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# Synthesis and structure modification of Ionic Liquids to optimize their thermoelectric properties

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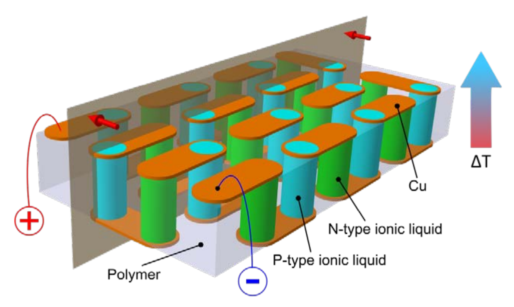
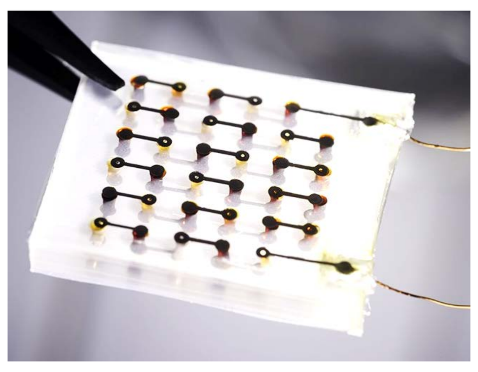
## Introduction

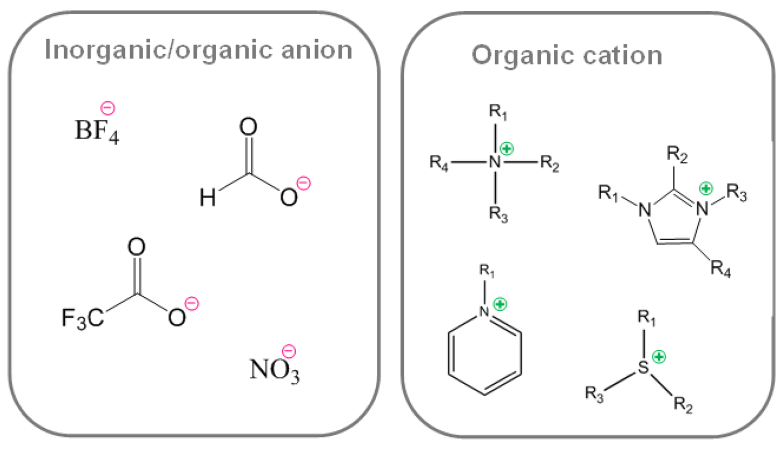
Ionic Liquids (ILs) are organic salts with a melting temperature typically below 100° C. The special properties of ionic liquids such as their excellent chemical and thermal stabilities, low vapor pressure and important ionic conductivity make them interesting compounds in material science and especially as **thermoelectric generators (TEGs)** for medical, pharma or electronic applications.[1] The majority of R&D groups work with TEGs based on rigid materials. The use of ILs in the TEGs improves the **flexibility** of the devices to reach this way.



## Ionic liquids

- Thermal stability
- Simple synthesis
- Usually liquid at room temperature
- Low thermal conductivity
- Lots of possible cation/anion combinations
- N-type and p-type



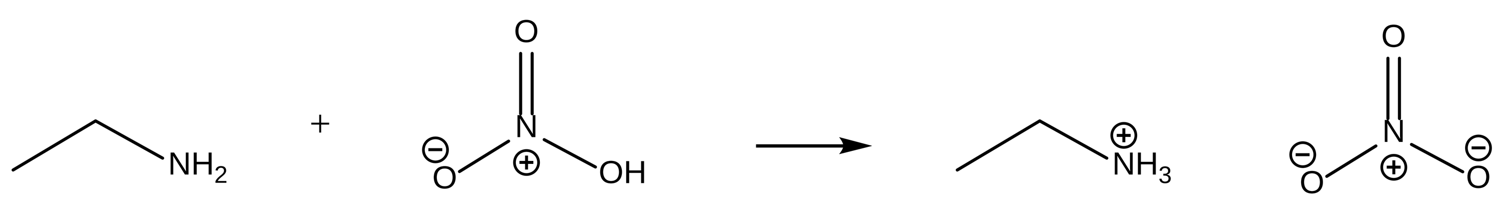



**Figure 1**: Example of a typical synthesis of a ionic liquid (Ethylammonium nitrate).

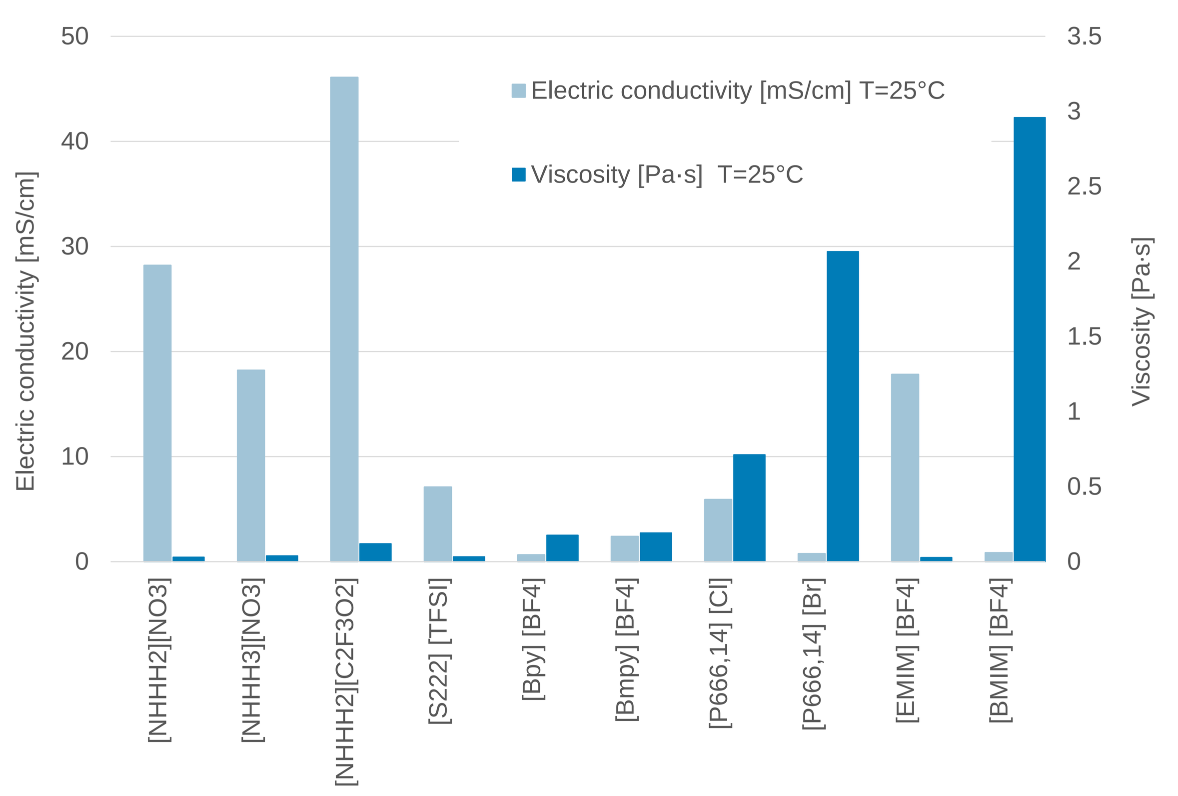



**Figure 2**: Comparisons of viscosity and electric conductivity for different Ionics liquids.

## Design of the test cell

The characterization of the ionic liquids as well as the current-voltage characteristic of the thermoelectric generators have been performed in specially designed test cells.

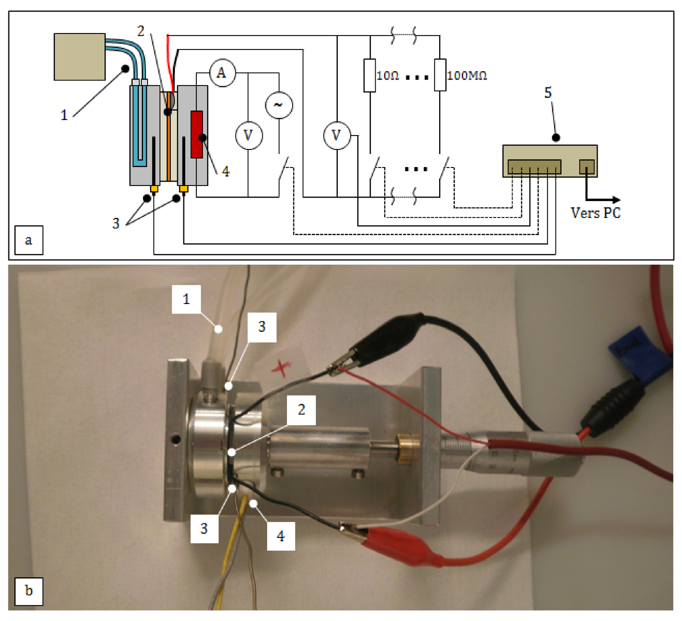



**Figure 3**: a. Scheme of the cell, b. Picture of the cell, 1. cooling system, 2. TEG, 3. Thermocouple, 4. heating system, 5. Data acquisition system Agilent.

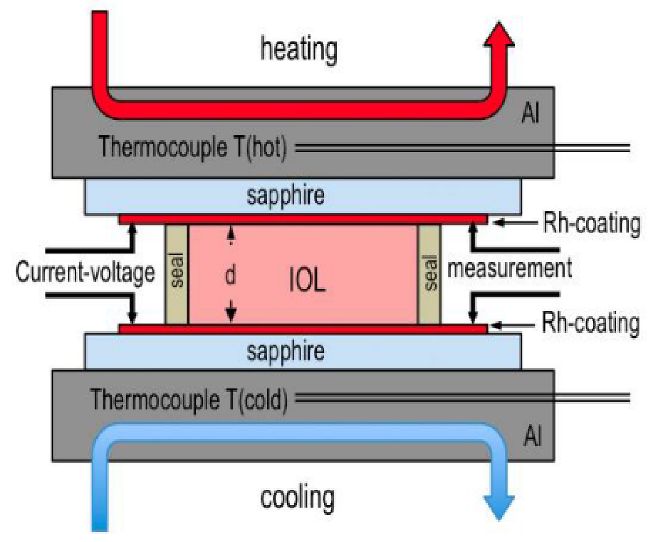



**Figure 4**: Zoom on the TEG.

## Seebeck coefficient and power demonstrator

The magnitude of the Seebeck effect is the response to a temperature difference between two electrodes where a voltage is induced. The Seebeck coefficient describes the thermoelectrical power. Positive and negative Seebeck coefficients (dV/dT) can be obtained (Figure 5), depending on the molecular structure and the viscosity of the ILs. To maximize the thermoelectric performance (Z), lower thermal conductivity (λ) and higher electrical conductivity (σ) are needed.

$$Z = \left(\frac{dV}{dT}\right)^2 \cdot \frac{\sigma}{\lambda}$$

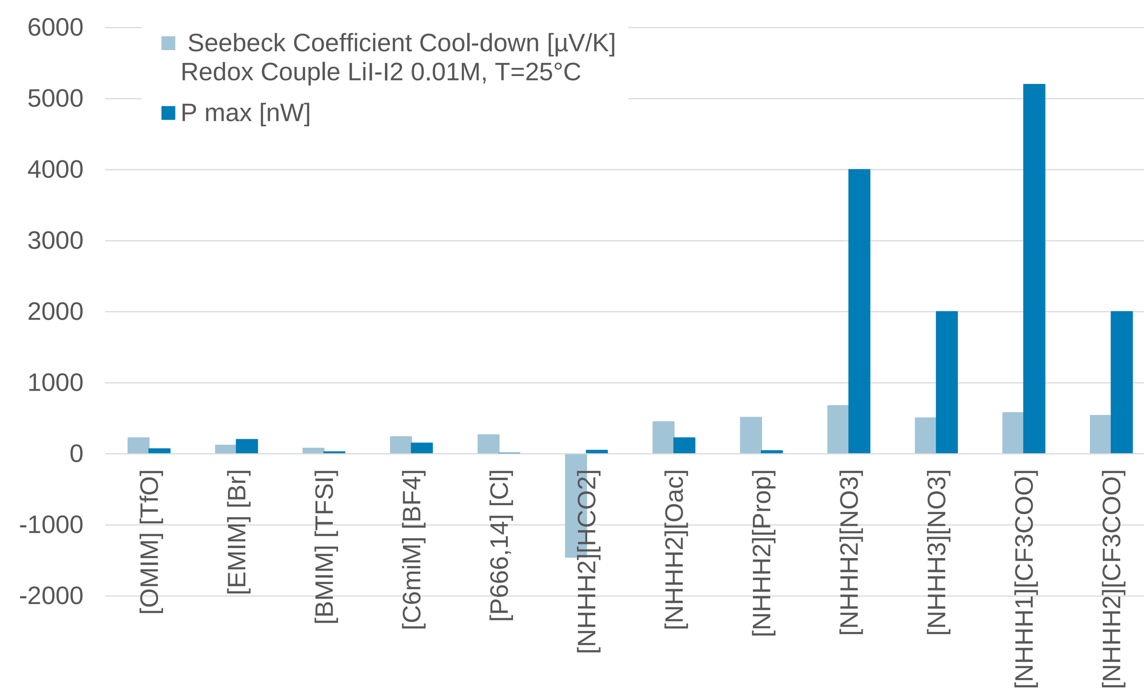



**Figure 5**: Comparison power demonstrator and Seebeck coefficients for different Ionics liquids.

## Conclusion

ILs offer a unique suite of properties that make them important candidates for energy applications. The biggest advantage of ILs is the endless number of cation/anion combinations, which allows task-specific ionic liquids synthesis for each applications, e.g. TEGs. The choice of the anion has a great influence on the Seebeck coefficient and a lower alkyl chain length in the cations affords the highest efficient results for the thermoelectrochemical devices.[2] Propylammonium formate and ethylammonium acetate are selected as the best ILs. A remarkable voltage of **11mV/K** is obtained with a gradient of temperature of **20K**.

[1] Siddique, T.A., et al., Synthesis and characterization of protic ionic liquids as thermoelectrochemical materials. Rsc Advances, 2016. 6(22): p. 18266-18278.
[2] Uhl, S., et al., Development of Flexible Micro-Thermo-electrochemical Generators Based on *Ionic Liquids.* Journal of Electronic Materials, 2014. **43**(10): p. 3758-3764.