

STAND-ALONE PROJECT - FINAL REPORT

Project title **Modeling and Simulation of Organic Semiconductors**

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P16862-N02

Project number

1. Summary for public relations work

Organische Halbleiter gehören zu einer speziellen Klasse von Kunststoffen, die sich durch ein konjugiertes Bindungssystem auszeichnen. In den vergangenen Jahren wurde die Entwicklung von Kunststoff-basierten, elektronischen Bauelementen zunehmend intensiviert. Anwendungen wie organische Dünnschichttransistoren, organische Leuchtdioden und Displays versprechen vielfältige und vor allem kostengünstige Alternativen zur herkömmlichen Silizium-Technologie.

In diesem Projekt wurden theoretische Modelle für den Stromtransport in halbleitenden Polymeren mit dem Ziel entwickelt, existierende Messdaten besser erklären zu können und die elektrischen Eigenschaften von Materialien und Bauelementen durch Simulation voraussagen zu können. Dazu wurden zwei Ansätze verfolgt, die einerseits auf der Monte Carlo Methode und andererseits analytischer Modellbildung beruhen. In beiden Fällen wird der klassische Ratenausdruck von Miller und Abrahams und ein Gauß'sches Unordnungsmodell verwendet. Es wurde ein drei-dimensionaler kinetischer Monte Carlo Simulator entwickelt, welcher sowohl den Stromtransport im Inneren des Halbleiters als auch die Injektion und Extraktion von Ladungsträgern an den Kontakten exakt modelliert. Da das elektrische Verhalten organischer Bauelemente in den meisten Fällen durch die Kontakte bestimmt wird, wurde auf deren Modellierung besonderes Augenmerk gelegt. Raumladungs- und Spiegelladungseffekte, ein verbessertes Injektionsmodell, Interband-Übergänge und molekulare Dotierung werden berücksichtigt. Die Kalibrierung des Simulators erfolgte hauptsächlich für Zink-Phthalocyanin.

Im zweiten Ansatz wurden basierend auf der so- genannten variable-range-hopping-Theorie verschiedene Modelle entwickelt, die den funktionalen Abhängigkeiten der Ladungsträger-Beweglichkeit vom elektrischen Feld, der Temperatur, sowie der Konzentration von Ladungsträgern, Dopanten und Haftstellen Rechnung tragen. Die Injektion von Ladungsträgern mittels Metallkontakten wurde für den Fall organischer Leuchtdioden untersucht. Zu diesem Zweck wurden Modelle hergeleitet, welche die Abhängigkeit des Injektionsstromes von der Temperatur, dem elektrischen Feld und der Barrierenhöhe an der Grenzfläche zwischen Halbleiter und Kontakt beschreiben. Weiters wurden Kompaktmodelle für Dünnschichttransistoren und organische Leuchtdioden zur Verwendung in der Schaltkreissimulation entwickelt.

Organic semiconductors in general are a family of polymers that are based on pi-conjugated carbon atoms. In the last years the development of electronic devices based on these materials has been considerably intensified. Applications such as thin film transistors, organic light emitting diodes, and displays are promising and inexpensive alternatives as compared to the well established silicon technology.

In this project, theoretical models for current transport in semiconducting polymers have been developed in order to enable a better understanding of measurement data and predictions of the electronic properties of materials and devices by means of simulation. Two approaches have been pursued, based on the Monte Carlo method and analytical models, respectively. Both approaches employ the classical Miller-Abrahams rate and a Gaussian disorder model.

A three-dimensional Kinetic Monte Carlo Simulator has been developed, taking into account both current transport in the bulk and the injection and extraction of charge carriers at the contacts. Since the electric characteristics of organic devices are often dominated by the contacts, the latter have been modeled carefully. Space charge and image charge effects, an improved injection model,

inter-band transitions, and molecular doping have been taken into account. The simulator has been calibrated mainly by comparison with the empirical data of Zinc Phthalocyanine.

Based on variable range hopping theory, different models have been developed that can explain the dependences of the carrier mobility in organic semiconductors on electric field, temperature, carrier concentration, and doping and trap concentration. The charge injection process between metal and organic semiconductor is examined for organic light-emitting diodes.

Finally, compact models of organic thin film transistors and unipolar organic light-emitting diodes to be used in circuit simulation have been proposed.

2. Brief project report

2. Report on the scientific work

Organic semiconductors in general are a family of electronic materials that are based on pi-conjugated carbon atoms. In the last three decades electronic devices based on this family of materials, such as field-effect transistors and light emitting diodes, have attracted much attention as possible inexpensive and flexible alternatives to inorganic devices.

The main goal of this project is to theoretically investigate the charge transport properties of organic semiconductor materials and devices. During the project, two approaches were pursued in parallel, employing the Monte Carlo method and analytical models, respectively.

A Monte Carlo simulator applicable to organic devices based on disordered semiconducting polymers has been developed in the 'C' programming language. This computer program has been presented at several international conferences and in a journal paper as well. It will also be presented in a book chapter. For program development and calibration, Gao and Kahn's empirical findings concerning the electrical properties of an amorphous single-layer Zinc-Phthalocyanine (ZnPc) device with gold contacts have been used. This simulator covers three-dimensional current injection, current propagation and current extraction, whereby all space-charge and image-force effects have been included rigorously. The Monte Carlo algorithm belongs to the class of Kinetic Monte Carlo procedures. Consequently, the simulated carrier dynamics, more precisely: the discrete sequence of charge configurations generated by the program, can be viewed as realistic model of the electron gases physical time evolution regardless of whether the carrier gas is in a stationary state or not. So, transient and time-critical phenomena can be accessed by the computer program with ease. Another motivation for the choice of the Kinetic Monte Carlo technique was the self-adapting time-steps, permitting the simultaneous simulation of competing processes, even if the latter stem from completely different time-scales. The time resolution of all simulations is maximal, i.e., all levels and rates were updated after each single electron transfer, no approximations were made. The program architecture's designing phase was also heavily influenced by the intention to reduce the number of fit parameters to a minimum. Thus, the code has been designed to map the polymer's molecular and morphologic structure as directly as possible: the organic semiconductor's bulk has been implemented as an arbitrary large ensemble of disordered chains. The chains themselves may exhibit an arbitrary number topological defects like kinks and cross-links with other chains. In chemical terms, a chain's strand between two kinks is labeled as "chromophore". In the simulator, chromophores decompose further into an arbitrary number of oligomers, which may be simple repetitions of one and the same monomer or not. In the latter case, one and the same chromophore may contain simultaneously electron donating and electron accepting molecules as well. The monomers, finally, are constituted by an arbitrary number of carbon atoms, represented by "sites". A site represents a single carbon atom exhibiting dangling pi-orbitals and is formed by a pair (spin up/down) of bonding ("HOMO") and a pair (spin up/down) of antibonding electron states ("LUMO"). Chains may share chromophores, oligomers, monomers or single sites. To the author's knowledge, most other simulators represent a polymer simply by a three-dimensional array of sites representing the compound's transport enabling entities. These sites are capable of holding one hole or electron and don't possess an inner structure. In the presented work, holes are not represented as individual, mobile particles but correspond to unoccupied bonding states. Such vacancies generate a Coulomb field due to an uncovered background charge stemming from the ions constituting the polymer's backbone. Both levels are charged and discharges during the simulation by the mechanism of phonon-assisted tunneling ("hopping"). The antibonding electron states form the n-conductive, the bonding states form the p-conductive states. One and the same compound can act as p- or as n-conductor depending on the constellation of work functions within the device. In case of doubly occupied levels, the electrons are treated as indistinguishable particles. The Coulomb singularity between two particles on the same level has been regularized by a cut-off, i.e. by a finite "on-site Coulomb interaction" comparable to the mutual repulsion between hard balls.

Astonishingly, the numeric value of this quantity turned out to influence the simulator's behavior at the current stage of development not very significantly. The more carbon atoms assemble a molecule, the bigger is thus the possible electric current across the molecule during a simulation. If, for example a semiconductor consists solely of molecules with 18 pi and 18 pi* electrons, in the simulator a monomer is thus assembled by 9 sites and each chain contains only one chromophore, which in turn contains only one of these molecules. However, since the memory demand increases dramatically with increasing molecule size, all simulations have been performed with molecules consisting of one single site. The program also pays tribute to the fact that different polymers can possess different transport enabling molecular entities. For example, the simulator can handle blends of organic semiconductors leading to simultaneous hopping transitions among chromophores (along and between chains) as well as hopping between small molecules as well. More generally, of course, molecularly doped combinations of p- and n-type conducting hydrocarbons can be simulated. Molecular disorder has been modeled by the well-established Gaussian Disorder Model proposed by Heinz Baessler. This model is based on the application of the Central Limit Theorem to the influence of disorder on the molecular spectra and is quite useful for the exploration of an organic semiconductor's bulk. Since many organic devices show contact-dominated behavior, the injection and ejection process of charges became the most crucial problem in this work. Following Baessler and most other scientists, the Miller-Abrahams expression was employed for the propagation of carriers in the bulk. For injection and extraction, the Miller-Abrahams rate has also been applied due to its simplicity. The pioneering papers of Wolf, Arkhipov, and Baessler discussed the extension of the Miller-Abrahams rate to the injection and extraction process. They did not extend the hopping process to interfacial charge exchange in a straightforward manner, that means: as hopping injection in real space, but injected into a pretty abstract "simulation lattice". Thereby, metal electrons were injected into randomly chosen pairs of adjacent lattice planes in the simulation lattice's interior using hopping distances as that for the two lattice planes next to the contact. In reality, however, transfer rates of course decay with increasing distance and electrons only jump into the molecular layer next to the electrode. Wolf's injection currents into this "simulation lattice" replicate the experimental results quite well. However, as he notes, these currents cannot be interpreted in a direct physical sense, but probabilistic. In contrast, the presented work focused on the creation of a simulator applicable to complex effects in real space like spacial and energetic disorder, dopant-assisted injection (extraction) enhancement, roughness and shielding effects due to space charge accumulation at the electrodes. Thus, numerous computer experiments were dedicated to the Miller-Abrahams based hopping injection and extraction in real space based on the Gaussian Disorder Model. To the author's knowledge, the device physics clearly has been regarded more detailed than in Wolf's simulations. All simulations were performed for clean ZnPc/Au interfaces, where the contact's Fermilevel is about at mid-gap and electron injection can occur concomitantly with the mainly p-conductive transport regime. All Coulomb interactions between all electrons and holes and their corresponding image charges in both the cathode and the anode have been considered rigorously. Due to the smallness of the simulated devices, also image charges of image charges and so forth have been regarded. The currents of one and two band simulations showed a similar shape, but differed by five orders of magnitude, when HOMO-LUMO transitions were governed by the Miller-Abrahams rate. This obviously unphysical numeric effect disappeared, when each band conducted isolated. In the case of forbidden HOMO-LUMO transitions, the two-band current was slightly higher than the one-band current. This was probably due not only to the increased number of current-carrying orbitals, but also due to the electrostatic influence of the injected electrons on the interface's electronic structure. The seemingly thermionic current-voltage characteristics already mentioned by Wolf et al. has been replicated. Moreover, in accordance with Wolf's results, it was found, that the J/V characteristic's temperature dependence was much weaker than predicted by the Richardson-Schottky-theory. Generally, the J/V characteristic's thermionic shape turned out to be very robust against even drastic variations of the Gaussian Disorder Model's parameters. When the excitation of metal electrons to higher metal states was included as competing event to the injection, the current of course decreased and the

thermionic shape flattened with increasing excitation frequency. The thermionic characteristic's slope is obviously incompatible with Gao & Kahn's measurements. The classical Miller-Abrahams rate turned out as inadequate for an overall device simulation on the grounds of a three-dimensional two-band Gaussian Disorder Model rigorously regarding space charge and influence effects. Since it still is very desirable to base the mechanisms for charge injection, charge propagation and charge extraction on a common microscopic expression, the replacement of the Miller-Abrahams rate by a much more advanced transition rate is currently under development.

The second approach pursued in this project focused on the development of analytical models for device and circuit simulation. Charge transport properties have been investigated in the framework of variable range hopping theory. In a previously published paper by Vissenberg, a percolation model has been developed in order to explain the temperature dependence of hopping mobility in organic semiconductors. One of our main theoretical goals is to develop different models that can explain the dependence of the mobility in organic semiconductors on electric field, temperature, carrier concentration, and doping and trap concentration. A both temperature and electric field dependent mobility model is developed based on a modified Miller-Abrahams rate equation. The carrier concentration-dependent mobility is formulated assuming a Gaussian density of states. A unified mobility model is presented which can explain the temperature, electric field and carrier concentration dependence. The doping and trap dependent mobility model is obtained by assuming a superposition of two exponential density of states functions. The charge injection process between metal and organic semiconductor is examined for organic light-emitting diodes. For this goal we develop both a diffusion-controlled and a master equation based injection model. These two models can explain the dependence of the injection current on the temperature, electric field and barrier height. Good agreement between calculation and experimental data is found. We examine closely the space charge limited current (SCLC) and the effect of the Fermi-Dirac statistics on the transport energy. It is found that the SCLC due to a Gaussian density of states is similar to SCLC controlled by shallow traps in regular semiconductors. The Fermi-Dirac statistics plays an important role for transport energy, even at low temperature. Finally, analytical models applicable to organic thin film transistors and to unipolar organic light-emitting diodes are presented.

2.2. Personnel development – importance of the project for the scientific careers of those involved

- Mr. Ling Li has finished his PhD study within the project period (final exam 02/2008). His specific research work on organic semiconductors enabled him to join a major European research institute (Belgium) and to continue research in this field.
- Mr. Gregor Meller is expected to complete his PhD thesis in summer 2008. After completion of this FWF project he joined another research project at our Institute for half a year. There he applies the Monte Carlo simulator for hopping transport in disordered systems to MOSFET degradation studies.

2.3 Effects of the project outside the scientific field

3. Information on project participants

not funded by the FWF			funded by the FWF (project)		
co-workers	number	Person-months	co-workers	number	Person - months
non-scientific co-workers			non-scientific co-workers		
diploma students			diploma students		
PhD students			PhD students	2	72
post-doctoral co-workers			post-doctoral co-workers	1	3
co-workers with "Habilitation" (professorial qualifications)	1	6	co-workers with "Habilitation" (professorial qualifications)		
professors			professors		

4. Attachments

List 1

1.a. scientific publications¹

1.a.1. Peer-reviewed publications (journals, contribution to anthologies, working papers, proceedings etc.)

- Ling Li, Gregor Meller, Hans Kosina:
"Micro- and Macroscopic Modelling of Optoelectronic Organic Devices"; to be published in: ADVANCES IN POLYMER SCIENCE, Special volume: ORGANIC ELECTRONICS (in preparation).
- L. Li, G. Meller, H. Kosina:
["Analytical Conductivity Model for Doped Organic Semiconductors"](#); *Journal of Applied Physics*, **101** (2007), 033716; 1 – 4.
- L. Li, G. Meller, H. Kosina:
["Carrier Concentration Dependence of the Mobility in Organic Semiconductors"](#); *Synthetic Metals*, **157** (2007), 243 – 246.
- L. Li, G. Meller, H. Kosina:
["Diffusion-Controlled Charge Injection Model for Organic Light-Emitting Diodes"](#); *Applied Physics Letters*, **91** (2007), 17; 1 - 3.
- L. Li, G. Meller, H. Kosina:
["Influence of Traps on Charge Transport in Organic Semiconductors"](#); *Solid-State Electronics*, **51** (2007), 445 – 448.
- L. Li, G. Meller, H. Kosina:
["Temperature and Field-Dependence of Hopping Conduction in Organic Semiconductors"](#); *Microelectronics Journal*, **38** (2006), 1; 47 – 51.
- G. Meller, L. Li, S. Holzer, H. Kosina:
["Simulation of Carrier Injection and Propagation in Molecularly Disordered Systems"](#); *Optical and Quantum Electronics*, **38** (2006), 12-14; 993 – 1004.

1.a.2. Non peer-reviewed publications (journals, contribution to anthologies research reports, working papers, proceedings, etc.)

1.a.3. Stand-alone publications (monographies, anthologies)

- Ling Li, Gregor Meller, Tibor Grasser:
ADVANCES IN POLYMER SCIENCE, Special volume: ORGANIC ELECTRONICS, Publisher: Springer Berlin / Heidelberg (Proceedings of the Workshop on Organic Electronics, in preparation)

¹ The publication list must mention for each work: all authors; full title; series/journal title; year; volume; and page numbers.

List 2 project-related participation in international scientific conferences

2.1. Conference participations - invited lectures

- L. Li, G. Meller, H. Kosina:
"Micro and Macroscopic Modeling of Charge Flows in Molecularly Disordered Organic Semiconductors"; Talk: SISPAD 2007 Companion Workshop 'Organic Electronics', Wien; 09-28-2007.

2.2. Conference participations - lectures

- L. Li, G. Meller, H. Kosina:
["Charge Injection Model for Organic Light-Emitting Diodes"](#);
Talk: International Conference on Organic Electronics (ICOE), Eindhoven; 06-04-2007 - 06-07-2007; in: "International Conference on Organic Electronics", (2007).
- G. Meller, L. Li, S. Holzer, H. Kosina:
["Simulation of Carrier Injection and Propagation in Molecularly Disordered Systems"](#);
Talk: Numerical Simulation of Optoelectronic Devices (NUSOD), Singapore; 09-11-2006 - 09-14-2006; in: "Proceedings of the 6th International Conference on Numerical Simulation of Optoelectronic Devices", (2006), ISBN: 0-7803-9755-x; 1 – 2.
- G. Meller, L. Li, H. Kosina:
["Monte Carlo Simulation of Molecularly Doped Organic Semiconductors"](#);
Talk: European Conference on Organic Electronics and Related Phenomena (ECOER), Winterthur; 09-27-2005 - 09-30-2005; in: "3rd European Conference on Organic Electronics and Related Phenomena Book of Abstracts", (2005), 44 - 45.

2.3. Conference participations - posters

- L. Li, G. Meller, H. Kosina:
["Charge Injection Model in Organic Light-Emitting Diodes based on a Master Equation"](#);
Poster: International Conference on Simulation of Semiconductor Processes and Devices (SISPAD), Wien; 09-25-2007 - 09-27-2007; in: "International Conference on Simulation of Semiconductor Processes and Devices 2007", (2007), ISBN: 978-3-211-72860-4; 377 – 380.
- G. Meller, L. Li, S. Holzer, H. Kosina:
["Dynamic Monte Carlo Simulation of an Amorphous Organic Device"](#);
Poster: International Conference on Simulation of Semiconductor Processes and Devices (SISPAD), Wien; 09-25-2007 - 09-27-2007; in: "International Conference on Simulation of Semiconductor Processes and Devices 2007", (2007), ISBN: 978-3-211-72860-4; 373 – 376.

- L. Li, G. Meller, H. Kosina:
["Field-Dependent Effective Transport Energy in Organic Semiconductors"](#); Poster: Meeting on Molecular Electronics (ELECMOL), Grenoble; 12-11-2006 - 12-15-2006; in: "3rd Meeting on Molecular Electronics", (2006), T2-PC18.
- L. Li, G. Meller, H. Kosina:
["Doping Dependent Conductivity in Organic Semiconductors"](#);
 Poster: International Conference on Simulation of Semiconductor Processes and Devices (SISPAD), Monterey; 09-06-2006 - 09-08-2006; in: "International Conference on Simulation of Semiconductor Processes and Devices 2006", (2006), ISBN: 1-4244-0404-5; 204 – 207.
- G. Meller, L. Li, S. Holzer, H. Kosina:
["Electron Kinetics in Disordered Organic Semiconductors"](#);
 Poster: ACS/IEEE/MRS Annual Organic Microelectronics Workshop, Toronto; 07-09-2006 - 07-12-2006; in: "Abstracts 2nd Annual Organic Microelectronics Workshop", (2006), 42.
- L. Li, G. Meller, H. Kosina:
["Percolation Current in Organic Semiconductors"](#);
 Poster: International Workshop on Computational Electronics (IWCE), Wien; 05-25-2006 - 05-27-2006; in: "11th International Workshop on Computational Electronics Book of Abstracts", (2006), ISBN: 0-9767985-8-1; 161 – 162.
- G. Meller, L. Li, H. Kosina:
["Kinetic Monte Carlo Simulation of Molecularly Doped Organic Semiconductors"](#);
 Poster: Meeting on Molecular Electronics (ELECMOL), Grenoble; 12-19-2005 - 12-21-2005; in: "Second Meeting on Molecular Electronics", (2005), 107.
- L. Li, G. Meller, H. Kosina:
["Temperature and Field-dependence of Hopping Conduction in Organic Semiconductors"](#);
 Poster: European Conference on Organic Electronics and Related Phenomena (ECOER), Winterthur; 09-27-2005 - 09-30-2005; in: "3rd European Conference on Organic Electronics and Related Phenomena Book of Abstracts", (2005), 112 – 113.

2.4. Conference participations - other

List 3 Development of collaborations

Indication of the most important collaborations (maximum 5), that took place (initiated or continued) in collaboration please give the name of the collaboration partner (name, title, institution) and a few words about the scientific content. Please also assign one of the following **categories** to each collaboration:

N			Nature	N (national); E (European); I (other international cooperation)
E	E		Extent	E1 low (e.g. no joint publications but mention in acknowledgements or similar); E2 medium (collaboration e.g. with occasional joint publications, exchange of materials or similar but no longer-term exchange of personnel); E3 high (extensive collaboration with mutual hosting of group members for research stays, regular joint publications etc.)
		D	Discipline	D within the discipline T transdisciplinary

N	E	D	Collaboration partner / content of the collaboration
			1) Name: _____ Title: _____ Institution: _____ Content: _____
			2) Name: _____ Title: _____ Institution: _____ Content: _____
			3) Name: _____ Title: _____ Institution: _____ Content: _____
			4) Name: _____ Title: _____ Institution: _____ Content: _____
			5) Name: _____ Title: _____ Institution: _____ Content: _____

Note: general scientific contacts and occasional meetings should not be considered as collaborations in the above sense.

List 4 “Habitations” (professorial qualifications) / PhD theses / diploma theses

4.1. Professorial Qualifications

4.2. PhD Theses

- Ling Li: “Charge Transport in Organic Semiconductor Materials and Devices”; Reviewer: H. Kosina, D. Suess; Institut für Mikroelektronik, 2008; oral examination: 08 Feb 2008.
- Gregor Meller: “Transient Microscopic Simulation of Organic Semiconducting Devices”; Reviewer: H. Kosina, Institut für Mikroelektronik, 2008 (in preparation).

4.3. Diploma Theses

List 5 Effects of the project outside the scientific field

Sections of the list:

5.1. Organization of scientific events

The 12th International Conference on Simulation of Semiconductor Devices and Processes (SISPAD) has been held at the TU Wien in September 2007. On September 28, 2007 a companion Workshop on Organic Electronics has been organized. The program is quoted below (see also <http://www.sispad.org>).

- 09:00 - 09:05 **Welcome**
Gregor Meller
[Interfaces in Organic Thin-film Transistors](#)
- 09:05 - 09:40 *G. Horowitz*
Universite Denis-Diderot (France)
[Charge Transfer at Hybrid Interfaces](#)
- 09:40 - 10:15 *W.R. Salaneck*
Linköping University (Sweden)
[Charge Transport Dynamics and Electric Field Effects in Organic Transistors](#)
- 10:15 - 10:50 *A. Dodabalapur*
University of Texas at Austin (USA)
[N-type Doping of Organic Molecular Films](#)
- 10:50 - 11:25 *A. Kahn*
Princeton University (USA)
- 11:25 - 11:45 **Coffee**
[On the Theoretical Description of Charge Transport in Disordered Organic Materials](#)
- 11:45 - 12:20 *S. Baranovski*
Universität Marburg (Germany)
[Utilizing Ions in Organic Electronic Devices](#)
- 12:20 - 12:55 *G. Malliaras*
Cornell University (USA)
[Charge Injection and Transport in Tris\(8-hydroxyquinoline\) Aluminum \(Alq3\)](#)
- 12:55 - 13:30 *M.A. Baldo*
MIT (USA)
- 13:30 - 15:00 **Lunch**
[Charge Transport Regime in Crystalline Organic Semiconductors: Predicting the Absolute Temperature Dependent Charge Mobility](#)
- 15:00 - 15:35 *A. Troisi*
University of Warwick (UK)
[Novel Approaches in Simulations of Organic Semiconductor Devices](#)
- 15:35 - 16:10 *Y. Preezant*
Technion (Israel)
Macro and Microscopic Modeling of Charge Flows in Disordered Organic Semiconductors
- 16:10 - 16:45 *L. Li, G. Meller*
Institute for Microelectronics, TU Wien (Austria)

- 5.2. Particular honours, prizes etc.**
- 5.3. Information on results relevant to commercial applications**
- 5.4. Other effects beyond the scientific field**
- 5.5. Relevance of the project in the organization of the relevant scientific discipline**

List 6. Applications for follow-up projects

6.1 Applications for follow-up projects (FWF projects)

1) In 2007 an FWF stand-alone project has been submitted by Tibor Grasser (with G. Meller as a PostDoc): "Modeling and Simulation of Upcoming Organic Photovoltaic Devices." The proposal has been rejected.

6.2 Applications for follow-up projects (Other national projects)

6.3 Applications for follow-up projects (International projects)