Environmentally Friendly Polyurethane (PU) Materials for Space Applications

Tomas Vlcek, **TOSEDA s.r.o.** (Czech Republic)
Ugis Cabulis, **Latvian State Institute of Wood Chemistry** (Latvia)
Arturs Jasjukevic, **Ariane Group GmbH** (Germany)
Malgorzata Holynska, **ESA-ESTEC** (The Netherlands)

General target

- Development of novel eco-friendly polyurethane materials avoiding use of toxic non-isocyanate based PU materials for versatile applicability in aerospace industry:
  - a/ potting systems (spacecrafts manufacturing),
  - b/ conformal coating (spacecrafts manufacturing), and
  - c/ thermal insulation foams (launchers manufacturing).

Requirements

- Elimination of toxic isocyanates used in traditional production of PU materials
- Minimization of health and ecological risks
- Sustainability aspect – use of renewable resources such as non-edible vegetable oils

Development of „Green“ Polyurethane Materials for Use in Spacecraft and Launcher Applications

ESA Contract No. 4000119685/17/NL/KML
2017 - 2019
Targeted TRL = 3-4

TOSEDA s.r.o. (CZ)
- SME
- Prime-Contractor
- Design, formulation, preparation and testing of HNIPU materials

ArianeGroup GmbH (DE)
- Large Systems Integrator (LSI)
- Sub-Contractor
- Definition of industrial requirements and evaluation of HNIPU materials

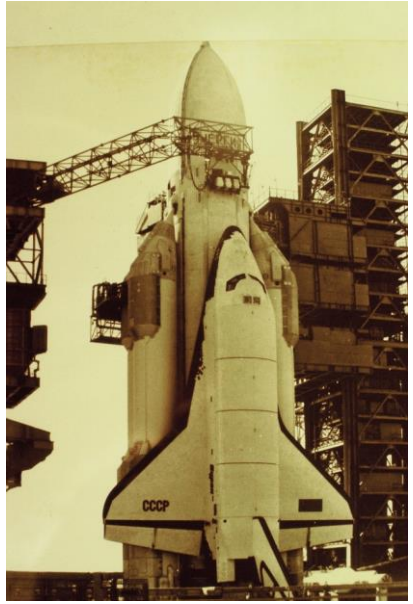
Latvian State Institute of Wood Chemistry (LV)
- Non-profit organization
- Sub-Contractor
- Semi scale of HNIPU foams by spraying and testing

TOSEDA s.r.o.

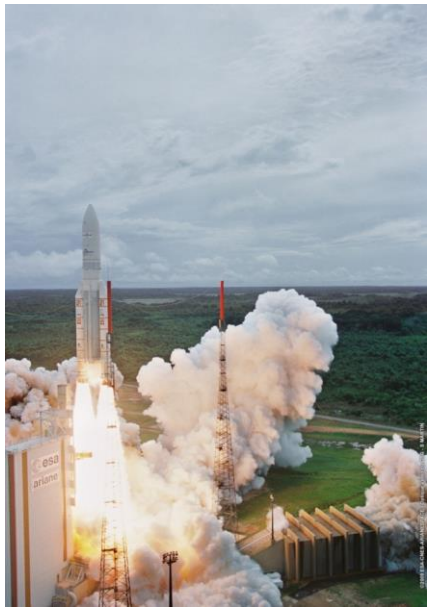
- 2010 - SME (Czech Republic)
- 2012 - Custom design, development and commercialization of polymeric and nanocomposite materials for hi-tech applications
- 2012 - registered at ESA
- 2013 - membership at Czech Space Alliance
- Space projects:
  - **Study of the LH2 Protective Layer Performance** (2013)
  - **Elastomers for Heat Shield Systems** (2013-2015)
  - **Development of Epoxy Based Syntactic Foam Encapsulant:** 3rd Call for Outline Proposals under the Czech Industry Incentive Scheme (2013-2016)
  - **Resin Development for Cryogenic Applications:** FLPP3 program (2014-2015)
  - **Nano-Hybrid Transparent Materials:** TRP program (2014-2016)
  - **Thermal Joint:** NEOSAT program (2014-2015)
  - **Design of Inner Wetted Thermal System for LH_2 Metallic Tank:** FLPP3 program (2014-2016)
  - **Carbon Nanotube Technology and Engineering for Various Space Applications (NATAP):** GSTP program (2016-2018)
  - **Electrically Conductive „Black Primer“:** TRP program (2017-2018)
  - **Development of „Green“ Polyurethane Materials:** TRP program (2017-2019)
  - **Thermal Joint Development for NEOSAT - Phase C:** ARTES Neosat Phase C program (2017-2019)
  - **Extended Pot Life Resins for Out of Autoclave Processing for Large and Complex Part:** GSTP program (2018-2020)

Latvian State Institute of Wood Chemistry

History



Present – cooperation with ESA and ArianeGroup



LS IWC mission is the development of knowledge-based, environment friendly low-waste technologies for obtaining competitive materials and products from wood and other plant biomass for sustainable utilisation of natural resources for economic, social and ecological benefits.

- Founded in 1946
- 118 employees;
- 38 Dr.

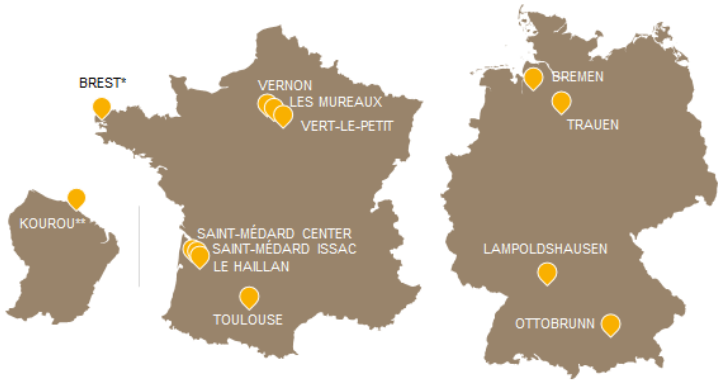
Cooperation with ArianeGroup (former Airbus DS; Airbus SL; ...) since 2004: development of ETI and IWTI

- Rigid Polyurethane Foams for External Tank Insulation for Launcher Upper Stages (**CRYOFOAMS**), 2015 – 2017
- Light Weight Polyurethane Insulation for the Bulkhead of Ariane Rocket, Produced with Next Generation Blowing Agents and Environmentally Friendly Catalysts (**CRYOFOAMS-LW**) 2018 - 2020

Development of Biobased Cryogenic Insulation Modified with Nanocrystalline cellulose

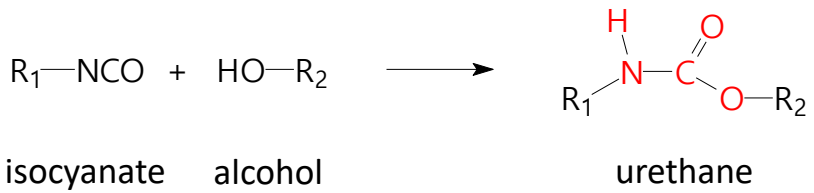
ArianeGroup

- A world leader in access to space, serving institutional and commercial customers and supporting Europe’s strategic independence
- 9000 employees, 11 subsidiaries & main affiliates
- 50/50 joint company between Airbus & Safran
- Main projects:
  - Ariane 5
  - Launch Services
  - Ariane 6
- Development and industrial application of the External Thermal Insulation (ETI) for the application on the Ariane 6 launch vehicle
- In the frame of the “Green” PU project:
  - Providing LSI inputs, as well as support in testing



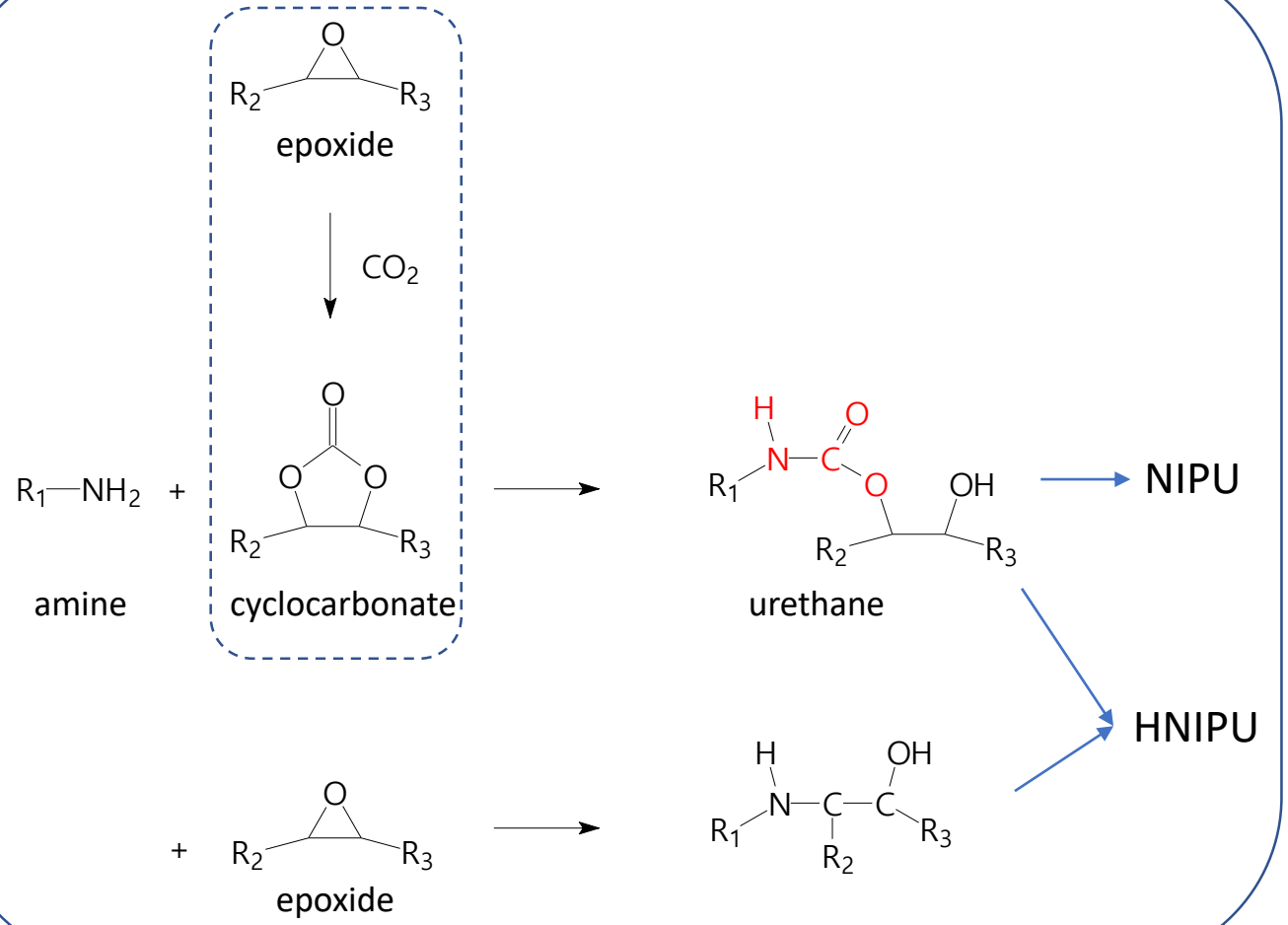
Approach

Traditional polyurethane synthesis



vs.

Non-isocyanate polyurethane synthesis



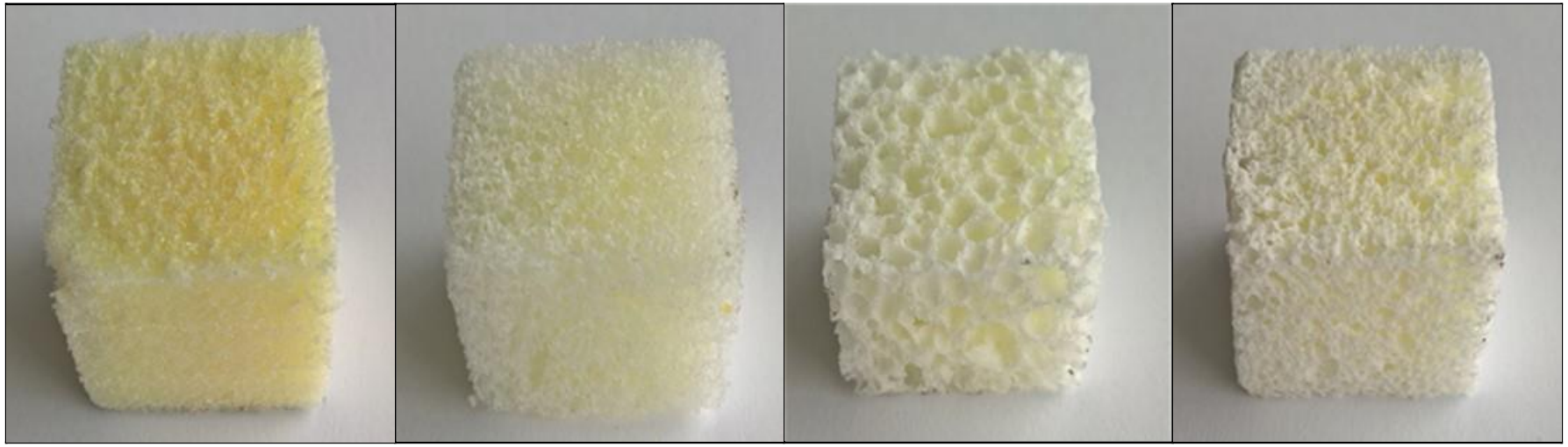
Synthesis of cyclocarbonates

Photo of TOSEDA’s laboratory pressure reactor set-up.

- Pressure: 40 bars (CO_2 inlet)
- Temperature: 110 °C (inside of the reactor)
- Mixing: by magnetic bar
- Raw materials loading: 100 g
- Catalyst: Quaternary ammonium salt
- Co-catalyst: Catechol based hydrogen bond donor
- Reaction time: ca 24 - 48 h

HNIPU rigid thermoinsulation foams

Laboratory testing



		PU CRS 127 reference	HNIPU F 1	HNIPU F 2	HNIPU F 3
Density [g/cm^3]	-	0.05	0.08	0.11	0.14
Compression strength at 10% deformation [MPa]	> 0.45*	0.16	0.17	0.35	0.48
Thermal conductivity [W/m.K]	< 0.035*	0.033	0.037	0.038	0.042

*Benchmark targets

Requirements for components of rigid thermoinsulation foams obtained by spraying equipment

Glascraft VR
Ratio 1 : 2.5 – 2.5 : 1
Viscosity <400 mPas
Temperature <80°C

Graco Reactor 10
Ratio 1 : 1
Viscosity <300 mPas
Temperature <40°C

HNIPU F 1

Renewables = 45 %
Non-isocyanates urethane bonds = 42 %

Laboratory preparation of the HNIPU foam in paper cup

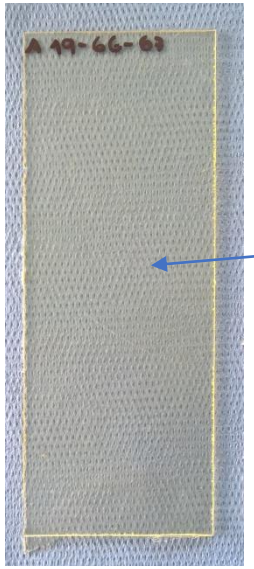
Cut through the HNIPU foam prepared in paper cup

- Best candidate HNIPU foam
- White color
- Fine cell structure
- No shrinkage
- HFC free blowing agent
- Mixing ratio A/B = 1/1

HNIPU conformal coatings

Renewables = 59 %
Non-isocyanates urethane bonds = 36 %

Sample ID	Tg (DSC) [°C]	Surface hardness [Shore A]	Tensile strength (25 °C) [MPa]	Elongation at break (25 °C) [%]	Thermal conductivity (27 °C) [W/m.K]	Surface resistivity [Ω]	Volume resistivity [Ω.m]
Reference C*	1	72	2.8	99	0.251	1.5×10^{9}	5.7×10^{11}
HNIPU C 1	-30	62	0.4	12	0.252	1.3×10^{11}	5.2×10^{7}
HNIPU C 2	-6	65	0.6	15	n.a.	1.0×10^{11}	1.4×10^{11}
HNIPU C 3	22	86	5.0	166	n.a.	1.4×10^{12}	1.7×10^{9}



* Reference system (Solithane S113 + Solithane C113-300; Crompton, US)

HNIPU C 1

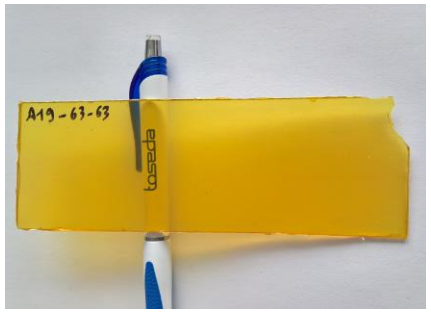
HNIPU C 2

HNIPU C 3

NIPU potting systems

Sample ID	Tg (DSC) [°C]	Surface hardness [Shore A]	Tensile strength (25 °C) [MPa]	Elongation at break (25 °C) [%]	Thermal conductivity (27 °C) [W/m.K]	Surface resistivity [Ω]	Volume resistivity [Ω.m]
Reference P*	52	72	37.4	18	0.164	6.1×10^{10}	3.2×10^{12}
NIPU P 1	52	80	31.5	4.6	0.242	6.9×10^{13}	2.1×10^{9}

* Reference system (Solithane S113 + TIPA; Crompton, US)



Renewables = 57 %
Non-isocyanates urethane bonds = 100 %

Conclusions

- Hybrid non-isocyanates polyurethanes as new environmentally friendlier alternative to traditional PU materials
  - Up to 100 % replacement of toxic isocyanate hardeners
  - Up to ca 60 % renewable raw materials

- HNIPU rigid foam potentially applicable as external thermal insulation of Ariane 6 launcher upper stage tanks for liquid propellants
- HNIPU resins suitable candidates for application in space vehicles electronics such as potting and conformal coating materials

Thank you for attention !