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Report on the 2nd Thematic School on Dielectrics 2021

Gilbert Teyssède, Petru Notingher and Sombel Diaham

The 2nd Thematic School on Dielectrics was organized under the sponsorship of CNRS – French National Research Center, and supported by DEIS, on Porquerolles Island in France, from September 24-29, 2021.

Viewed from the CNRS standpoint, a Thematic School is intended to provide training of different kinds of staff, ranging from engineers, to PhD students and to confirmed researchers, on a particular topics of the present time. After a first edition organized in July 2018 related to the ageing and reliability of dielectric materials and related structures [1], the topics of this second edition was the multiscale modelling of dielectric materials.



Group picture of the attendees of the 2nd Thematic School on Dielectrics 2021, Porquerolles Island, France.

SCOPE OF THE SCHOOL

Improving the energy efficiency of Power Engineering systems requires a move forward to more compact devices as well as an increase in thermal, mechanical and electrical operating stresses, while insulation constitutes one of the main reasons for system failure. The evolution of energy conversion systems brought about by power electronics involves stressing the insulators by high-frequency impulsive stresses and a rise in temperature in the vicinity of wide-gap semiconductors. In the aeronautical field, the increase in on-board electrical power requires an increase in voltage in the electrical systems, with consequences for the insulators, given the specific environment of aeronautics

(depressurized environment, humidity, thermal cycling, etc.). The development of high voltage direct current energy networks (HVDC, favored by the evolution of conversion systems and by the need to collect energy from distributed sources (off-shore wind power etc.) and to reinforce network interconnection, raises questions about the reliability of insulators under DC stress. Finally, environmental standards require processes or products for electrical insulation to be reinvented.

Progress in the efficiency of these energy conversion and transmission systems therefore goes with better control of materials and stresses to which they are subjected. These evolutions occur in a context where new possibilities for creating, functionalizing and modulating the properties of materials are emerging (nano-composites, functionalization, gradation, etc.) without necessarily being able to derive the best benefit from these advances.

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More information: <https://seedsschool.sciencesconf.org/>

Modeling activities are a response to an optimal design of materials and structures. The modeling techniques and tools are evolving, are very diverse (density functional at the molecular scale, finite elements, statistics, scale laws, etc.) and it appeared important, through this thematic school, to provide the Electrical Engineering community with benefits from these advances. A wide range of problems relating to insulators has been addressed, ranging from formulation - electronic properties relationships, to the calculation of stress distributions in objects combining fluids and solids, to multi-physics aspects, and to life models.

The cement of the school is with the mixing of different generation of researchers, the opening to different disciplines, being electrical engineering, materials science, physics, and very importantly to an equilibrium between plenary lectures and practical works.

ORGANIZATION AND ATTENDANCE

The Thematic School was supported by the CNRS, by the IEEE Dielectrics and Electrical Insulation Society (DEIS) and by the French Working Group on Dielectric Materials belonging to the SEEDS-CNRS Electrical Engineering Research Network (<http://seeds.cnrs.fr/>).

As for the first edition, the Thematic School was held at the IGESA Center of Porquerolles Island, belonging to the French army as a recreation and meeting site. Porquerolles Island, on the French Riviera, is a protected area classified as 'Heart of National Park' since 2012.

The dates were chosen based on the availability of the hosting center, and of the sanitary situation. The shadow of Covid-19 issues was present all over the preparation and organization period. We maintained our objective to keep the Thematic School an on-site and in-person event, respecting the safety social distancing, because the physical interaction between trainees and teachers is an invaluable environment for learning, at the sessions and between the sessions. In addition, organizing practical works does not cope with on-line participation. In spite of that, for late travel authorization issues, a few lectures had to be given on-line using a connection system arranged accordingly.

For this Edition, 64 attendees registered and participated. Among them, 26 were from academia, 13 coming from industry and 25 were students, with representatives from



Attendees class during the Lectures

Italy, Germany, Ireland, USA and France. The participation from abroad France was lower than expected, as a consequence of travel restrictions, notably from Asia. In total, 76 persons joined the event, making it a very successful edition in respect to the ambition of the organizers as the full accommodation capacity was used.

LECTURES AND LECTURERS

A total of 14 plenary lectures of 1.5 hours each were given on the following topics, involving lecturers from both the electrical engineering domain and from materials science:

- Issues and challenges related to insulation materials
- Theoretical basis on dielectric properties of materials
- Multi-physics modelling: tools, applications, risks
- Ageing models, life expectancy, scaling laws
- Ab-initio and dynamic molecular methods
- Process and properties of dielectric nanocomposites
- Characterization techniques for insulations

Our objective was to bring international opening to the event. In that perspective, the involvement of the DEIS, broadly advertising the event, was well appreciated. We also invited international and national experts and involved them within the training program.

As introductory lecture, issues and challenges for HV insulation with liquid and gases were presented by Dr. O. Lesaint, (CNRS, Grenoble). The topic was completed by presentations on gas discharge physics by Prof. O. Eichwald, (Univ. Toulouse) and electrohydrodynamic phenomena in liquids by Prof. T. Paillat (Univ. Poitiers).



Relaxing atmosphere and discussions during lunchtime and coffee breaks.



Three lecturers in action. From left to right: Olivier Lesaint, Giovanni Mazzanti, Lionel Flandin.

Short term breakdown phenomena, statistics, ageing laws and life prediction models for solid dielectrics were addressed by Prof. G. Mazzanti (Univ. Bologna).

Fluid models for transport and their resolution for different media (liquid, solid, gas) were treated by Prof. Y. Serdyuk (Univ. Chalmers) while Dr. G. Teyssedre (CNRS, Toulouse) presented experimental inputs to macroscopic and fluid models for solids and Assoc.-Prof. F. Baudoin (Univ. Toulouse) discussed numerical schemes and optimization tools for fluid models resolution. This latter presentation and lectures given by Prof. P. Notingher (Univ. Montpellier) and Assoc.-Prof. S. Diahm (Univ. Toulouse) on techniques for probing dielectric properties of materials introduced to related practical works.

The principle of materials for field grading and thermodynamics of non-linear phenomena were addressed by Dr. T. Christen (Hitachi PG, Baden, Switzerland). Finally, different aspects of materials at nanoscale were treated. Prof. L. Flandin (Univ. Savoie-Mont Blanc) presented his vision of the nanostructuration effects in polymeric matrices. Dr. M. Uge (NKT and KTH, Västerås, Sweden) exposed interfaced physics and various methods having grounds in quantum chemistry to anticipate energy levels in solid dielectrics.

To conclude, a broad horizon about application and issues with insulating materials and the way their behavior can be probed, interpreted and predicted has been covered. The opportunity for participants from different horizons to interact was certainly an invaluable aspect of the school.

PRACTICAL WORKS AND INSTRUCTORS

Aside from these main courses, which were organized mainly as morning sessions, the most original and demanding aspect of the school in terms of organization and logistics was the training of all participants to measurement techniques on lab test benches and on simulation. This latter unique activity was greatly appreciated by the participants.

For that purpose, a total of 6 experimental test benches were brought to the island from Laplace and IES Institutes and installed on-site. Characterization techniques covered the different theoretical concepts taught during the lectures. The attendees were trained on dielectric spectroscopy, transient and conduction current measurements, space charge characterization by pulsed electro-acoustic and thermal step methods and dielectric breakdown with statistical analysis and FEM electrostatic modeling. A last activity concerned the opening to the importance of numerical schemes involved in numerical resolution of models and on optimization method for identifying physical parameters. Each attendee followed a total of 8 hours of practical training out of 32 hours for the entire School. Participants were split in four groups that attended successfully 4 workspaces run in parallel.

Practical work instructors

Prof. S. Agnel, Univ. of Montpellier, France.

Assoc.-Prof. F. Baudoin, Univ. of Toulouse, France.

Assoc.-Prof. L. Boudou, Univ. of Toulouse, France.

Assoc.-Prof. J. Castellon, Univ. of Montpellier, France.

Assoc.-Prof. S. Diahm, Univ. of Toulouse, France.

Assoc.-Prof. V. Griseri, Univ. of Toulouse, France.

Assoc.-Prof. N. Lahoud-Dignat, Univ. of Toulouse, France.

Assoc.-Prof. L. Laudebat, Univ. of Albi, France.

Assoc.-Prof. J.-C. Laurentie, Univ. of Montpellier, France.

Dr. S. Le Roy, CNRS, Toulouse, France.

Prof. P. Notingher, Univ. of Montpellier, France.

Dr. Z. Valdez Nava, CNRS, Toulouse, France.

Dr. G. Teyssède, CNRS, Toulouse, France.



A group working on breakdown and field modelling with N. Lahoud-Dignat and L. Laudebat from Laplace



J. Castellon from IES, one of the instructors for the TSM space charge measurements, in front of students.



F. Baudoin from Laplace in a modelling WorkGroup

INPUTS FROM YOUNG RESEARCHERS

The innovation in this second edition of the school came from the involvement of participants in the program.

Poster Session

A first initiative was the possibility offered to young researchers to present a Poster on a free topic they expected to discuss with teachers and other attendees to the Thematic School. A total of 26 Posters were presented in an outside

2h-session on a friendly Wednesday evening. Discussions were intense and went way beyond the scheduled time window. The organization of such event, ahead of the school was really appreciated according to the feedback from participants.



Discussion at the Poster Session: J. Martinez-Vega, V. Bley, L. Laudebat, L. Boudou. from Laplace



Broad view of the group during the evening Poster session

PhD working groups

The objective of this activity was to identify and treat several questions relevant to topics of the Thematic School. PhD students were divided into five different topical working groups, formed by affinity, depending on the academic background of its members. Various challenging questions were associated to each topic, among those, the group members had to choose one and try to answer it. In particular, the picked questions were:

1. Aging and lifetime – “How can regular condition monitoring and testing improve the life of electrical systems?”
2. New polymers and innovative composites – “How can



Simone Vincenzo Suraci chairing the Working Group session.

e.g., surface coatings, nanofillers and additives improve polymer strategic properties?”

3. Dielectrics application in Industry – “Differences between Lab and Industrial scales? How to tighten the gap?”
4. Space charge and charge transport – “Can analysis of the space charge distribution really account for the state of the structure of a dielectric?”
5. Nonlinear dielectric properties – “What is a nonlinear electrical phenomenon? What this type of phenomenon brings to the knowledge of dielectric materials?”

Each group had to prepare, during the week, a short presentation describing the current state-of-the-art on the topic and highlighting issues, open questions and ‘knowns vs. unknowns’. After each presentation, another time slot was assigned to the discussion with the audience, including lecturers and other PhD students. The presentation was done in the final session of the School. The presence of many people coming from different scientific background allowed a fruitful and enjoyable discussion throughout the various chosen topics. During the discussion section, a number of transversal skills, e.g., materials science, electrical engineering, chemistry and physics, were put together and, from this, very interesting comments and suggestions were raised. In particular, it was possible to underline current limitations of knowledge and techniques which do not allow to overcome some scientific issues associated to the topics. We are very thankful to Dr. S.V. Suraci from Univ. Bologna and Prof. J. Martinez-Vega from Univ. Toulouse for organizing this activity.

Lessons Learnt and Future of the School

A questionnaire was distributed among the participants asking for comments regarding school technical content, site facilities and environment as well as suggestions for improvement. As for the first edition, the possibility to attend the practical laboratory training was definitively the very well acknowledged feature of the school, rarely encountered at similar events or forums. As expected, the location was also admired, the latter being strengthened, this year again by the sunny weather all over the week. Accommodation, which was a perfectible point of the 1st edition, was definitively improved with renovation of most of the rooms. The internet connection remains fragile, as a general problem for the Porquerolles island. Globally, the marks are extremely good and we thank all the participants for the exhaustive and invaluable feedback they provided.

This Thematic School on Dielectric has well responded to the need of our interdisciplinary research community, and entering into a cycle of schools seems not a difficulty as variants of topics can be introduced from now. We therefore expect to propose a next issue in a couple of years on another topic of Dielectrics. Porquerolles Island offers an excellent tradeoff between a convenient to reach location and, at the same time, an ‘isolated’ study environment. It may become a famous gathering place as other events did in the past. The School is a great opportunity for networking inside the DEIS and beyond. We hope the initiative can be

repeated beyond the frontiers, and why not, imagine that parallel events could be organized in Asia or America to reach a broader audience and more generally contribute to the Education tasks of DEIS.

ACKNOWLEDGMENTS

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The organizers also greatly thank all the lecturers and instructors for their contributions to setting up the course program and the practical works on the 'insulated island'. Finally, the organizers warmly thank all the participants for coming over to share a better insight on Dielectrics.

REFERENCES

[1] S. Diaham, P. Notingher, and G. Teyssedre, "Report on the 1st Thematic School on Dielectrics 2018", IEEE Electrical Insulation Magazine, vol. 35, n°2, pp. 73-75, 2019.