Investigation of Arc Plasma in Argon Carbon Dioxide Gas Mixtures

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ABSTRACT

This independent research aims to study the arc plasma of a mixed gas composed of argon and carbon dioxide. The experiment begins with the measurement of the relative intensity of light emitted during the arc plasma process using argon at a flow rate of 1 liter per minute(lpm). The flow rate is then increased to 2, 3, 4, 5, 6, 7, and 8 lpm. The spectra obtained from the relative intensity versus wavelength are used to calculate the electron temperature, which is subsequently plotted against the varying argon flow rates is analyzed using a Mobile Air Plasma Arc system. The study also explores the impact of replacing pure argon with a gas mixture of argon and carbon dioxide, beginning with 100 cc/min of carbon dioxide and varying argon flow rates, and extending to 500 cc/min of carbon dioxide. The objective of the study is to describe the influence of argon flow rates (1–8 lpm) as well as the effect of introducing carbon dioxide into the gas mixture. The experimental results indicate that as the flow rate of Argon (Ar) gas increased, the Electron Temperature (T_e) exhibited a tendency to rise across all tested concentrations of Carbon Dioxide (CO_2). The maximum Electron Temperature (T_e) was specifically recorded at a CO_2 flow rate of 400 cc/min in conjunction with an Ar flow rate of 8 lpm. Moreover, the study examines the effect of plasma treatment on the surface properties of materials, particularly changes in wettability, which are assessed through contact angle measurements. The experimental results reveal that the plasma arc surface treatment resulted in a significant enhancement of the material's wettability, evidenced by a substantial reduction in the contact angle from 42◦ to approximately 6◦. Concurrently, the adhesion energy increased from 0.126 to 0.143 N/m. These findings definitively confirm that the Cold Plasma component of the arc system successfully modified the material surface to exhibit pronounced hydrophilic properties.

THEORY

The mobile air plasma arc

The mobile air plasma arc operates via microdischarges between electrons and the ground, which excite Ar and provide sufficient energy to dissociate CO_2 bonds.

Electron Temperature

The Boltzmann plot method can be used to calculate electron temperature (T_e) by relating the population of excited energy levels to the intensity of emission lines, based on the Maxwell-Boltzmann distribution.

$$\ln\left(\frac{I_{ki}\lambda_{ki}}{g_k A_{ki}}\right) = -\frac{E_k}{k_B T_e} + C \qquad T_e = -\frac{1}{slope}$$

Assuming a quasi-steady-state, the plasma releases constant energy and follows Boltzmann statistics within the measurement region.

Carbon dioxide Production

Carbon monoxide (CO) can be produced from CO_2 using plasma at room temperature

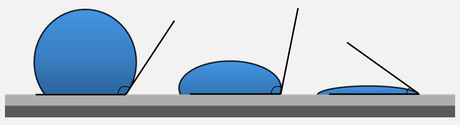
$$e^- + CO_2 \rightarrow CO + O + e^-$$

$$Ar^* + CO_2 \rightarrow Ar + CO_2^+ + e^-$$
$$Ar^* + CO_2 \rightarrow Ar + CO + O$$

where high-energy electrons from a CO_2–Ar plasma jet cause electron impact and Penning dissociation, breaking CO_2 bonds to generate CO.

wettbility changing surface

Wettability is the ability of a liquid to wet a surface, depending on the intermolecular forces between the liquid and the surface.



It is measured by the contact angle a small angle indicates good wetting (hydrophilic), while a large angle indicates poor wetting (hydrophobic).

CONCLUSION

Experimental analysis of the properties of argon (Ar) gas arc plasma.

As the argon gas flow rate increases, the electron temperature (T_e) tends to decrease . Adding more argon. When argon is added, the kinetic energy of the electrons may not be high enough to create plasma. However, when the right amount of argon is added, the electrons will have very high kinetic energy to create plasma.

The experiment involved mixing argon and carbon dioxide gases.

As the argon gas flow rate increases, the electron temperature (T_e) tends to increase for all CO_2 values. At an argon flow rate of 8 liters per minute, the maximum electron temperature (T_e) is reached at a CO_2 of 300 cc/min. This is because it is the point of equilibrium between the amount of excited gas (CO_2) and the amount of electron carriers (argon). If there is too much CO_2, it will reduce the energy conductivity of the plasma.

Experiments and analysis of contact angles to test the wetting ability of glass slide surfaces.

Plasma arc surface treatment can significantly improve the wetting ability of surfaces, with the contact angle decreasing from 42.55° to approximately 16.25° and the adhesion energy increasing from 0.126 to 0.143 N/m. This confirms that cold plasma can achieve hydrophilic surface treatment without the use of any chemicals.

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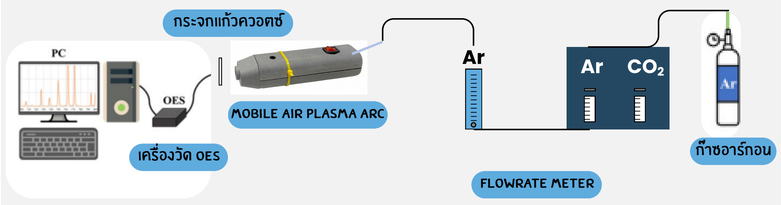
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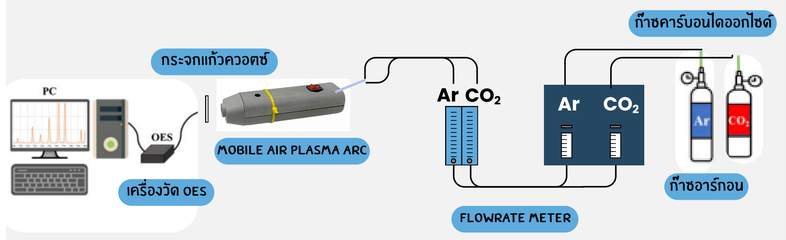
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METHODS

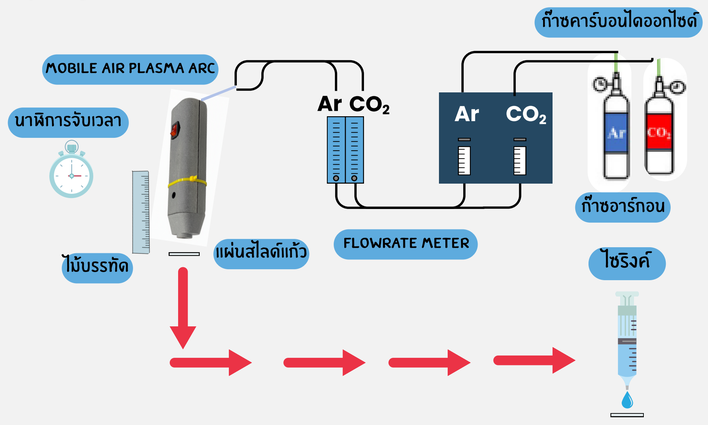
Experimental analysis of the properties of argon (Ar) gas arc plasma.



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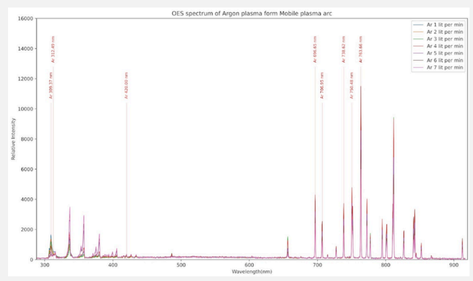


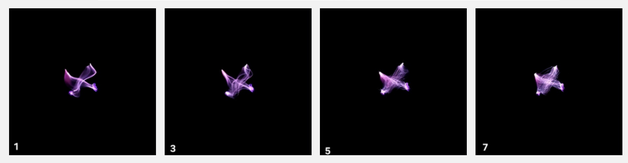
Experiments and analysis of contact angles to test the wetting ability of glass slide surfaces.



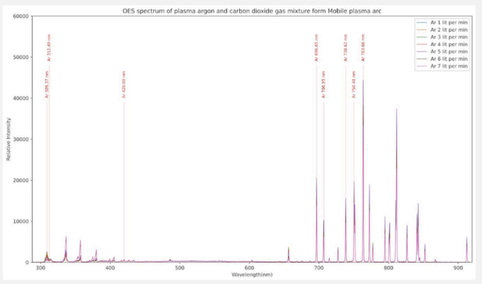
MOBILE AIR PLASMA ARC

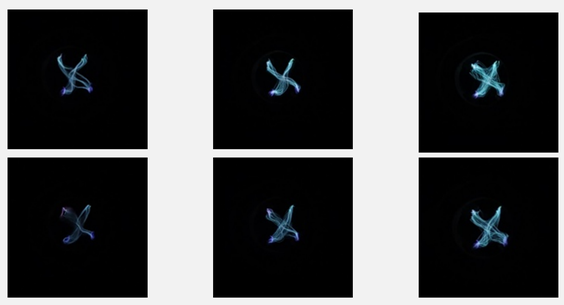
Argon gas plasma during arc at flow rates of 1, 3, 5, and 7 liters/min.





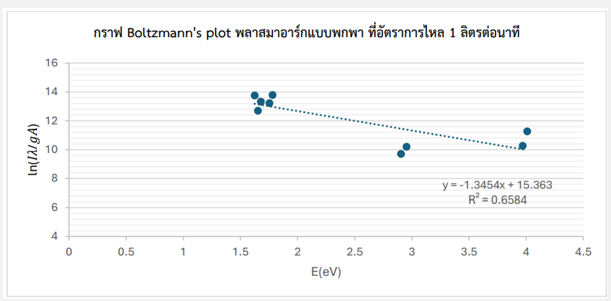
Plasma during arcing of a carbon dioxide gas mixture at flow rates of 300 and 500 cc/min, and argon at flow rates of 3, 5, and 7 liters/min.

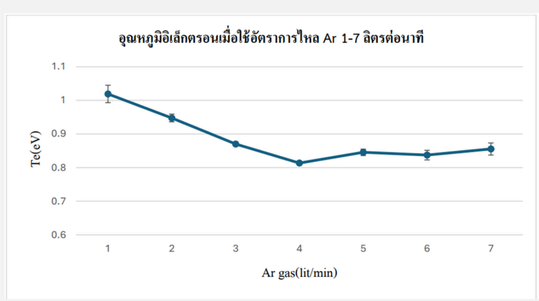




RESULTS

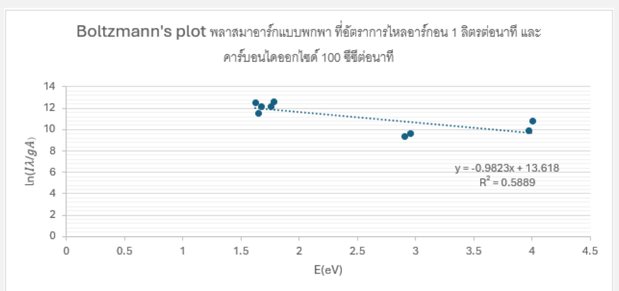
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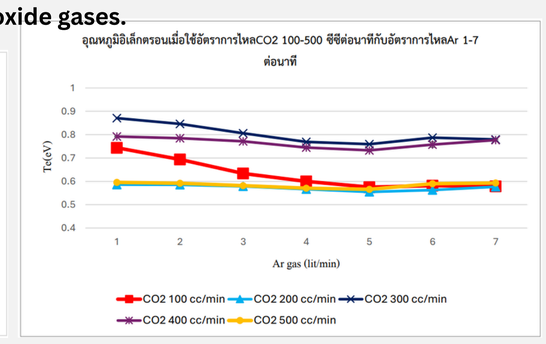




Comparison of T_e values of plasma arc at argon gas flow rates between 1 and 7 L/min showed that the Te tends to decrease , with the maximum Te being found at Ar 1 L/min, and there is a slight upward trend at argon gas at 5 liters per minute.

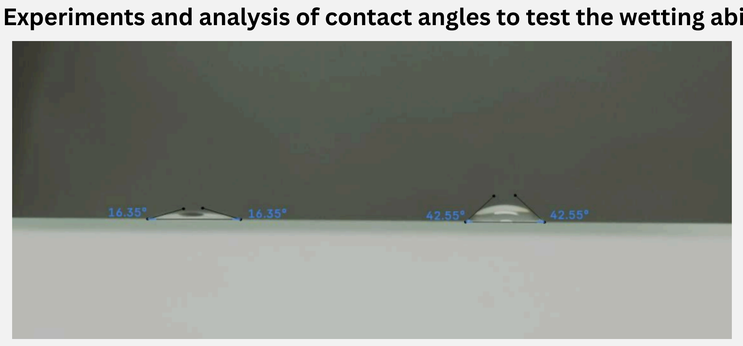
The experiment involved mixing argon and carbon dioxide gases.





Comparison of T_e values of plasma arc containing 100 to 500 cc/min of carbon dioxide at argon gas flow rates between 1 and 7 L/min showed that the Te tends to decrease for all values of CO_2, with the maximum Te being found at CO_2 300 cc/min, indicating a equilibrium condition between CO_2 and Ar gas contents.

Experiments and analysis of contact angles to test the wetting ability of glass slide surfaces.



It is measured by the contact angle a small angle indicates good wetting (hydrophilic), while a large angle indicates poor wetting (hydrophobic).