

Final evaluation of FANAS

Summary

1. Scientific achievements

There is a consensus among the reviewers that the FANAS programme has *demonstrated excellent science and achieved a substantial advancement of our understanding about friction*. All the CRPs have published their results in high impact journals, and the final FANAS conference, “Trends in Nanotribology” held in Trieste in September 2011, also demonstrated the outstanding success of the programme.

Scientific breakthroughs have been achieved in experiments (ARFI) and theoretical modelling (ACOF), leading to new scaling laws for superhydrophobic contact and basic understanding of anisotropy in friction and transition to sliding processes. A duality phenomenon in friction was discovered involving metallic nanoparticles in the contact zone (NANOPARMA).

Novel experimental methods and techniques have been developed, such as

- the method to control friction by external vibrations developed by ACOF;
- the sliding over the superconducting phase transition investigated by AFRI;
- the damping mechanism during friction that was resolved at the atomic scale by AFRI;
- the method of identification and manipulation of nanoclusters on isolating substrates developed by NOMCIS;
- the computation method to capture multi-scale behaviour of friction developed by EBioAdI;
- the bimodal force microscopy with highly improved lateral resolution, a new ultrahigh vacuum tribometer (AFRI);
- the real-time nanoparticle manipulation technique developed by NANOPARMA.

Novel materials have been investigated, such as isolating substrates (NOMCIS), graphene and carbon nanotubes (AFRI, ACOF), molecular crystals (AFRI), fractal surfaces where roughness and fractal dimension are controlled (ACOF, EBioAdI), quasi-crystal surfaces (ACOF), flakes which demonstrate superlubricity (ACOF), new synthesized lubricant materials with promise of low friction and low wear, such as polymer brushes and PEG derivatives (AQUALUBE), and even artificial meta-materials (cold ion traps) (AFRI).

The success of the programme has been in part due to the *integration across the disciplines* of chemistry, physics, material science, mechanical engineering, and biology. Good examples are the combination of mechanics, physics and chemistry in ACOF, the combination of atomic-scale simulations with the finite element method in the EBioAdI, and an extensive usage of *ab initio* calculations in interpretation of experimental results.

Some minor remarks are that larger groups (ACOF, EBioAdI, AFRI and NANOPARMA) have been more productive and innovative than smaller groups in a non-proportional manner, which is likely due to lesser extensive exploitation of collaborations in the latter, and that FUNDTRIBO has not performed fully according to the plan.

2. Collaboration and networking

There is a consensus among the reviewers that the overall *performance of the FANAS programme in terms of networking has been excellent*. The programme has made a very good use of its meetings to enable the members of different teams to discuss their results and exchange ideas. A substantial part of the results have been obtained in collaborative work between individual teams, such as those obtained by combining the experimental studies (Fineberg, Popov) and the theoretical/simulation investigations (Urbakh, Tosatti) within ACOF, a very strong cooperation of all teams in AFRI (e.g., the combination of *ab-initio* simulation with dynamic AFM experiments), the combination of macroscopic and AFM studies in AQUALUBE, and exchanges with students/postdocs in the NANOPARMA project. New collaborations have been established that would have unlikely been formed without the FANAS programme. Good examples are the collaborations established between different CRPs, for example, between NOMCIS and AFRI, or AFRI, ACOF and NANOPARMA.

A number of excellent workshops have been organised by FANAS, including a mini-symposium on multi-scale modelling of friction and adhesion in 2009 (Rhodes), a meeting in India in 2008, the workshops "Stick-slip dynamics, from nano to geophysical scales" in 2010 (Lausanne, CECAM) and 2011 (Israel), the "Nanoparma" meetings in 2008 and 2009 (organized by the NANOPARMA team) which then extended to "Nanomanipulation workshops" in 2010 and 2011 organised jointly by NANOPARMA and NOMCIS, and the three annual programme-wide FANAS meetings (Trieste 2009, 2011, Saarbrücken 2010).

The FANAS programme has also demonstrated its dedication to *training*. In almost all projects, postdocs and students participated (e.g., 16 in the AFRI project, and 39 in the NANOPARMA project). Young scientists have regularly participated in FANAS meetings and presented their results. Student exchanges have been organised by some CRPs. In addition, two winter schools were held in Denmark on the topics of nanotribology.

The FANAS programme has been performing well in terms of *dissemination*. The results have been published in a large number of papers in leading scientific journals and presented via a huge number of high-level (including international) conference contributions (e.g., 40 in ACOF, 50 in AQUALUBE). As the most exciting FANAS events the two ICTP-FANAS conferences (Trieste 2009 and 2011) with participation of world-leading scientists should be mentioned. As a whole, the FANAS meetings have served as an outstanding platform enhancing the visibility of the scientific results achieved by its participants.

3. Exploitation of the programme's potential

The participating teams have taken full advantage of this EUROCORES programme in terms of collaborations, exchanges, and scientific meetings. Almost all tasks/milestones declared in the FANAS projects have been fulfilled and even surpassed. The programme resulted in new results and ideas, and worked on novel materials that may find applications in European industry (for example, polymer-brush lubricants studied within the AQUALUBE project may be used by metalworking industry in Switzerland).

The FANAS programme has substantially increased the capacity of nanotribology research in Europe. It allowed the realisation of multidisciplinary research tasks through the creation of strong international teams with reciprocal use of equipment. Through FANAS, its participants

were offered, and made a very good use of, unprecedented opportunities in (i) starting research collaborations and maintaining them throughout the programme, (ii) carrying out research that requires a critical mass and a combination of diverse competencies, and (iii) creating an environment that attracts young researchers. A number of PhD students defended their theses either within or soon after the programme ended. Some CRPs (AFRI, ACOF, and EBioAdI) provided useful links to other programmes so that the research findings could feed into the other areas seamlessly. New US-Europe collaborations have emerged, in particular in the bio-medical field.

FANAS has also strongly contributed to the international visibility of the European tribology research. During the ICTP-FANAS conferences in Trieste (2009, 2011), almost all leading scientists from FANAS CRPs gave talks to audience consisting of leading scientists from around the world (including the USA and Japan). Proceedings of the annual FANAS conferences were published in special issues of Tribology Letters - the leading tribology journal. The results obtained within the FANAS programme were published in leading scientific magazines such as Nature Materials and Science. As regards research achievements, there has been media coverage, such as the newspaper articles listed in the AFRI report. In addition, the election of Prof. Erio Tosatti (ACOF and AFRI projects) to the US NAS may be considered as an indirect achievement of the FANAS programme.

A very important outcome is that many of the collaborations started due to the FANAS programme will continue in the future. In particular, the collaborations within AFRI have resulted in the synergy project "Dissipation across phase transitions" between Swiss and Italian partners (started in September 2011), the collaboration between Basel and Krakow groups in ACOF has led to a new bilateral project between the Jagiellonian University and the University of Basel (the Polish-Swiss Research Programme started in October 2011), and the "Nanomanipulation workshops" by NANOPARMA and NOMCIS will be continued in 2012.

In summary, the participating scientists have made a very good use of the programme, and the obtained valuable results have proven the usefulness of the EUROCORES scheme in strengthening interdisciplinary scientific cooperation at the European level.

4. Recommendations

Some shortcomings of this EUROCORES programme have been noted that would require attention if similar schemes would be implemented in the future:

- (i) the duration may be too short for developing truly interdisciplinary initiatives;
- (ii) the time lapse between the application and concession has been too large, which can be a major problem in fields that are evolving fast;
- (iii) the funding mechanism of individual teams via national funding agencies and the associated application procedures, resulting in the need to apply to the ESF and separately to the national agencies, essentially doubled the effort. The uncertainty of participation of some teams even in highly ranked CRPs and scatter of starting dates of different individual projects have decreased the achievable level of collaborations;
- (iv) there has been an imbalance in funding of different individual projects in some CRPs (for example, in the ACOF project the Project Leader's funding was 30 kEur, PI2 – was not funded, while grants of the remaining teams were in the range of 100–300 kEur);
- (v) there have been no measures to improve the gender balance.

Apart from those observations, a common opinion stated by scientists participating in FANAS is that it has been an impressively efficient programme, with very unbureaucratic and helpful service on behalf of the programme coordination. This programme has evidenced that collaborative efforts can achieve significant advances in novel areas of research. The platform for networking set by the EUROCORES scheme has been highly successful and the discontinuation of the scheme is an unfortunate development. If a future initiative in this area is eventually implemented, longer duration of such programmes and better synchronisation of national procedures of the participating funding agencies are two aspects that may be improved.