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National Recovery and Resilience Plan
OF THE REPUBLIC OF BULGARIA

Conversion of CO2 in Gliding and Stabilized Arc Discharges with Enhanced Gas Cooling

Research Group: Plasma and Gas Discharges Physics Group
Research Field: Physics

Introduction

The aim of this work is to investigate the conversion of CO_2 using an atmospheric pressure low current DC gliding arc/glow discharge. Three modifications of discharge are studied: classic gliding arc, magnetically accelerated and magnetically retarded gliding arc. In the latter two, permanent magnets sustain a magnetic field that either accelerates or retards the discharge downstream. The study investigates the effect of the gas flow, the discharge current, the electrodes material, and the distance *d* between dielectric quartz glasses on the CO_2 dissociation and energy efficiency of the process. The distance *d* is determined by the electrodes thickness, which are sandwiched between the two glasses. The results show that the increase of the relative velocity between the arc and the gas flow because of the magnetic field Lorentz force is beneficial for the performance of the CO_2 dissociation.

Experimental setup

➢ Experimental setup Figure 1 (a):

- CO_2 gas is controlled by mass flow controllers (MFC);
- Discharge device based on the classic gliding arc;
- Active cooling system (not shown in the figure);
- Electrical parameters are measured by a HV differential probe and a current probe, connected to an oscilloscope;
- The gas analysis is made with Fourier Transform Infrared (FTIR) Spectrometry, based on the absorption of a single line with wavenumber 2209 cm^{-1} (4527 nm).

➢ Discharge device Figure 1 (b):

- Discharge device based on the classic gliding arc discharge with and without magnets;
- Knife-shaped electrodes sandwiched between two quartz glass plates;
- *d* = 1 – 4 mm distance between the quartz glass plates;
- 3 different materials for the electrodes – Cu, Al, Stainless Steel;
- 3.5 mm distance between the electrodes in the narrowest distance.

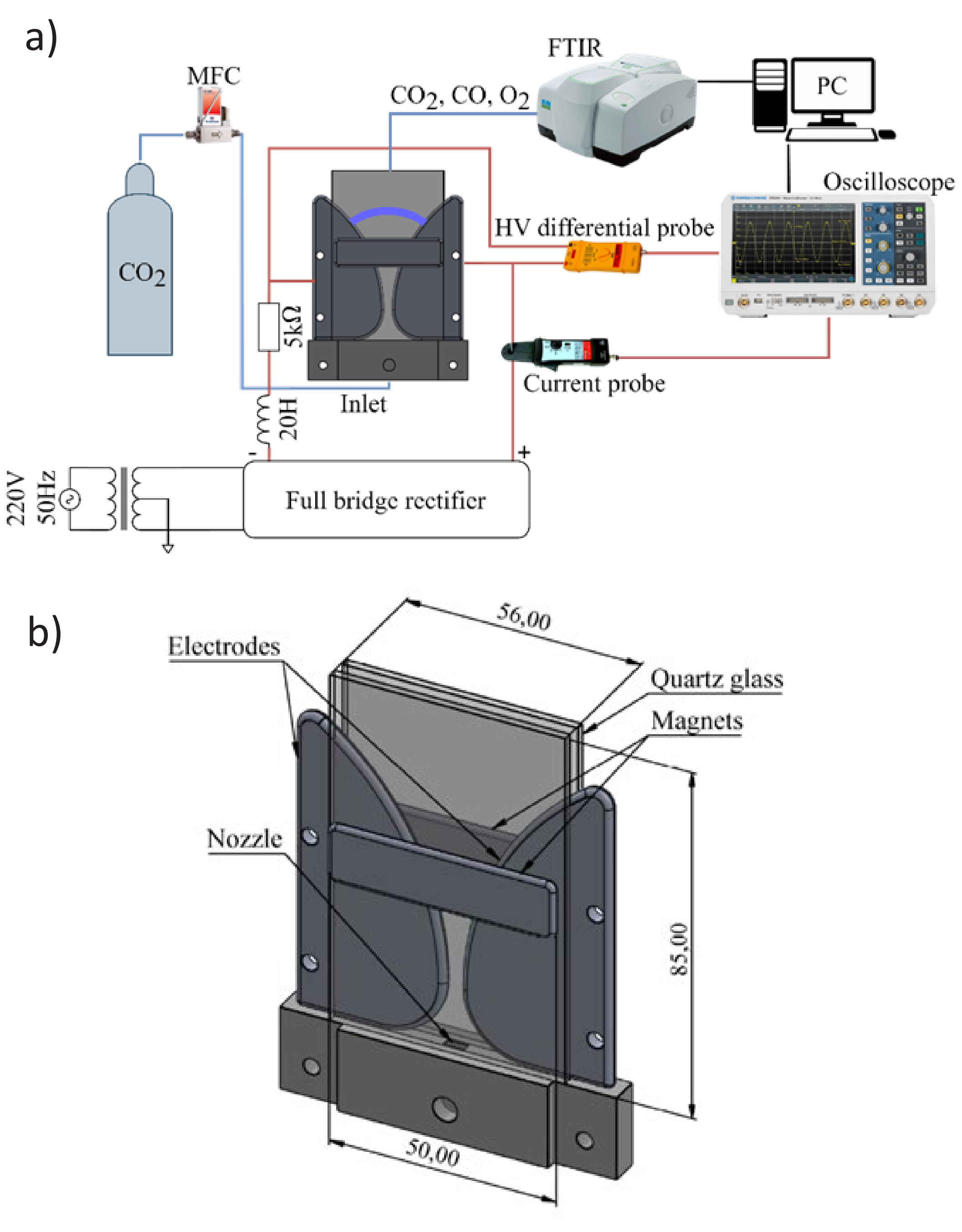

Figure 1. Schematic representation of the experimental set up (a) and the discharge device (b).

Results

➢ Quantities of interest:

- $Conv.rate\ [\%] = \frac{n_{CO_2}^{in} - n_{CO_2}^{f}}{n_{CO_2}^{in}} \times 100\%$, where $n_{CO_2}^{in}$ and $n_{CO_2}^{f}$ are the initial and the final concentrations of CO_2 respectively.
- $SEI\ \left[\frac{J}{mol}\right] = \frac{P[J/s]}{MFR\ [Ln/s] \times (1/22,4)[mol/Ln]}$, where MFR is the Mass Flow Rate of the gas.
- $\eta[\%] = \frac{Conv.rate \times \Delta H_R}{SEI} \times 100\ \%$, where $\Delta H_R = 379.8 \times 10^3\ \left[\frac{J}{mol}\right]$ is the reaction enthalpy for the CO_2 splitting reaction.

➢ Parameters:

- Gas flow rates: 2 – 12 Ln/min;
- Current values: 50, 100, 210 mA;
- Electrode thickness: 1, 2, 3, 4 mm;
- Electrode material: Cu, Al, Stainless Steel;
- Discharge configuration: GD, MAGD, MRGD.

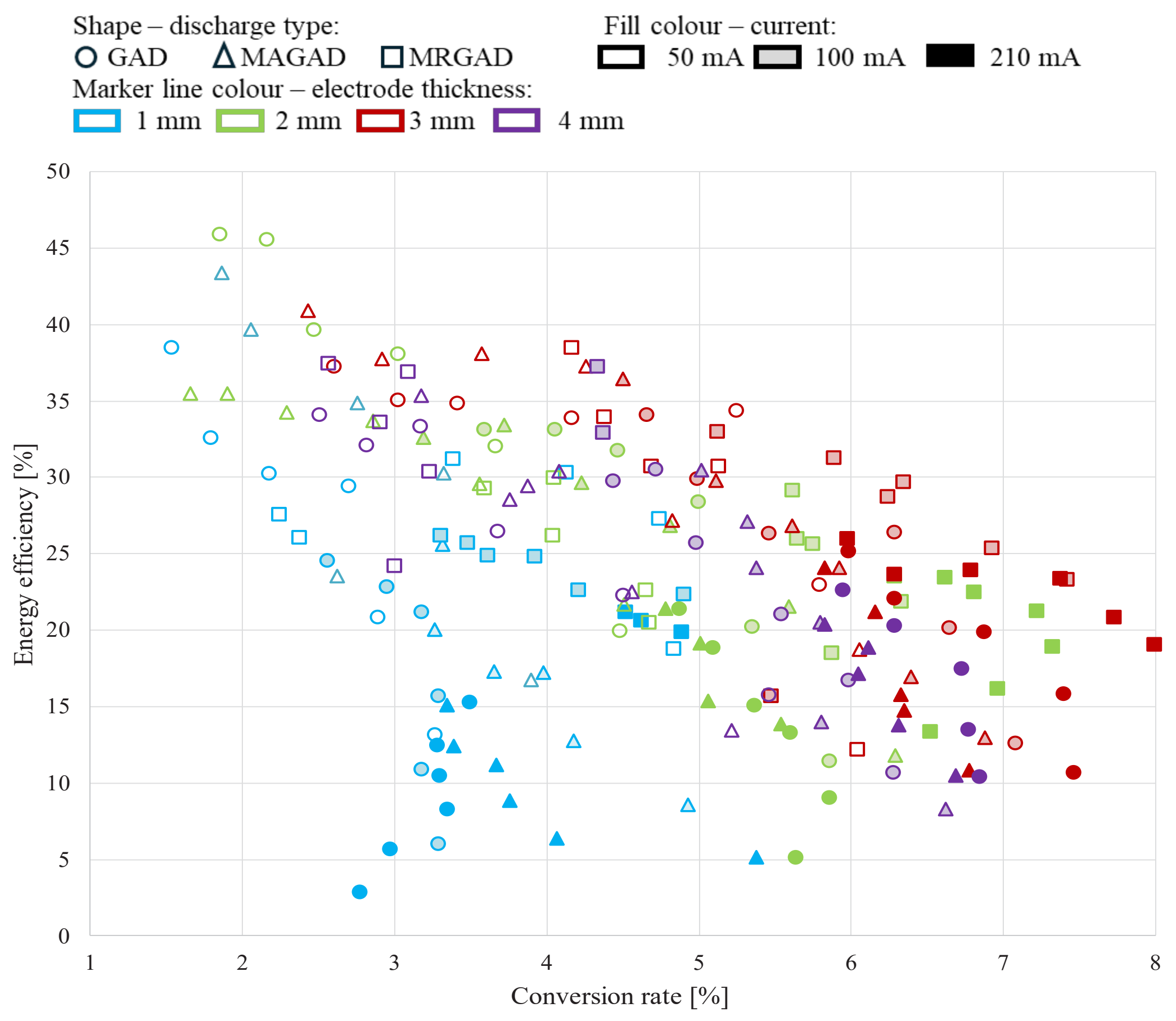

Figure 2. Energy efficiency vs. conversion rate for all configurations with Cu electrodes.

➢ Figure 2 shows the energy efficiency as a function of the conversion rate for the three different configurations with Cu electrodes at all thicknesses:

- The best overall configuration – MRGD with 3 mm electrodes at 100 mA: 6 % conversion rate and 30 % energy efficiency;
- The highest conversion rate (8%) – MRGD with 3 mm electrodes at 210 mA;
- The highest energy efficiency (35 – 40 %) achieved by MAGD and MRGD with conversion rates of 4 – 5%;

➢ Figure 3 shows the conversion rate and the energy efficiency as a function of the SEI for all configurations with 2 and 3 mm electrodes:

- The conversion rate increases with SEI;
- The energy efficiency decreases with SEI increases;
- Configurations with 3 mm electrodes achieving higher values for both parameters.

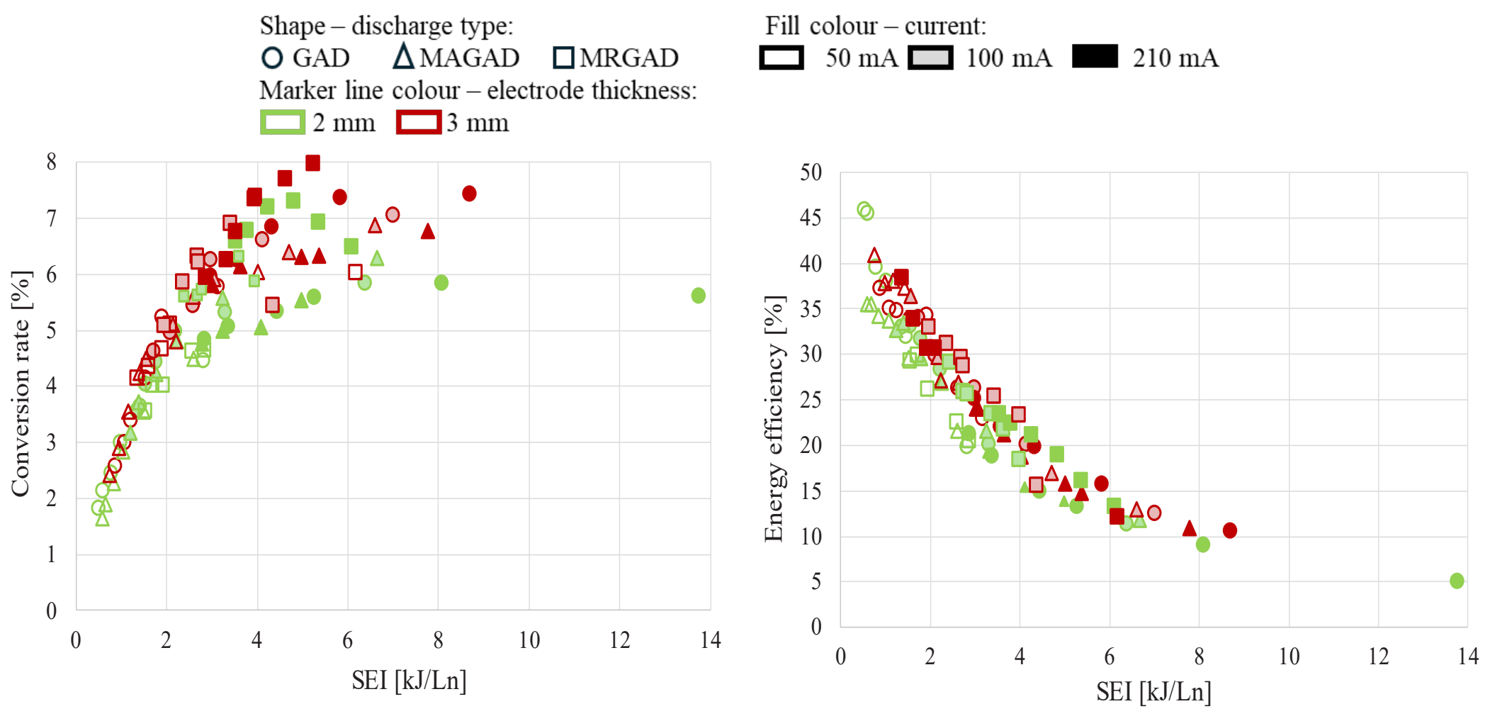

Figure 3. Conversion rate and energy efficiency as a function of SEI.

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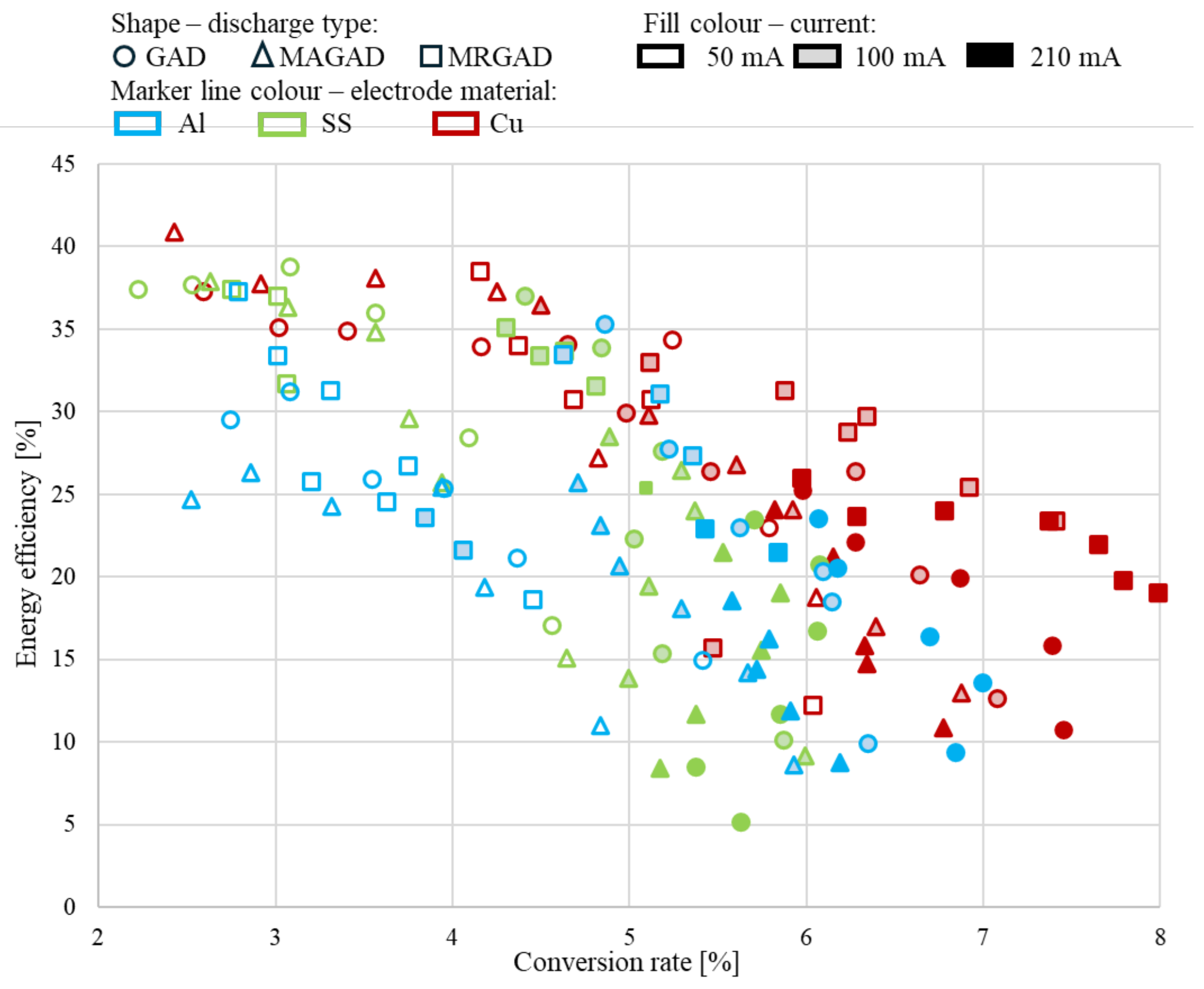

Figure 4. Plot of the obtained energy efficiency vs the CO_2 conversion rate for electrode thickness 3 mm for the three different configurations (GAD- circles, MAGAD – triangles, MRGAD - squares) with three different electrode materials (Cu, SS, Al). The discharge current is presented as the filling rate of the symbols (empty – 50 mA, semi filled – 100 mA, filled – 210 mA).

➢ Figure 4 shows the energy efficiency as a function of the conversion rate for the three different configurations with different electrode material:

- The Cu electrodes show the best overall performance;
- Cu electrodes – the best configuration is MRGAD;
- Al electrodes – no sufficient difference between the MRGD and GD;
- Stainless steel electrodes – no configuration has a clear advantage.

Conclusion

Three different configurations are studied: GD, MAGD, MRGD with respect to active cooling.

The results at different wall distances show that:

- The distance between the walls strongly affects the conversion rate and the energy efficiency;
- A distance of 1 mm shows the worst overall performance;
- Wall distances of 2 and 3 mm show the best overall performance;
- Distance of 4 mm leads to reduced conversion rate;

In terms of electrodes material, the Cu electrodes tend to show the best performance.

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