Mediated electrochemical recovery process of copper from waste printed circuit boards

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Introduction

Waste printed circuit boards (WPCBs) are the most important high Cu content fractions of e-waste and their amount is projected to increase significantly due to relatively short and continuously decreasing lifespan of mobile phones, computers, printers, radio, TV sets etc. as a result of rapid changes in characteristics and performance [1]. If both economic value and eco-toxicity are considered copper has the highest recovery priority instead of precious or other base metals due to the fact that adding 1 t of Cu to electricity consuming equipment, such as motors and transformers can save 100 to 7500 t of CO_2 emissions, 0.5 to 50 GWh of primary energy, and 24 k€ to 2.4 M€ over their lifetime [2, 3]. Also, by 2027, more than 100 kt of Cu will be needed to build 40 million charging points for electric vehicles coming on the market [1]. All this data prove that Cu is expected to be a cornerstone of a low-carbon future but requires innovative and eco-friendly solutions that can be applied at industrial level for its recovery from WPCBs. Unfortunately, many recycling technologies neglect the environmental aspects and importance of copper for the achievement of a carbon neutral economy, and target only the recovery of precious metals from the electronic components found on WPCBs while the recovery of copper from these Cu rich wastes is not exploited at full potential. To respond to these crucial issues and considering the experience and success with mediated electrochemical processes, the same approach was used for the cost-effective and flexible recovery of Cu from WPCBs. The developed process uses the $SO_4^{2-}/S_2O_8^{2-}$ redox system which allows $CuSO_4$ or Cu sheets production with minimal involvement of auxiliary materials because the oxidant form of the redox system can be regenerated by anodic oxidation in parallel with Cu deposition at the cathode. To promote the recovery of high purity copper, only the electronic component free base boards are used, which are obtained in a preliminary dismantling step.

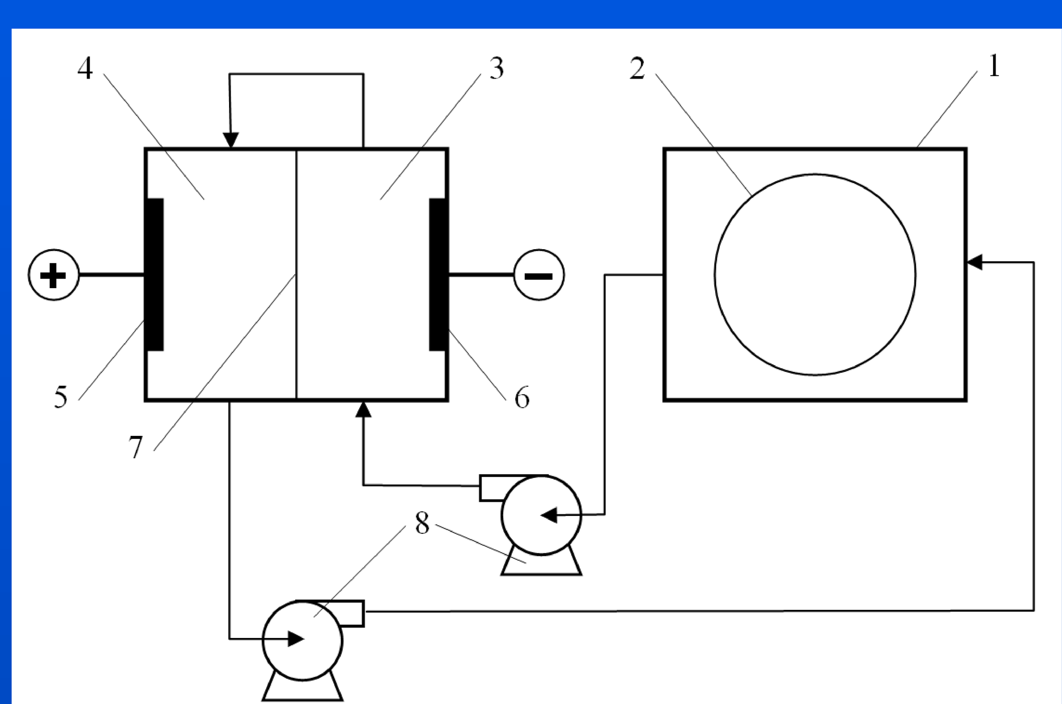


Figure 1. Experimental setup: leaching reactor (1), rotating perforated drum (2), cathodic (3) and anodic (4) chambers, lead anode (5) and stainless-steel cathode (6), CEM (7), pump (8).

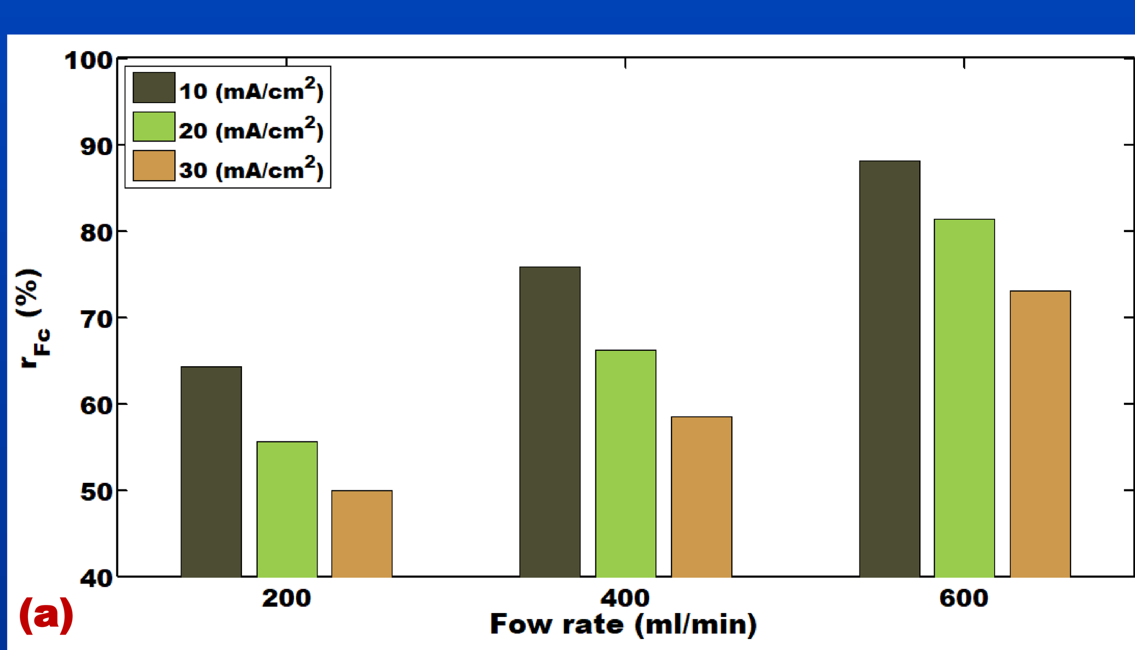
EXPERIMENTAL CONDITIONS

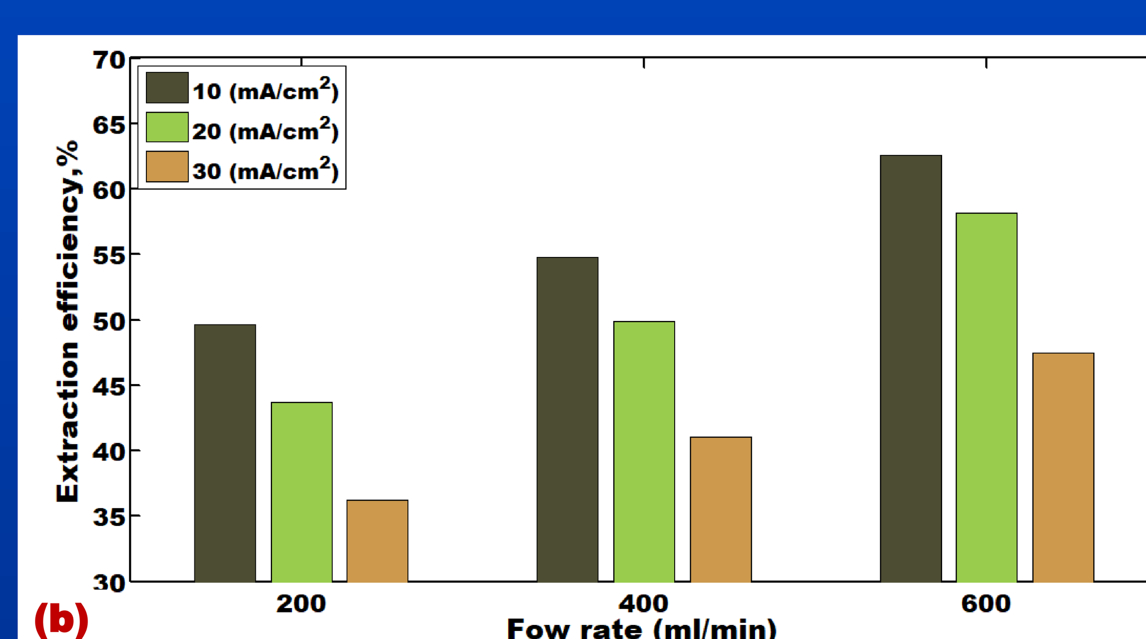
- **Electrolyte composition: 0.5 M $Na_2S_2O_8$ & 0.1 M $CuSO_4$**
- **Leaching reactor volume: 200 mL**
- **Compartmented electrochemical reactor: 200 mL**
- **Galvanostatic mode: 10-20-30 mA/ cm^2**
- **Processing time: 2 h**
- **Reference electrode: Ag/AgCl/$KCl_{(sat)}$**
- **Flow rate: 200- 400 – 600 ml/min**
- **Drum rotation speed (30 rpm)**
- **Solid/liquid ratio(1/5)**
- **Computer equipped system**
- **Potentiostat / galvanostat: DXC236 (5 A, ± 20 V)**

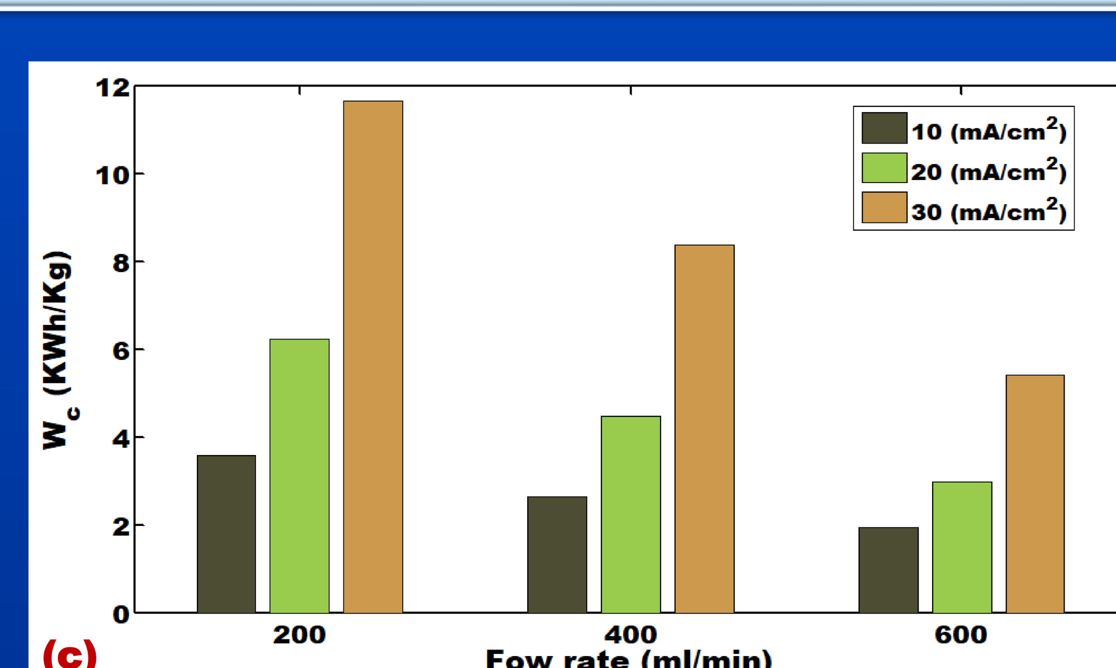
Key technical performance indicators

Extraction efficiency (%): the ratio between the amount of electrodeposited Cu and total dissolved Cu.
Current efficiency (%): the ratio between the amount of electricity used for the formation of the cathodic deposit and the total amount of electricity consumed in the process.
Dissolution degree (%): the ratio between the amount of dissolved Cu and the total amount of Cu in the initial sample.
Specific cathodic energy consumption (KWh/Kg): the amount of energy used for the formation of 1 Kg of cathodic deposit.
Specific energy consumption for the dissolution process (KWh/Kg): the amount of energy for the dissolution 1 Kg of Cu.

Results & Discussion







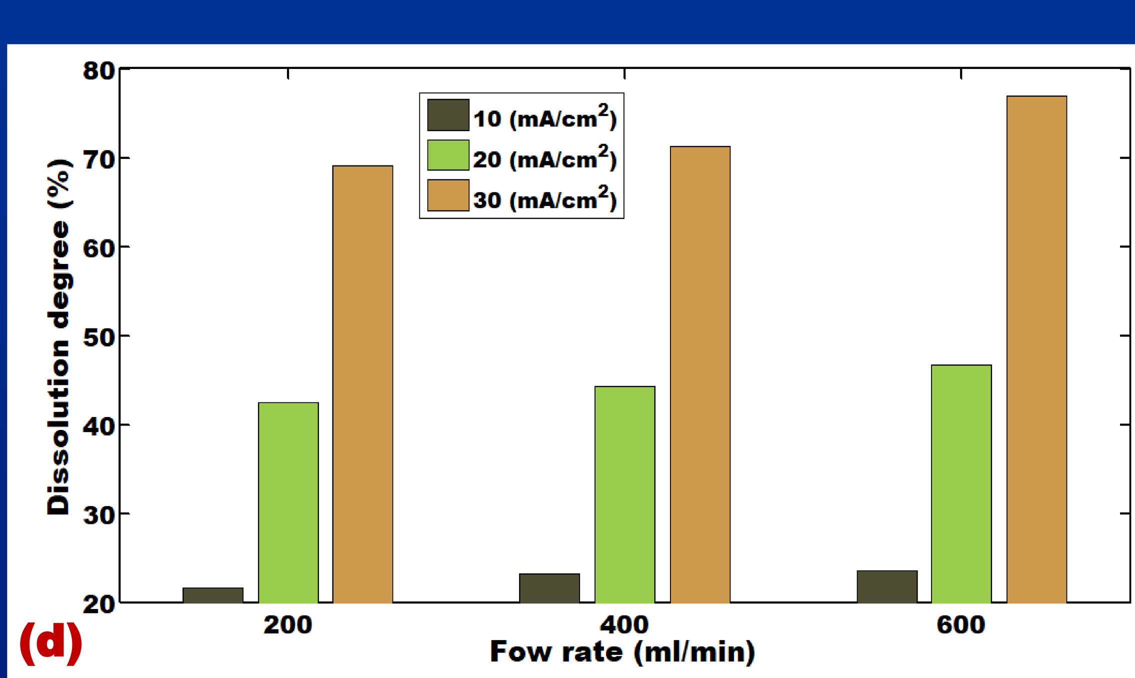
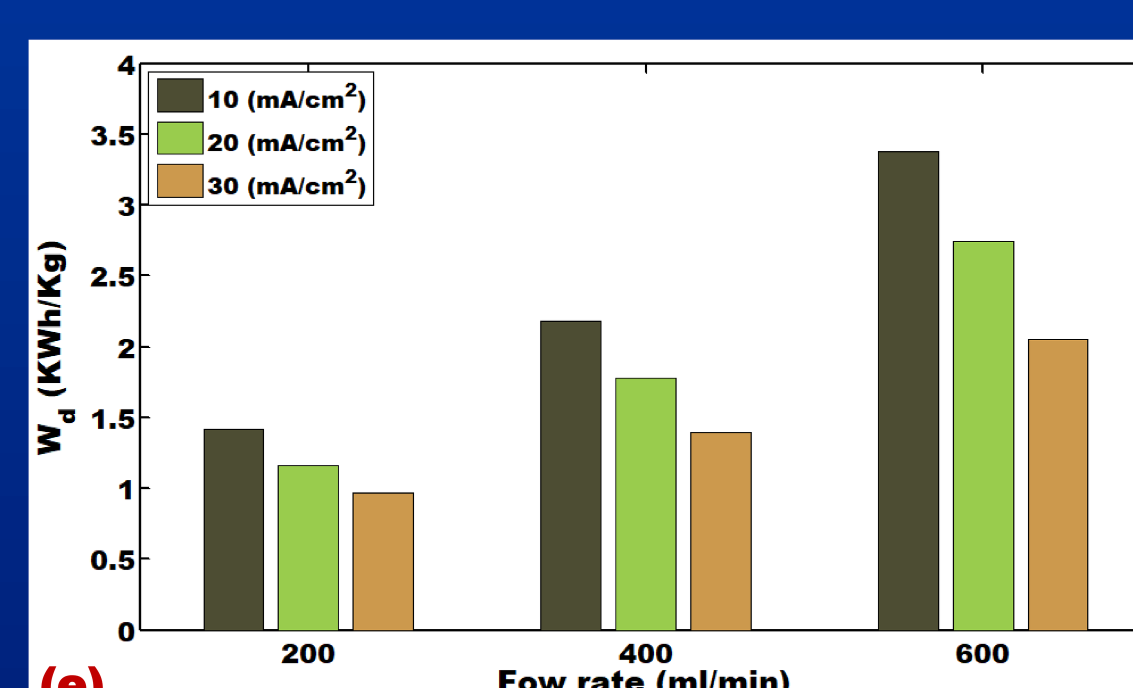


Figure 2. (a) current efficiency, **(b)** extraction efficiency, **(c)** specific cathodic energy consumption, **(d)** dissolution degree, and **(e)** specific energy consumption for the dissolution process at different current densities and flow rates.



Conclusions

- ► **In the current study it has been demonstrated that the $SO_4^{2-}/S_2O_8^{2-}$ redox system can be used efficiently for the mediated electrochemical recovery of Cu from waste printed circuit boards.**
- ► **Based on the experimental results it can be stated that highest amount of Cu can be recovered the most efficiently at the lowest current density and the highest flow rate.**
- ► **It was found that in the best operating conditions the purity of the obtained Cu deposit was more than 99 wt.% which makes it suitable for many industrial applications.**

References

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