Visitors Activity Report: Novel Organic Semiconductor Devices

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4. Duration of Stay: March 16 to June 15, 2009

During my stay at IMR, I used the excellent facilities of IMR and the very large experience of colleagues on organic materials and on silicon solar cells to perform two projects on organic devices. These projects are still ongoing and here we can only report intermediate results, since it is expected that the projects will last for another several months. The two projects are:

First, we started a project to combine organic emitter layers with inorganic semiconductor cells. In particular, the goal was to deposit a C_{60} derivative on a silicon solar cell p-type backplane. The idea was to check whether such a structure allows to realize a very simple hybrid solar cell which does not need a high-temperature n-doping process. The advantage of such an approach would be that such cells might be produced using much simpler processes than employed so far. As organic materials, we used a soluble C_{60} (PVBM) derivative which is well known from all-organic solar cells as a good electron transporter. The devices were prepared by spin coating on a silicon wafer where the back contacts were prepared by conventional proceses before, and then depositing a metallic cathode on top of that.

The first experiments showed that the principle can basically work, but there is a large hysteresis observed which is probably caused by the fact that there is still a native oxide present at the Si surface, which could not be avoided by the experimental procedure which we have used so far. Further experiments will try to realize this structure without the oxide layer.

Secondly, we worked on a project which intends to combine light-emitting organic single crystal field-effect transistors with dielectric microresonators, thus combining experience from IMR and the IAPP of the TU Dresden: At IMR, there is excellent experience on single crystal light emitting transistors [1], at Dresden, there is detailed experience in dieelectric mirrors and microcavities containing organic active layers [2-4].

The idea here was to provide the transistor structures with optical feedback and find out whether stimulated emission can be observed (which is a very challenging goal and cannot be expected to be observed in the course of first experiments).

After jointly discussing the sample design in Sendai, first substrates with back mirrors were prepared in Dresden and sent to Sendai. After some delay due to lab reconstruction, the field-effect transistors were deposited. Then, the samples will be completed in Dresden.

The first round of experiments has shown that there are a number of challenges in performing the task: In the first experiments, the ambipolar light emitting transistor device using a single crystal green emitter on one of the substrate did not work as transistors. Apparently there are several challenges that we faced and it has to be discussed how to solve them: Apparently the surface of the DBR substrate was too rough for the single crystals to be laminated

Second, there was a problem with the insulating oxide thickness: The gate dielectric broke down before any carriers get accumulated and transported, probably related to a too thin oxide and leaks.

Additionally to these works, I gave at the IMR a series of three seminars on the research work performed at the Institut für Angewandte Photophysik, TU Dresden: A seminar on the basics of organic materials, a seminar on organic light emitting diodes and optically pumped lasers, and a seminar on organic solar cells. The seminars were visited well and I had stimulating discussion with many coworkers.

Finally, I worked on a review: I was invited to write the part on organic semiconductors in Elsevier's forthcoming encyclopedia - the Comprehensive Semiconductor Science and Technology. This task is to be performed in collboration with my coworkers Dr. Moritz Riede and Dr. Björn Lüssem.

References:

1 Taishi Takenobu, Satria Zulkarnaen Bisri, Tetsuo Takahashi, Masayuki Yahiro, Chihaya Adachi, Yoshihiro Iwasa. "High Current Density in Light-Emitting Transistors of Organic Single Crystals". Physical Review Letters 100, 066601 (2008).

2 R.Gehlhaar, R.Schuppel, M.Koschorreck, T.Fritz, H.Frog, V.G.Lyssenko, K.Leo, L.Connolly, D.G.Lidzey, Time-resolved and cw photoluminescence from strongly coupled organic microcavities, J. Luminesc. 110, 354 (2004)

3 R. Gehlhaar, M. Swoboda, M. Sudzius, M. Hoffmann, H. Fröb, V.G. Lyssenko, and K. Leo, Polarization splitting and terahertz oscillations from a single planar Fabry-Pérot microcavity, Appl. Phys. Lett. **88**, 091121 (2006)

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