Picolinium-based Eutectic Systems in the Lubrication of Silicon Surfaces

Mariana T. Donato[a,b], Hermínio Diogo[a], Luís Santos[a], Rogério Colaço[c], Luís C. Branco*[b], Benilde Saramago*[a]

[a] Centro de Química Estrutural, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

[b] LAQV-REQUIMTE, Departamento de Química, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus da Caparica, 2829-516 Caparica, Portugal

[c] IDMEC-Instituto de Engenharia Mecânica, Departamento de Engenharia Mecânica, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal. * *Corresponding authors: l.branco@fct.unl.pt; b.saramago@tecnico.ulisboa.pt*

Introduction

Eutectic systems (ESs) have recently been proposed as "green" alternatives to mineral oils and ionic liquids (ILs) in the lubrication of several surfaces.[1, 2] ESs have similar physical properties to ILs but have the advantage of being cheaper and easier to prepare. In a previous work, we have synthesized Sulphur-containing ESs that showed very interesting lubrication properties.[3] Herein, new picolinium salts-based ESs were prepared and tested in the lubrication of silicon surfaces which are relevant for Nano/microelectromechanical systems (NEMS/MEMS). All prepared ESs were characterized in terms of their viscosity, wettability and tribological properties. The friction coefficients were measured using steel spheres against Si surfaces. The most promissory ESs showed a good tribological performance, both in terms of friction and wear reduction comparing to commercial lubricants.

Ionic Liquids have several applications

- Alternative solvent for synthesis and catalysis
- Electrochemistry
- Chemical Engineering
- Biology
- Pharmacy

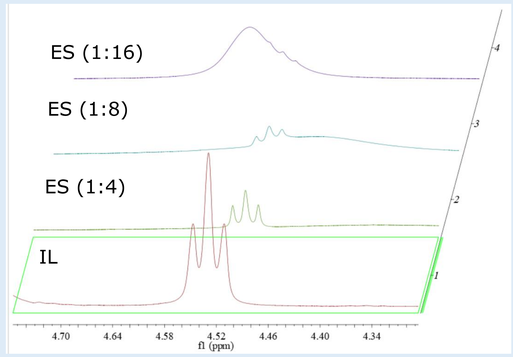
BUT... **Too expensive** → **Eutectic Systems** (mixture of IL – hydrogen bond acceptor - and base oil) ⇒ **Cheaper**

Nano and Micro electromechanical devices (NEMs and MEMs) → **Lubrication** (Si surfaces)

Adequate lubricant that forms a thin film between the sliding surfaces

^{1}H-NMR, ^{13}C-NMR, ^{19}F-NMR → FTIR → Elemental analysis → Contact angle → Water content → Viscosity

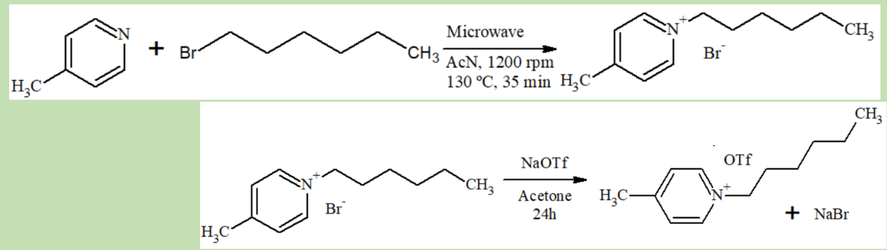
NMR results



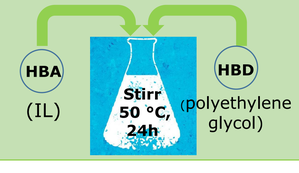
All peaks shift from 4.53 ppm to 4.51 ppm.

IL synthesis and ESs preparation

Steps 1&2: Synthesis of the Ionic Liquid (microwave method) + ionic exchange reaction



Step 3: Eutectic systems preparation



Molar proportions
[C_6-4-pic][TfO]:PEG200 (1:4)
[C_6-4-pic][TfO]:PEG200 (1:8)
[C_6-4-pic][TfO]:PEG200 (1:16)

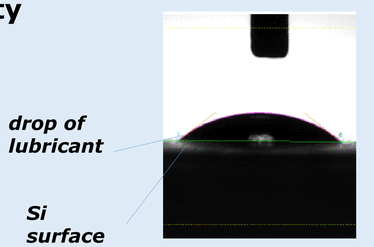
DSC characterization

Sample	Tg/ °C	ΔCp/ J(mol·°C)
PEG 200	-83.42	0.00476
ES (1:4)	-80.64	0.00075
ES (1:8)	-80.21	0.00040
ES (1:16)	-82.15	0.00028

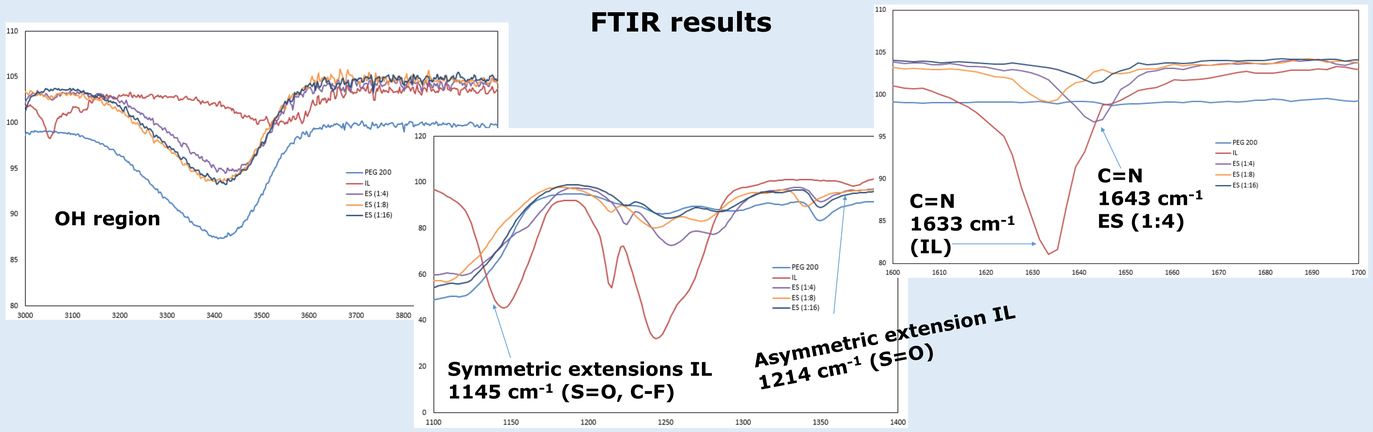
The values of T_g are too close, so no relevant conclusions were taken from the DSC results.

Wettability and viscosity

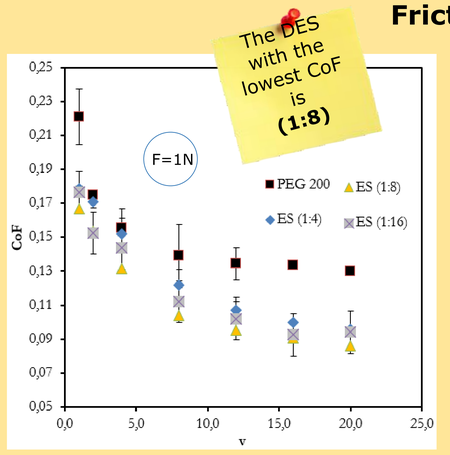
Sample	Contact angle/ °	Viscosity/ mPa·s^{-1}
PEG 200	28±2	53
ES (1:4)	35±2	80
ES (1:8)	41±2	75
ES (1:16)	43±1	66

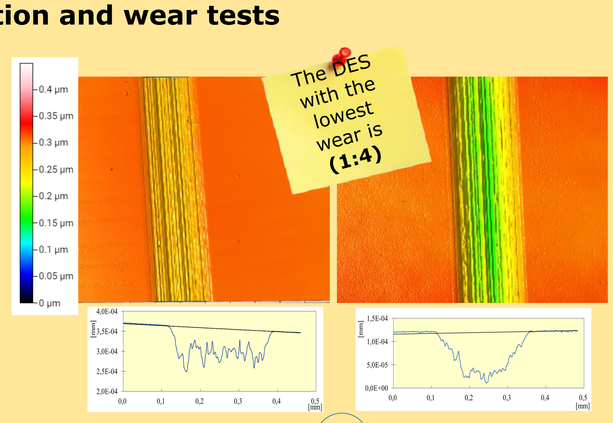


FTIR results



Friction and wear tests





Wear volume (PEG 200) = (7±1)*10^{-5} mm^3

F=8N

Wear volume (ES 1:4) = (5.5±0.3)*10^{-5} mm^3

Conclusions

✓Microwave-assisted synthesis was successfully performed for a picolinium-based ionic liquid.
✓[C_6-4-pic][TfO]:PEG 200 (1:8) yielded the lowest CoF values.
✓[C_6-4-pic][TfO]:PEG 200 (1:4) was the most efficient at protecting the Si surface from wear.

References:
[1] M. T. Donato, . Colaço, L. C. Branco, B. Saramago, *J. Mol. Liq.* 333 (2021).
[2] A. Somers, P. Howlett, D. MacFarlane, M. Forsyth, *Lubricants* 1 (2013) 3–21.
[3] M. Antunes, M. T. Donato, V. Paz, F. Caetano, L. Santos, R. Colaço, L. C. Branco, B. Saramago, *Tribol. Lett.* 68 (2020) 1–14.

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