

# PolymColdSprayCoat

Resilient Polymeric Cold Spray Coating

## MAIN PARTICIPANTS

<b>Kazuhiro Ogawa<sup>a,b</sup></b>	<b>Chrystelle Bernard<sup>b,c</sup></b>	<b>Olivier Lame<sup>d</sup></b>	<b>Jean-Yves Cavaille<sup>b</sup></b>	<b>Kesavan Ravi<sup>e</sup></b>
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## OVERVIEW (keep within this page)

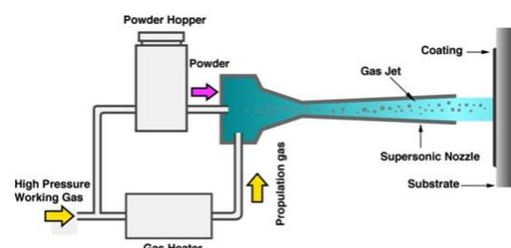
Starting year: 2014

Current researchers (permanent/non-permanent): 3/1

<b>Positioning</b> <i>(Multiple selection allowed – total 100%)</i>	<b>Transportation</b>	<b>Energy</b>	<b>Eng. for Health</b>	Include partner from <input type="checkbox"/> Outside ELYT <input type="checkbox"/> Industry
				Main funding source(s) <input checked="" type="checkbox"/> Public project(s) <input type="checkbox"/> Industrial <input checked="" type="checkbox"/> Own resources
				IFS CRP/LyC project? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
				For main projects: Agency / year / name of project ( <i>up to 3, past projects in gray</i> ) <ul style="list-style-type: none"> <li>• CRP-IFS 2020-2021, J20Ly03</li> <li>• CRP-IFS, 2019-2020, J19Ly01</li> <li>• CRP-IFS, 2018-2019, J18I061</li> <li>• Kakenhi A, JSPS, 2017-2021, Solid-phase film formation ...</li> </ul>
<b>Other:</b>	Estimated annual budget: 400,000 yen/an			

### Highlights & Outstanding achievements (3-5 bullet points)

- Understanding of the formation of UHMWPE powder on metallic substrates
- Modelling of the flow dynamics inside the nozzle and investigation of the particles' thermal gradient
- In total,
  - 9 publications in peer-review journals directly.
  - 1 patent
  - 5 awards



## PROJECT DESCRIPTION

Polymer coatings have a strong variety of applications like surface protection from corrosion, protection from cavitation erosion or mechanical impacts, electronic applications, packaging, and biocompatible membrane etc. The applications of coatings have greatly increased, largely driven by the competitive need to reduce costs, weight and volume. The high molecular weight of UHMWPE provides exceptional mechanical properties. In particular, it has an excellent wear resistance. It also has an excellent resistance to impacts. It has a large elongation at break (typically several hundred percent) and, as a result, a great ability to absorb energy before fracture. Cold-Spray technique is being observed as a technique to coat UHMWPE onto different materials, i.e. to perform particles sintering by projecting them at ultrahigh speed. The challenge consists in (i) improving adhesion between the coated polymer layer (1<sup>st</sup> layer) and the substrate and the subsequent layers of polymers to limit particle rebounds and (ii) in finding the conditions leading to a near bulk density compaction.

### Key scientific question (2 lines max; Calibri 11)

What are the mechanisms involved in polymer coating by cold spray?

How is it possible to optimize the process to obtain such coatings using numerical simulation?

### Research method (8 lines max; Calibri 11)

This project is based on both (i) experimental approaches and (ii) modeling & simulation. Two scales are targeted, molecular scale for adhesion analysis and mesoscopic scale for understanding the polymer behavior under ultra-high deformation and temperature rate.

Encouraging results have been already obtained for UHMWPE coatings as well as preliminary molecular simulations on adhesion. UHMWPE cold spray simulations are ongoing.

And also, the other polymer materials, such as fluoropolymer and polyimide coatings have been studying. It is successful to make the coatings by low pressure cold spray system.

### Research students involved (gray color for previous years)

#### Ph.D. candidates (years, institution):

- Kesavan Ravi (2015-2018, Double PhD degree between TU and MATEIS)

#### Master/Bachelor students (years):

- none

### Visits and stays (gray color for previous years)

#### FR to JP (date, duration):

- |               |   |          |
|---------------|---|----------|
| • JY Cavaillé | Stay at ELYTMaX, Feb-March 2019                     | 2 weeks  |
| • JY Cavaillé | Stay at ELYTMaX, Apr-2019                           | 1 week   |
| • JY Cavaillé | Stay at ELYTMaX, June-July 2019                     | 2 weeks  |
| • JY Cavaillé | Stay at ELYTMaX, Oct-Nov 2019                       | 2 weeks  |
| • JY Cavaillé | Stay at ELYTMaX, Decembre-2019                      | 1 week   |
| • K. Ravi     | Stay at GSE & ELYTMaX (TU), January – February 2018 | 2 months |
| • K. Ravi     | Stay at GSE & ELYTMaX (TU), May – October 2017      | 6 months |
| • K. Ravi     | Stay at GSE & ELYTMaX (TU), May – October 2016      | 6 months |

#### JP to FR (date, duration):

- |              |  |          |
|--------------|--|----------|
| • C. Bernard | Stay at INSA Lyon, September 2019                        | 1 week   |
| • C. Bernard | Stay at University of Grenoble, September – October 2018 | 2 months |

## COMMUNICATIONS AND VALORIZATION

### Journal publications *(gray color for previous years)*

	Authors	Title	Journal	Vol.	pp. / ID	Year	DOI
1	CA Bernard, O Lame, T Deplancke, JY Cavaillé, K Ogawa	From rheological to original three-dimensional mechanical modelling of semi-crystalline polymers: application to a wide strain rate range and large deformation of Ultra-High Molecular Weight semi-crystalline polymers	Mechanics of Materials	151	103640	2020	doi.org/10.1016/j.mechmat.2020.103640
2	CA Bernard, H Takana, G Diguët, K Ravi, O Lame, K Ogawa, JY Cavaillé	Thermal gradient of in-flight polymer particles during cold spraying	Journal of Materials Processing Technology	286	116805	2020	doi.org/10.1016/j.jmatprotec.2020.116805
3	W Lock Sulen, K Ravi, C Bernard, Y Ichikawa, K Ogawa	Deposition Mechanism Analysis of Cold-Sprayed Fluoropolymer Coatings and Its Wettability Evaluation	Journal of Thermal Spray Technology		Accepted.	2020	
4	W Lock Sulen, K Ravi, C. Bernard, N Mary, Y. Ichikawa, K Ogawa	Effects of nano-ceramic particle addition for cold sprayed fluoropolymer coatings	Key Engineering Materials	813	141-146	2019	doi.org/10.4028/www.scientific.net/KEM.813.141
5	K Ravi, W Lock Sulen, C Bernard, Y Ichikawa, K Ogawa	Fabrication of micro-/nano-structured super-hydrophobic fluorinated polymer coatings by cold-spray	Surface and Coatings Technology	373	17-24	2019	doi.org/10.1016/j.surfcoat.2019.05.078
6	K Ravi, T Deplancke, O Lame, K Ogawa, JY Cavaillé, F Dalmas	Influence of nanoceramic interlayer on polymer consolidation during cold-spray coating formation	Journal of Materials Processing Technology	273	116254	2019	doi.org/10.1016/j.jmatprotec.2019.116254
7	K Ravi, T Deplancke, K Ogawa, JY Cavaillé, O Lame	Understanding deposition mechanism in cold sprayed ultra high molecular weight	Additive Manufacturing	21	191-200	2018	doi.org/10.1016/j.addma.2018.02.022

		polyethylene coatings on metals by isolated particle deposition method					
8	K Ravi, Y Ichikawa, K Ogawa, T Deplancke, O Lame, JY Cavaille	Mechanistic Study and Characterization of Cold-Sprayed Ultra-High Molecular Weight Polyethylene-Nano-ceramic Composite Coating	Journal of Thermal Spray Technology	25	160-169	2016	<a href="https://doi.org/10.1007/s11666-015-0332-1">doi.org/10.1007/s11666-015-0332-1</a>
9	K Ravi, Y Ichikawa, T Deplancke, K Ogawa, O Lame, JY Cavaille	Development of ultra-high molecular weight polyethylene (UHMWPE) coating by cold spray technique	Journal of Thermal Spray Technology	24	1015-1025	2015	<a href="https://doi.org/10.1007/s11666-015-0276-5">doi.org/10.1007/s11666-015-0276-5</a>

**Conferences** (gray color for previous years)

	<b>Authors</b>	<b>Title</b>	<b>Conference</b>	<b>Date</b>	<b>City</b>	<b>Country</b>	<b>DOI (if applicable)</b>
1	W Lock Sulen, H Saito, C Bernard, S Onodera, J Ishizaki, N Mary, Y Ichikawa, K Ogawa	Improvement of Deposition Efficiency and Adhesion by Laser Surface Texturing for Cold Sprayed Fluoropolymer Coating	10th Asian Thermal Spray Conference	1st-3rd Nov. 2020	Ningbo	China	
2	CA Bernard, H Takana, O Lame, K Ogawa, JY Cavallé	Computational simulation on particle- laden flow during polymer cold-spray process	ICFD2020	Oct. 28-30, 2020	Sendai	Japan	
3	CA Bernard, H. Takana, G Diguët, K Ravi, O Lame, K Ogawa, JY Cavallé	Polymer coating by cold-spray: a review	ElyT Workshop 2020	Feb. 17-19, 2020	Vogüé	France	
4	W L.ock Sulen, K Ravi, C Bernard, N Mary, Y Ichikawa, K Ogawa	Effects of Nano- Ceramic Particle Addition for Cold Sprayed Fluoropolymer Coatings	33rd Conference on Surface Modification Technologies	June 26, 2019	Naples	Italy	
5	W Lock .Sulen, K Ravi, Y Ichikawa, K Ogawa	Development of fluoropolymer coating using low pressure cold spray	International Thermal Spray Conference 2019	May 28, 2019	Yokohama	Japan	

**Patents** (gray color for previous years)

	<b>Inventors</b>	<b>Title</b>	<b>PCT #</b>	<b>Year</b>
	Cavaille Jean-Yves [Fr]; Lame Olivier [Fr]; Deplancke Tiana [Fr]; Ogawa Kazuhiro [Jp]; Kesavan Ravi [Jp]	Powder for Cold Spray, Method for Manufacturing Macromolecular Coating Film, and Macromolecular Coating Film,	International Patent: WO2015185546 (A1)	2015



**Others** (gray color for previous years)

	<b>People</b>	<b>Event</b>	<b>Description</b>	<b>Date</b>
1	CA Bernard	The 2 <sup>nd</sup> Caterpillar STEM Award	Special Recognition Award	Feb.2020
2	CA Bernard	16 <sup>th</sup> International Conference on Flow Dynamics	Best Presentation Award for Young Researcher	Nov. 2019
3	K Ravi	Japan Thermal Spray Society (JTSS) 2015	Award for young Engineer	May 2015
4	K Ravi	6th Asian Thermal Spray Conference (ATSC) 2014	Best Poster Award	Nov.2014
5	K Ravi, W Lock Sulen, S Gao, Y Ichikawa, K Ogawa	The 15th "Challenge Cup" International Students Technology Innovation Carnival	Grand Prize	Nov.2017