bahawa filem Mylar yang telah dirawat oleh plasma jet N_2 dan Ar menunjukkan keupayaan untuk meningkatkan kebolehbasahan permukaan. Kesan penuaan pada filem Mylar yang dirawat untuk 120 s menunjukkan bahawa sampel tersebut tidak pulih sepenuhnya kepada keadaan yang tidak dirawat walaupun selepas 50 hari penuaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

C_g	air gap capacitance
AC	alternating current
A	ampere
Å	angstrom
Ar	argon
APGD	atmospheric pressure glow discharge
AFM	atomic force microscopy
V_b /V_{ON}	breakdown voltage / ignition voltage
cm	centimeter
CCD	charge-coupled device
Q-V	charge-voltage
CFC	chlorofluorocarbon
CMOS	complementary metal–oxide–semiconductor
θ	contact angle
A	cross sectional area
°C	degree Celsius
DI	deionized
D	density
Ø	diameter
DBD	dielectric barrier discharge
C_d	dielectric capacitance
DC	direct current
d	distance
E	electric field / energy deposited per cycle
e	electron
eV	electron volt

T_e	electron temperature
F	farad
FWHM	full width half maximum
f	function / focal length
Hz	hertz
H.V.	high voltage
ISO	image sensitivity
T_i	ion temperature
K	kelvin
kHz	kilohertz
kVp-p	kilovolt (peak-to-peak)
LPM	litre per minute
Ma	mach number
P	mean power dissipated per cycle
MHz	megahertz
MΩ	mega ohm
Hg	mercury
MOSFET	metal–oxide–semiconductor field-effect transistor
µF	microfarad
µL	microlitre
µm	micrometer
µs	microsecond
mA	milliampere
mm	millimetre
ms	millisecond
min	minute
nC	nano Coulomb
nF	nanofarad

nm	nanometre
ns	nanosecond
NIR	near infrared
T_n	neutral gas particles temperature
N_2	nitrogen
N	number density
V_p	peak voltage
pF	picofarad
PE	polyethylene
PET	polyethylene terephthalate
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
p	pressure
RF	radio frequency
τ	residence time
RMS	root mean square
γ	secondary emission coefficient
SLR	single lens reflex
T	temperature
C_T	total capacitance
UV	ultra violet
USB	universal serial port
VIS	visible
VOC	volatile organic compounds
W	watt
XPS	X-ray photoelectron spectroscopy