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Ink formulation for gravure printed Lithium-ion batteries

Maria Montanino, Anna De Girolamo Del Mauro, Claudia Paoletti, Giuliano Sico
ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development
maria.montanino@enea.it

Introduction: Driven by the growing interest on printed batteries [1], gravure printing was recently successfully proposed for the production of electrodes for lithium-ion batteries (LiBs) [2,3]. Printing is a highly sustainable production method which offers many advantages even compared to the conventional coating techniques. In particular, among the printing techniques, gravure is the only one able to couple high speed and high resolution, resulting very appealing for the mass production of functional layers, even in case of large area, and of any shape and pattern [4]. Despite of its many advantages, gravure printing is few investigated because of the necessity to use low viscosity ink, which make difficult to obtain the proper functionality of the layer, especially in case of composite materials, and a mass loading suitable for practical use. Moreover, every time the materials are changed, a new suitable ink has to be formulated. Considering the feasibility of such technique in the field of LiBs, to boost its possible industrial manufacture, the ink formulation and preparation have to be ruled. For this purpose, a systematic study on the ink formulation of different materials has to be carried out. Here a study on the ink formulation and preparation of different materials for the production of electrodes for LiBs is proposed.

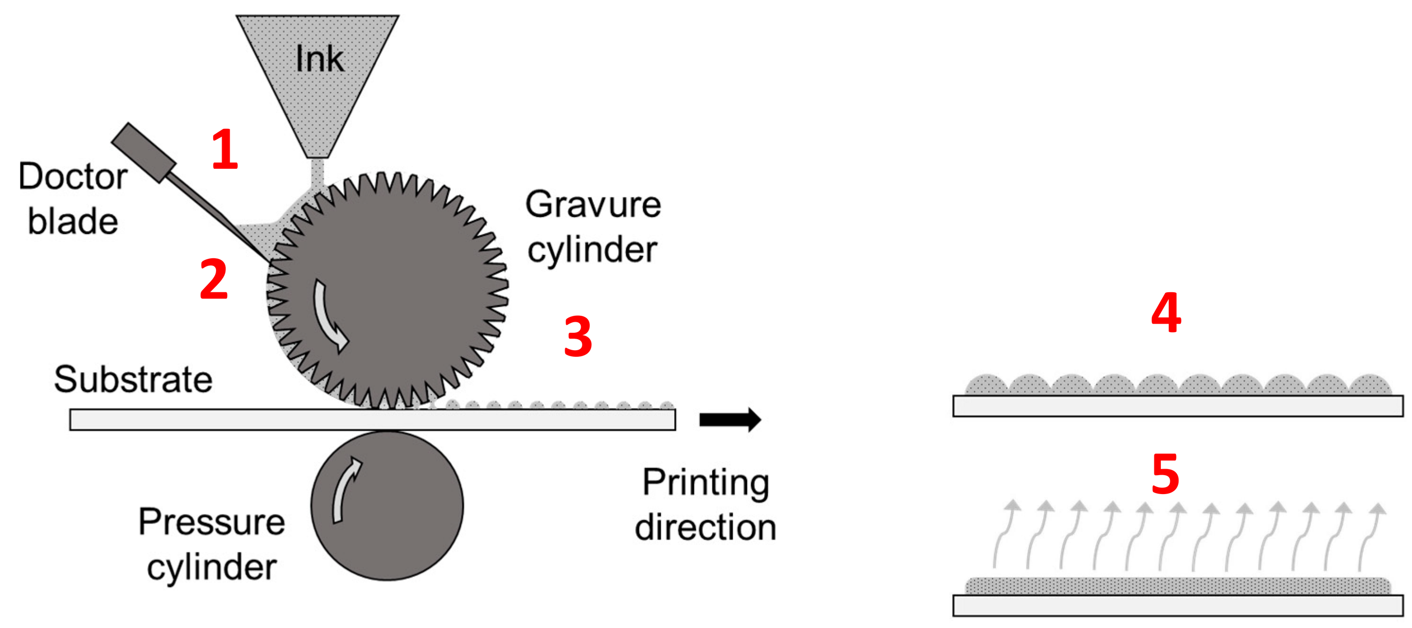
Method: aimed by the propose to prepare a gravure printable ink for the electrodes manufacturing, the combination of several requirements and experimental tests has to be made.
Material components:
- Active material (80-85 wt%) acordding to the type of electrodes to be gravure printed a suitable active material has to be selected
- Conductive carbon (5-10 wt%) the electric conductivity requires the presence of a conductive carbon coating the active material
- Binder (<10 wt%) for the mechanical stability of the membrane
- Solvents for the printing process

Gravure ink requirements:
- The viscosity of an ink suitable for gravure printing has to be lower 100 cP
- The dry content has to be lower than 20 wt%
- The ink surface tension has to be lower than the substrate surface energy

experimental:
Ink preparation ➡ ink charachterization ➡ printing test ➡ ink/layer optimazation ➡ test in device

Gravure printing process: is composed of several sub-processes:

1. *Inking*
2. *Doctoring*
3. *Transfer*
4. *Spreading*
5. *Drying*



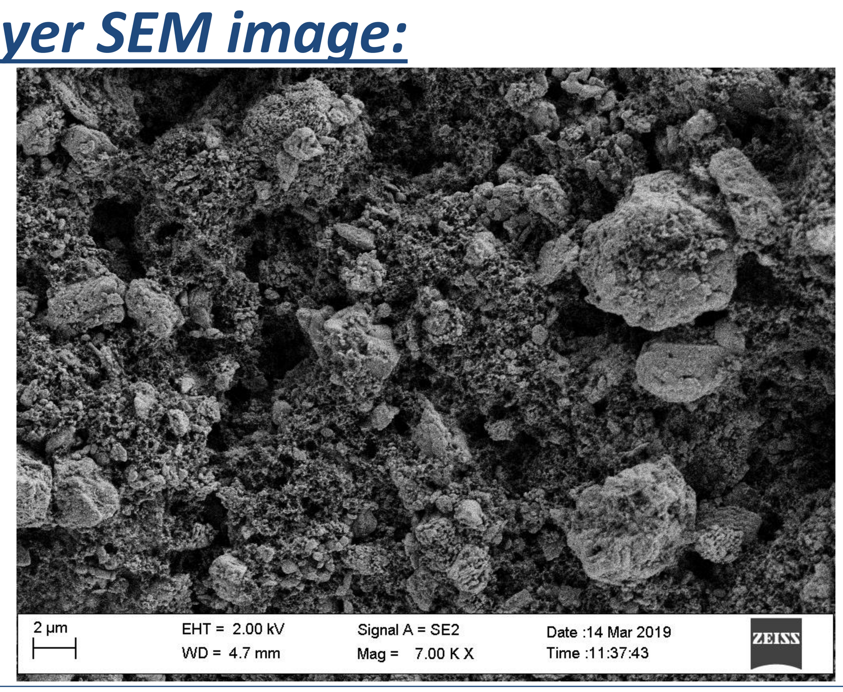
Example of study case

Materials:
- ***Active material: $LiMn_2O_4$***
- ***Conductive carbon: Super P***
- ***Binder: carboxymethyl cellulose*** water soluble for green purpose
- ***Solvents: water + isopropanol*** water
- is the main sovent enhanching the sustainability of the manufacture; isopropanol decrease the surface tension improving the printability

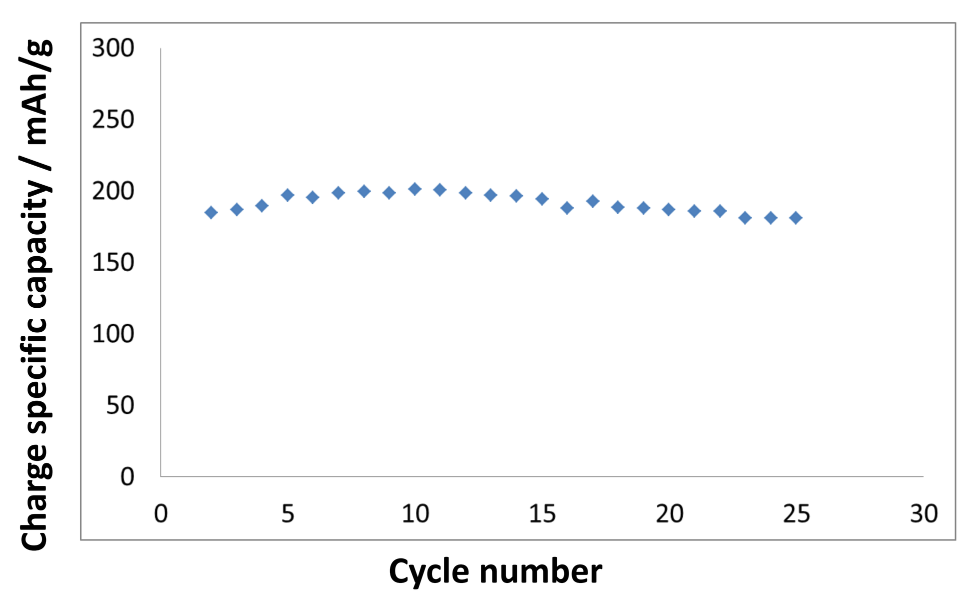
Ink charcaterization:

Ink dry content (%)	Viscosity (mPa s)	Density (g/cm^3)
22	150	5,63
20	120	5,29
18	93	5,19
16	82	5,00

Layer SEM image:



Test in device:



Conclusion: The possibility to gravure print electrodic layers was proven. The advantages related to the production method are relevant and induce to further investigate such technique as viable industrial production method to enhance the sustainability of the batteries production. A systematic study can allow to overcome the challenge related to the ink preparation, creating an automatable path for their production. Such automatable path includes the ink formulation, percentage of components and dry content, the choice and the amount of solvents, and the ink preparation methodology, pushing the use of such technique at industrial level.

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