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Project acronym: KMM-NoE

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Instrument: Network of Excellence

Thematic Priority: 3

PUBLISHABLE FINAL ACTIVITY REPORT

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www.kmm-noe.org

Summary. Network of Excellence "Konwlege-based Multicomponent Materials for Durable and Safe Parformance" (**KMM-NoE)** of the EU's 6th Framework Programme was launched on 1 Nov. 2004 and finished on 31 January 2009. The Network consisted of 36 institutional partners from 10 countries representing leading European research institutes and university departments (26), SME (5) and large industry (5) in the field of knowledge-based multicomponent materials (abbreviated as *KMM*)

The knowledge-based multicomponent materials are understood here as advanced materials designed for enhanced performance in highly demanding loading and environmental conditions like thermo-mechanical and impact loading, high strain rates and temperature regimes, aggressive chemical environment, and combinations thereof. Such regimes are typical of applications e.g. in aerospace and automotive industry, turbo-machinery, tribology, chemical industry, electronic devices, biological implants, microsensors, household appliances.

Representatives of *KMM* are intermetallics, metal-ceramic composites, functionally graded materials and thin layers. These are materials with high knowledge contents devised and tailored in research laboratories to arrive at desired physico-chemical properties that are well beyond the performance limits of traditional materials.

The main goal of the KMM-NoE Project was to mobilise and concentrate the fragmented scientific potential in the *KMM* field to create a durable and efficient organism capable of developing leading-edge research while spreading the accumulated knowledge outside the Network and enhancing the technological skills of the related industries. The KMM-NoE concentrated on understanding, designing and developing novel knowledge-based mulitcomponent materials with superior properties like low density, high strength and hardness while fulfilling some specific functionalities like excellent performance in high-temperature regimes, enhanced fracture toughness and fatigue lifetime, superior resistance to wear, corrosion and oxidation.

The joint programme of activities of KMM-NoE consisted of integrating, jointly executed research, spreading of knowledge and management activities. The integrating activities comprised strategy-making and network integration activities. The strategy-making activities set out directions of progressive integration and built up a potential for long lasting integration following three logical phases of integration: activation, strengthening, consolidation. The integration activities were permanent tools aimed at integration of research facilities, exchange of researchers and research groups, technology transfer (Competence Centres) and Intranet.

The jointly executed research activities included processing, characterisation, modelling and industrial applications of *KMM*. The spreading of excellence comprised training of researchers (Integrated Post-Graduate School), dissemination of knowledge in industry, foresight studies to evaluate technological needs and developments. Two external networks: External Research Network and External Industrial Network were created for external partners interested in closer interaction with KMM-NoE.

The major deliverable of the KMM-NoE Joint Programme of Integration was the self-supporting pan-European research organisation in the field of knowledge-based multifunctional materials called *KMM Virtual Institute* (KMM-VIN). The KMM-VIN was created in 2007 as an international non-profit association (AISBL) incorporated on Belgian law with its registered seat in Brussels. It combines industry oriented research and services with educational/training activities.

The KMM-NoE project was coordinated by Instytut Podstawowych Problemów Techniki PAN (Institute of Fundamental Technological Research of the Polish Academy of Sciences), Warsaw, Poland. The EU funding for KMM-NoE was 8.1M€ for the project duration of 4.25 years. Details of the project can be viewed on www.kmm-noe.org.

KMM-NoE Consortium

1	Institute of Fundamental Technological Research, Polish Academy of Sci.	IPPT	Poland
2	Technische Universität Darmstadt	TUD	Germany
3	Fraunhofer-Gesellschaft zur Föerderung der angewandten Forschung	FHG	Germany
4	Vienna University of Technology	TUV	Austria
5	Office National d'Etudes et de Recherches Aérospatiales	ONERA	France
6	Université de Metz	UM	France
7	Politecnico di Milano	POLIMI	Italy
8	Università degli Studi di Padova	UNIPAD	Italy
9	Cardiff University	UWC	UK
10	Institute of Mechanics, Bulgarian Academy of Sciences	IMBAS	Bulgaria
11	AGH University of Science and Technology	AGH	Poland
12	Institute of Metallurgy and Materials Science, Polish Academy of Sciences	IMIM	Poland
13	NetComposites	NETCOM	UK
14	Instituto de Tecnología Cerámica	ITC	Spain
15	Imperial College London	IMPER	UK
16	University of Hertfordshire	UH	UK
17	Ecole Normale Supérieure de Cachan	LMT	France
18	Politecnico di Torino	POLITO	Italy
19	Università Politecnica delle Marche	UNIVPM	Italy
20	Fundacion CIDETEC	CIDETEC	Spain
21	Institute of Construction and Architecture, Slovak Academy of Sciences	ICASAS	Slovakia
22	Institute of Materials Research, Slovak Academy of Sciences	IMRSAS	Slovakia
23	Cracow University of Technology	CUT	Poland
24	Warsaw University of Technology	WUT	Poland
25	Institute for Problems of Strength, National Academy of Sciences	IPSUA	Ukraine
26	Materials Centre Leoben	MCL	Austria
27	Fundación Inasmet	INASMET	Spain
28	Materials Engineering Research Laboratory	MERL	UK
29	ATECA	ATECA	Spain
30	Institute for Ferrous Metallurgy	IFM	Poland
31	Wytwornia Sprzetu Komunikacyjnego 'PZL-Swidnik'	PZL	Poland
32	EADS Deutschland	EADSG	Germany
33	EADS France	EADSF	France
34	Snecma Moteurs	SNECMA	France
35	Centro Ricerche Fiat	FIAT	Italy
36	Alenia Aeronautica	ALENIA	Italy

Project Objectives

The mission of KMM-NoE was to mobilise and concentrate the dispersed scientific and industrial potential in the KMM field (intermetallics, metal-ceramic composites, functionally graded materials) to create a durable and efficient organisation capable of developing leading-edge research while spreading the accumulated knowledge in- and outside the Network, and enhancing the technological skills of the related industry.

The specific objectives of KMM-NoE that remained in force for the whole project duration were:

- to create a common platform for intensive scientific cooperation in the area of KMM
- to harmonise Participants' research efforts by jointly generating, executing and monitoring interdisciplinary research projects
- to share research infrastructure among the Participants
- to achieve a durable integration of KMM-NoE partners by creating a new legal organization KMM-VIN in *KMM* domain
- to create External Research Network with coordinated research agenda and External Industrial Network closely cooperating with KMM-NoE
- to enhance KMM-NoE research and technological skills to achieve and hold the world leading position in KMM area
- to transform Participants' individual competitiveness into a synergistic Joint Programme of Activities
- to create and disseminate novel materials' concepts that go beyond conventional approaches
- to avoid "double-research" thus to optimise the cost of research
- to establish an effective system of information exchange
- to interact with manufacturers of the KMM to get stimulus for new research projects
- to disseminate accumulated knowledge (education, promotion, conferences, publishing)
- to establish relationships with other European/International Organisations in KMM area
- to protect knowledge accumulated within the KMM-NoE from unauthorised access

Integration within KMM-NoE through the Joint Programme of Activities was attempted within all three major domains of the activities of a NoE: (i) integration of partners' research programmes, (ii) integration of PhD programmes and (iii) integration of research infrastructure.

The Joint Programme of Activities (JPA) of KMM-NoE consisted of 14 workpackages: 7 Integration (WPI), 3 Research (WPR), 3 Spreading of Excellence (WPS) and 1 Management (WPM). In what follows the achievements of WPI, WPR and WPS will briefly be reported.

Achievements

The unparalleled concentration of research expertise and infrastructure brought in by the KMM-NoE partners into the joint programme of research was organized within 12 internal KMM-NoE projects, reminiscent of small and medium size cooperative projects in FP7. Each of the 12 internal KMM-NoE projects involved an interdisciplinary group of international experts from several partners. Most of the topics for these 12 projects were suggested by European industry for specific engineering applications. The durability of this joint programme of research has been ensured by carrying it over to the newly created transnational organization with legal personality and unlimited duration, KMM Virtual Institute (KMM-VIN AISBL), as a part of its research roadmap. The competitiveness of KMM-NoE research resides also in its unique methodology promoting a problem-solving oriented comprehensive approach comprising the

material processing, characterisation of properties, modelling of material behaviour in service conditions and pre-industrial verification of the obtained materials. Last but not least is the partners' specialised and often unique research infrastructure that had been systematically catalogued and made accessible to the project partners on preferred conditions to carry out joint research; it is also available to external customers on commercial conditions as an offer of KMM-VIN.

The scientific excellence of the KMM-NoE project should, in the first place, be credited to the excellence of its individual partners. On the other hand, it was significantly boosted by the synergy effect inherent in the NoE instrument of the FP6. For example, the integrated approach to research has resulted in publication of three volumes (600 pages each) of the state of the art study in intermetallics, metal-ceramic composites and FGMs, 150 scientific papers (most of them jointly with other KMM partners), 15 PhD and 5 MSc theses. Much of this scientific production would not be possible without the KMM-NoE project.

The scientific excellence of the consortium has been enhanced by the effective Mobility Programme of PhD students / young researchers (53 fellowships, total duration 133 person-months) and experienced researchers (64 mobility grants, total duration 74 person-months). The KMM-NoE research results were presented at three annual KMM Integration Conferences and 11 technical KMM Workshops involving all together several hundreds of participants.

The KMM-NoE contribution to the realisation of European Research Area is manifold. Besides the core consortium consisting of 36 partners from Austria, Bulgaria, France, Germany, Italy, Poland, Slovakia, Spain, Ukraine and the UK, two external networks were established: External Research Network (42 members) and External Industry Network (35 members). A number of the ERN members joined the KMM Virtual Institute and are partners in new R&D proposals submitted by KMM-VIN to FP7 and other European programmes.

The KMM-NoE project has implemented an intensive joint programme of spreading of excellence towards external research/academia centres and the industry via its: Integrated Post-Graduate School comprising (i) PhD-Path Intensive Sessions lasting two weeks (5 Sessions with total of 145 attendees) and (ii) Skill-Path Sessions lasting one week (3 Sessions with 86 attendees) and (iii) Summer Schools (3 schools with 136 participants).

A contribution to ERA can also be seen in the KMM Integrated PhD Programme involving so far 7 university partners from 5 EU Member States who signed the respective Memorandum of Understanding and held the first set of six accredited doctoral courses. Another evidence of KMM consortium's contribution to ERA is its active role in the European Technology Platform on Advanced Engineering Materials and Technologies (EuMaT), e.g. in the Steering Committee, one of the technical Working Groups and in the Secretariat which is currently being run by KMM-VIN.

KMM-NoE has contributed to the economic competitiveness and innovation by direct transfer of research results to the industry partners from the core consortium and to external industry via KMM Competence Centres network (12 Info Days in 7 different Member States) and the so-called Industrial Workshops (3 events) specially tailored to the industry needs identified by prior surveys among large companies and SMEs. Several patents have been filed, two of them already granted.

A possible contribution of KMM-NoE to sustainable development can be sought in the active involvement of New Member States (Bulgaria, Poland, Slovakia) and Ukraine in project activities and in sharing of the project results. Specifically, these partners benefited a lot from the Mobility Programme that made it possible for them to improve skills and gain research experience while working in foreign institutes and laboratories of KMM-NoE. Also, one should not underestimate the experience these partners have achieved in managing the European projects, including the one of the overall project coordination by the Polish group from the IPPT in Warsaw.

It is a firm conviction of KMM-NoE partners that for this effort to truly benefit Europe a continuation of the integration process is necessary, as well as more involvement from the European industry. To achieve that the durable integration structures such as KMM-VIN, which is the main deliverable of the project integration activities, appears a perfect tool. The major challenge, though, is to make the Virtual Institute self-funded and financially stable once NoE

grant from the Commission is over. The concept of a virtual institute was tried out under FP5 but without spectacular successes. In FP6 the starting point seems to be different. This time virtual institutes naturally emerge from the networks of excellence and integration achieved within the NoE provides a solid foundation to believe that at least some virtual institutes will flourish.

This observation can also be found in the final report of the KMM-NoE International Advisory Board - an independent advisory body consisting of world class scientists in materials science and mechanics of materials:

"KMM-NoE Partnership has performed a truly outstanding job in maintaining a credible and thriving research effort while at the same time staying true to the fundamental concept of these European Commission funded partnerships in establishing an extensive network of collaborators from universities, research institutes and industry, and in promoting the transfer of knowledge within and outside this network through their "mobility programs" and technology transfer efforts. KMM-NoE Partnership has undoubtedly established an extensive and functioning network of research investigators that spans the map of Europe. This group of researchers has been, and is still, actively involved in numerous collaborative programs of various intensity, and it is clear that these collaborations have been largely effective. In reality, although the KMM-NoE has almost ended, it is poised for even greater involvement with these collaborations. To us, this is the truly most outstanding achievement of the program. It would be literally a crime to walk away from this and not provide additional funding to capitalize on the network that has been established. In this regard, the Virtual Institute KMM-VIN is the ideal mechanism to continue the KMM-NoE research programs and aid the development of new collaborations that draw on the diverse talents of so many researchers, in industry, universities and research institutes, in so many countries."

Joint Programme of Research

The Joint Programme of Research of KMM-NoE consisted of three Workpackages (WPR1, WPR2 and WPR3) comprising 12 Tasks which can be seen as an independent research projects involving from 4 to 12 partners (research groups) from the consortium.

WPR1: INTERMETALLICS

Task 1-1 Intermetallics for high, moderate, low temperature applications (acronym HIMOLO)

Task 1-2 Thin films and intermetallics layers (FIMLA)

Task 1-3 NiTi for biomedical devices and transportation (NiTiBiT)

Task 0-1 Joining of KMM: new concepts and testing (JOINING)

WPR2: METAL-CERAMIC COMPOSITES

Task 2-1 Interpenetrating metal ceramic composites based on performs (PREFORMCERMET)

Task 2-2 New particulate Al and Ti matrix composites produced by self-propagating high temperature synthesis (PARTMMC)

Task 2-3 Metal ceramic nanostructured bulk composites and coatings (NANOCERMET)

WPR3: FUNCTIONALLY GRADED MATERIALS

Task 3-1 Tailoring FGMs for biological environments (BIO-FGM)

Task 3-2 New multifunctional 3D cellular metallic materials with graded pore density (CELMET)

Task 3-3 Graded ceramic-metal composites with wear resistance and thermal insulation (CERMET)

Task 3-4 High performance graded coatings (GRADCOAT)

Task 3-5 Stress-related phenomena (STRESS)

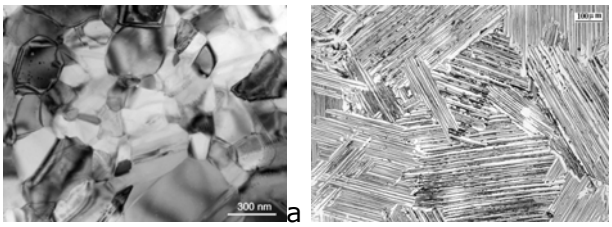
As a starting point for the research activities within the project, KMM-NoE consortium elaborated extensive state of the art reports (SOA Reports) in the three main themes of KMM:

- Volume 1: Intermetallics
- Volume 2: Metal-Ceramic Composites
- Volume 3: Functionally Graded Materials.

These SOA Reports were the basis to formulate the 12 internal KMM-NoE research projects listed above, with active participation of industry members in the topics formulation process.

The **original research results** obtained within the 12 internal projects include, e.g.:

- New processing route for TiAl intermetallics: Synthesis by Mechanical Alloying + Self propagating High Temperature Synthesis (SHS)
- New processing route for FeAl intermetallics by a two stage reaction sintering: SHS of Fe_2Al_5 + powder milling, mixing with Fe and sintering
- Modelling of Nb_3Sn behavior in super-conducting cable using homogenisation technique (strand model).
- Processing of multicomponent intermetallic Al-Ni or Al-Ti or Ni-Ti using a duplex method (Physical Vapour Deposition or Electrochemical Method + Treatment under glow conditions).
- Processing of NiTi components using metal injection moulding or hot compaction.
- Development and characterization of joined stainless steel (Crofer22APU) to ceramic samples through an original glass ceramic seal (for Solid Oxide Fuel Cells).
- Method to join carbon fiber /carbon composites (CFC) to copper, with a flat or curved geometry (for ITER components.
- Combined numerical (FEM)-experimental methodology to investigate fracture phenomena in different kinds of joints (metal on composite, ceramic on ceramic, glare).
- Processing route of Al_2O_3-Cu composites with interpenetrating network micro-structure (infiltration of molten Cu into porous ceramic performs).
- Processing route for Ti-matrix composites reinforced with ceramic particulates using the SHS technology.
- Processing of ceramic nanoparticles and nano-structured ceramics by wet chemical methods and densified by spark plasma sintering.



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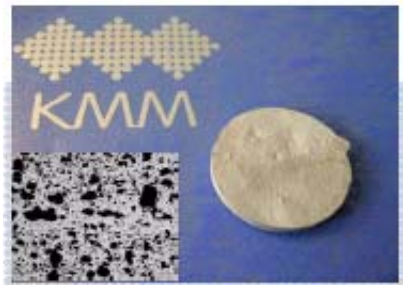
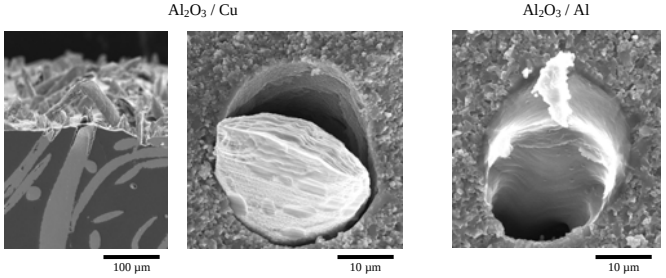
Lamellar microstructure of TiAl intermetallics (KMM-NoE)

Real superconducting cable modelled by a homogenization technique (KMM-NoE)



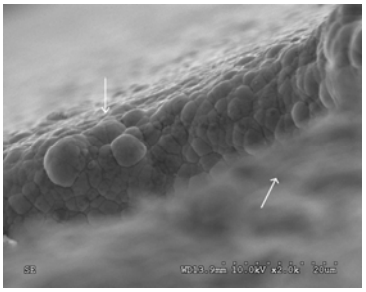
Porous NiTi sample and micrograph obtained by metal injection moulding (KMM-NoE)



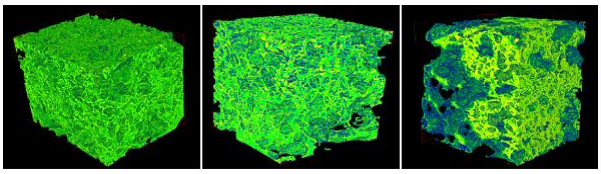
Fracture of Al_2O_3-Cu composite (KMM-NoE); for comparison plastic deformation of Al ligaments in Al_2O_3-Al composite (KMM-NoE)

- Development of electrochemistry based processing routes for reliable and reproducible fabrication of nanostructured bulk composites and coatings with metal matrix.
- Deposition of nanostructured coatings by atmospheric plasma spraying.
- Processing route of carbon nanotubes containing composites and coatings by electrophoretic deposition.
- Processing route for Alumina-Ni nanocermets and metal nanoclusters-silica composites
- Processing routes of porous titanium, various glass-ceramic and glass-metal composite and their characterization including European large-scale radiation facilities.
- Development of the continuum micro-mechanics models exploiting Computer Tomographic Data for state-of-the-art biomaterials, leading to reliable simulation tools.
- Novel hierarchical multilevel homoge-nisation models for the effective mechanical, thermal, acoustic and vibration damping properties of multi functional cellular materials with graded microstructure for application in aerospace components.
- Processing of functionally graded composites (FGMs) by metal infiltration into ceramic performs using fiber based pore forming agents.
- Processing of protective coatings based on γ-TiAl intermetallics on TIMETAL834.
- Processing of protective SiO_2-Al_2O_3–CaO-Na_2O glass-ceramic based coating on TIMETAL834

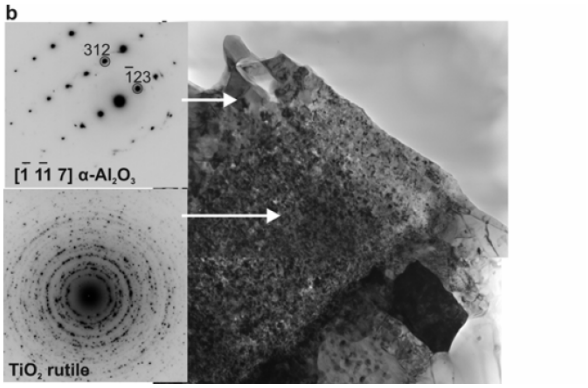
- Deposition of nanocrystalline tribo-logical multilayers basing on Ti/TiN; Cr/CrN and CrN/TiN systems up to 64 individual layers in 1µm film thickness.
- Deposition of TiN and Ti(C,N) (potential biomaterials for blood-contact application on (titanium) and polymer substrates.



Metallisation (Ni) of ceramic nanoparticles (KMM-NoE)



3D micro Computer Tomographic reconstruction of CEL2 glass-ceramic scaffold. The image shows the scaffold (green) and the new phase (blue) (KMM-NoE).



Microstructure of the coated TIMETAL834 after oxidation at 800°C during 300h in air (KMM-NoE)

The results obtained in KMM-NoE were disseminated via publishing in journal and conference papers. The publications of KMM-NoE research have been structured into four categories:

Category A: Joint publications with co-authors from KMM-NoE consortium - resulting from integrated research in KMM-NoE.

Category B: Own publications resulting from KMM-NoE without co-authors from KMM-NoE consortium or External Research Network (ERN)

Category C: Joint Publications with co-authors from ERN or other non-KMM partners.

Category D: PhD Theses which resulted from the student's involvement in the NRT, e.g. via Research Fellowships at other KMM-NoE partners.

Using this categorisation, the KMM-NoE **publication statistics** are as follows:

- 75 papers (Cat. A)
- 52 papers (Cat. B)
- 21 papers (Cat. C)
- 15/5 PhD/MSc theses.

Of the three main areas of NoE integration, i.e. research, PhD programmes, and infrastructure, the integration of research groups is probably the most successful and valuable achievement of the KMM-NoE. The twelve NRTs have established strong cooperation links between different Task Force members not only within the grouping of mechanicians, or materials scientists, physicists or chemical engineers but also cross-links between the researchers from different disciplines.

This effect would not have been attained without KMM-NoE. A majority of the consortium members recognize the impact and benefits for their own institutions when doing research together via KMM structure. Therefore, and that can also be credited to research integration, the majority of KMM-NoE research partners decided to continue and deepen the integration in the framework of KMM Virtual Institute even if initially there is no new funding to support their research. This development is to be recognized as an integration effect induced by the NoE.

In year 4 this positive attitude was transformed into some successes in getting new research funding for KMM-VIN members through new proposals to FP7, MATERA+ and national funding agencies.

Joint Programme of Integration

The permanent tools of Network integration included General Assembly (GA) meetings, regular meetings of the Executive Board (EB) and the International Advisory Board (IAB). Over the project execution there were held: 6 General Assembly (GA) meetings, 15 Executive Board (EB) meetings, 4 International Advisory Board (IAB) meetings, 3 Integration Conferences (IC). To promote integration and stimulate partners' involvement these meetings were organized by different KMM-NoE partners at different locations. Routinely, the GA, EB and IAB meetings were all minuted in a detailed way.

An important contribution to KMM-NoE integration, although not easy to quantify in measurable terms, was the output of the **International Advisory Board** work. The professional assessment and recommendations of the IAB significantly contributed to the quality of KMM-NoE deliverables in all NoE activities. The IAB, whose members are renowned researchers in the KMM field, played a very important monitoring and mentoring role for the KMM-NoE consortium. Their criticism combined with constructive advice had an impact on the consortium because of their unquestionable position in research communities of advanced materials. Also, the simple organizational solution employed in KMM-NoE that not only the project coordinators but the entire Executive Board (comprising all 14 WP Leaders) reported to the IAB at the dedicated joint IAB/EB meetings held every year, amplified the effect of the IAB recommendations on the project execution. The role of the IAB should be recognized in the final evaluation of the KMM-NoE results.

KMM-NoE **Editorial Office** proved to be an effective unit in editing and publishing KMM-NoE works such as KMM State of the Art (3 volumes), Lecture Notes from the PhD Path Sessions of the Integrated Post-Graduate School (5 volumes), Proceedings of the Industrial Workshops (3 volumes). All these works have been placed in the KMM-NoE e-Library to assist the consortium members in their research activities.

The promotion of KMM-NoE, initially with the project coordinator (IPPT) then a combined effort of IPPT and ITC Spain, can be considered a success in terms of informational materials, posters, roll-ups. This, for the most part, can be credited to ITC partner and its excellent cooperation with IPPT. It is also an example of coordinators' intuitive and flexible response to emerging talents/capabilities of partners that have not been known at the project start.

The Strategy-making Integration Activities was one of the key Workpackages for the success of KMM-NoE project in its integration part. To this end the **KMM Virtual Institute** was the most critical one as the creation and self-sustainability of this new organization was considered as the main deliverable of the NoEs under the NMP Priority. The KMM-NoE coordinating group was well aware of that and invested a lot of time and effort into creation of KMM-VIN right from the project beginning. Undoubtedly, KMM-VIN AISBL was the main achievement of the KMM-NoE Joint Programme of Integration.

Interestingly, KMM-VIN is not just a group of stakeholders driven and kept together by individual interests of getting new projects. It has its internal research structure of Working Groups that continue to conduct KMM-NoE research not waiting for the next project to come. Obviously, searching for new project opportunities and forming consortia for that purpose has been captivating the KMM-VIN membership.

It is perhaps worth reporting how KMM partnership approaches the issue of forming **project consortia** and distributing the work of writing proposals among themselves. In KMM-VIN this is a process stimulated and initiated by the Board of Directors (BOD). Knowing that a cooperative research opportunity as opened by a public agency (EC, national research councils, etc.) the BOD proposes to create a small core group of partners with suitable expertise for devising and writing the future project proposal and outlines its main points. Then, the core group starts acting as an independent, self-organized group to work out the project idea. It nominates from among themselves, in a natural process, a proposal coordinator who seeks contacts with relevant industry and designs the future consortium. The core group is entirely autonomous in their thinking and decision making. The BOD provides assistance in proposal preparations based on their own experience in EC projects. This method proved effective in several cases of KMM-VIN initiated proposals and is being implemented in the upcoming proposals inspired by KMM-VIN.

The main objective of the KMM-NoE **Mobility Programme** was to facilitate the execution of the KMM-NoE interdisciplinary and comprehensive Joint Programme of Research. The mobility programme was intended to strongly support the integration of the KMM research capacities within the research tasks. Two systems of internal KMM-NoE fellowships were operating: (1) Mobility Grants for experienced researchers (i.e. post-docs and professors), and (2) Research Fellowships for PhD students and young researchers (< 4 years of experience).

In total 52 Research Fellowships with 133 person months were awarded. The outcome comprised 20^{+} manuscripts to scientific journals and 18 contributions to scientific conferences. The fellowship provided significant contributions to Ph.D. theses (i) by enabling the use of experimental equipment which was not available at the home institutions, (ii) by application of complementary methods for better understanding of fabrication methods, and (iii) by transfer of know-how on different numerical and experimental methods for material characterisation.

For the experienced researchers a total of 64 Mobility Grants with 73 person months were awarded. The outcome of this personnel exchange were 50^{+} manuscripts to scientific journals), 30^{+} contributions to scientific conferences, and 5 proposals for joint research projects. The scientific activities performed during these research stays were mainly focussed on different experimental techniques and numerical simulation methods for microstructure characterisation, sample preparation and processing of KMM materials.

To sum up, the work performed within the KMM Mobility Programme contributed significantly to the establishment and improvement of the KMM network integration by initiating and

deepening new and existing collaborations, and through successful scientific developments by joint research activities. In more detail, KMM Mobility Programme was very well appraised and accepted by the participants and highly evaluated by the KMM International Advisory Board.

Research infrastructure of KMM-NoE partners was one of the key assets of the Network. It has been continuously shared by the NoE partners using the mobility of researchers programme as a platform to access specialised pieces of equipment located at other partners labs. Importantly, the KMM-NoE Catalogue of Expertise, Infrastructure and Equipment was transformed into an internet tool called Work Assignment Matrix which will help the KMM-VIN Board of Directors to find competent KMM-VIN labs to the incoming service orders from industry. A legal basis for contracts of KMM-VIN sub-consortia with external clients (the so-called Multi-Participant Master Service Agreement) has been worked out, approved by the KMM-VIN members' legal offices, and is now available for use.

Joint Programme of Spreading of Knowledge

KMM-NoE spreading of knowledge activities were carried out using three main instruments: Integrated Post-Graduate School (KMM IPGS) consisting of the PhD Path and the Skill Path, Summer Schools and the External Research Network (ERN). The PhD Path sessions lasted two weeks and comprised three 20 hour academic courses at a PhD level. The Skill Path sessions were addressed to university graduates who wanted to enhance their skills in a particular field or techniques and lasted one week (practical trainings in experimental labs were part of the sessions). Altogether KMM-NoE organized five PhD-Path Intensive Sessions with total of 145 attendees, three Skill-Path Sessions with 86 and three Summer Schools with 136 participants.

Another highlight was the integration of the PhD programmes. This was not planned initially in KMM-NoE project but as the project developed some core partners decided to establish a nucleus of a European Doctoral Programme (EDP) in KMM area and signed an official Memorandum of Understanding. The EDP launched 6 courses on KMM related topics held at TU Vienna, Politecnico di Milano and IPPT Warsaw. Importantly, the KMM and ERN participants of these courses were eligible to apply for EDP scholarships via a competitive call (15 short term Educational Scholarships were granted).

The External Research Network (ERN) was established as a loose grouping of research teams from outside the Consortium interested in KMM-NoE research programme and other Network activities. The candidates to ERN had to be active in at least one of the main research KMM fields and be recommended by a member from KMM-NoE Consortium. The number of ERN members at the project end reached 42 including research teams from Cyprus, Czech Republic, France, Germany, Greece, Italy, Poland, Romania, Serbia, Slovenia, Spain and Switzerland. Most ERN members were very active in seeking research interaction with KMM-NoE consortium (e.g. ERN lectures at KMM-NoE Integration Conferences, joint publications of KMM-NoE and ERN members). A natural development of KMM-ERN research integration was the accession of ERN members into KMM-VIN (8 members). Some of ERN members were also invited to the consortia of KMM-VIN proposals submitted to FP7 Calls

Dissemination of knowledge in industry was done through External Industrial Network (EIN) and the so-called KMM Industrial Workshops. The EIN was set up: (i) to promote and disseminate KMM-NoE activities and research results in the industry outside the NoE, (ii) to collect indications from industry as to the future research directions for KMM-NoE and KMM-VIN, (iii) to develop mechanisms of integration of academic/research partners and European industry. At the project end the EIN consisted of 33 companies and SMEs.

KMM Industrial Workshops were open events considered as an important tool to come into contact with industry - prospective clients of the KMM Virtual Institute. Three Industrial Workshops were organised by different KMM-NoE partners along the project's lifetime: ITC (Castellón), IFAM (Bremen) and CRF (Orbassano). Workshops programmes were based on the inputs from industrial companies, some being members of KMM-NoE, some others from KMM-NoE satellite networks (External Industry Network) and some more from other associations, platforms (EuMaT), etc. A number of speakers was also recruited from companies from within and from outside the NoE. The total audience of each workshop was well above 50 on average.

KMM-NoE continued to have close links to the European Platform for Advanced Engineering Materials and Technologies (EuMaT) contributing to the EuMaT Strategic Research Agenda and to the activities of the EuMaT Working Group on Knowledge-based Multifunctional Materials and Materials for Extreme Conditions. KMM-NoE was benefitting from EuMaT information channels to inform research and industrial communities in Europe about the IPGS sessions (post graduate school), summer schools and industrial workshops organised by KMM-NoE.

A good cooperation is to be acknowledged with another FP6 large project ExtreMaT IP. KMM-NoE and ExtreMat were two European projects that had much in common in terms of research roadmap. One KMM Integration Conference (Vienna) was organized jointly with ExtreMaT IP.

An objective that remained valid throughout the whole project duration was to bring the spreading of knowledge activities of KMM-NoE to a matured state so that the educational/training offerings for external participants were attractive and in demand. Besides that it was possible to establish legal and technical basis for the European Doctoral Programme in KMM. This, when combined with the efforts of other NoEs in Materials may contribute to creation of the European Doctorate in Advanced Materials – an idea that has been around for quite some time but de facto has not been given any concrete form yet. Horizontal activities (including integrated PhD programmes) of all 14 NoEs in Materials have recently been analyzed by the NoE coordinators to check if there is a common ground on which any joint endeavours can be founded after the EC funding is finished.