Niyazi Serdar Sarıçiftçi
Doctor Honoris Causa

Laudatio Domini

Niyazi Serdar Sariçiftçi

Este o onoare pentru Universitatea din București să acorde domnului Profesor Doctor Niyazi Serdar SARICIFTCI titlul onorific de Doctor Honoris Causa, primit de-a lungul timpului de personalități științifice marcante. Realizările remarcabile ale domnului Profesor Sariciftci în plan academic, dar mai ales ca cercetător în domeniul Știința Materialelor, în general, și cel al Celulelor Fotovoltaice Organice, în particular, sunt bine cunoscute în comunitatea științifică, dovedind pasiunea și dedicarea totală pentru această profesie.

S-a născut pe 19 martie 1961 în Konya, Turcia. Părinții săi, Sukran și Ibrahim Sariciftci, au fost profesori de muzică. S-a căsătorit în 1987 în Viena cu Veronica Matschnigg și au împreună doi copii, Boris Ali Sariciftci și Caroline Ayse Sariciftci.

Domul Profesor Sariciftci a urmat cursurile primare și cele gimnaziale la Conservatorul din Istanbul, Turcia, studiind pianul clasic. Și-a continuat studiile la Austrian Sankt Georg Kolleg în Istanbul, finalizându-le cu calificative foarte bune. Absolvă Facultatea de Fizică a Universității din Viena, iar în 1986 finalizează cursurile de Masterat în Fizică.

Între 1986 și 1989, la aceeași Universitate, lucrează pentru finalizarea tezei de doctorat cu titlul: ”*Investigații spectroscopice ale tranzițiilor metal-izolator induse chimic în polianilină*”, axându-se pe spectroscopia optică, spectroscopia Raman și FTIR. A dezvoltat, în această perioadă, tehnici pentru spectroscopia vibrațională și optică în vederea caracterizării proceselor electrochimice de dopare, precum și mecanismele de inducere a pH-ului prin doparea polianilinei. O altă importantă contribuție a fost cea legată de modelarea structurală a polianilinei prin modificarea compoziției chimice în timpul proceselor de dopare și analizarea rezultatelor cu ajutorul spectroscopiei vibraționale.

În următorii doi ani, domnul Profesor Sariciftci a efectuat un stagiu postdoctoral de cercetare la Universitatea din Stuttgart (2^{nd} Physics Institute), în electronică moleculară, specializându-se în rezonanță electronică de spin (ESR), rezonanță electronică nucleară dublă (ENDOR) și transfer electronic fotoindus în cazul structurilor supramoleculare. A raportat pentru prima dată prezența efectului Overhauser în cazul politiofenei. De asemenea, folosind tehnici ENDOR a determinat distribuția spinilor pentru supermoleculele donor-acceptor, rezultatele experimentale obținute fiind confirmate de calcule numerice INDO și MNDO. A studiat ceea ce numim „a treia generație" de polimeri conductori având grupuri funcționale specifice. În 1991, domnul profesor Sariciftci obține „Abilitarea" în Fizica Solidului la Central University Commission (YOK) în Ankara, Turcia.

Între 1992 și 1996 domnul profesor Sariciftci lucrează ca Cercetător Specialist Asociat la Institutul pentru Polimeri și Solide Organice, afiliat Universității din California, Santa Barbara, împreună cu profesorul Alan J. HEEGER. Trebuie amintit că HEEGER, MacDIARMID și SHIRAKAWA au primit **Premiul Nobel** pentru Chimie în 2000 pentru descoperirea proprietăților metalice ale poliacetilenei dopate chimic; datorită lor se pot obține astăzi semiconductori, dielectrici sau polimeri metalici.

Cercetările domnului Sariciftci au fost direcționate cu precădere spre studiul polimerilor conductivi, fiind analizate fenomenele optice fotoinduse, cele de transport și rezonanță magnetică. A raportat **pentru prima dată** în literatura de specialitate prezența transferului electronic fotoindus ultra-rapid în polimerii conjugați/fulerene C60 și heterojoncțiuni și a folosit cunoștințele dobândite pentru a crea celule solare eficiente pe suport flexibil. Pentru aceste contribuții, domnul profesor Sariciftci are un brevet de invenție internațional, și de asemenea, o specializare în SQUID.

Începând cu 1996, domnul Sariciftci este profesor principal pentru fizică-chimie la Universitatea Johannes Kepler (JKU) din Linz, Austria.

Dezvoltarea dispozitivelor fotovoltaice anorganice, bazate pe semiconductori anorganici are câteva constrângeri importante: pe de o parte, costul mare al tehnologiei bazate pe siliciu (Si), iar pe de altă parte rezervele naturale sărace ale materialelor care pot fi folosite pentru realizarea unor dispozitive eficiente. Aceste limitări pot fi depășite dacă ne orientăm spre celulele fotovoltaice bazate pe materiale organice. Principalul avantaj al dispozitivelor fotovoltaice bazate pe polimeri conductori este acela că a introdus metode ieftine și uzuale prin care este produsă energie electrică prin conversia radiației solare, iar acesta este un prim pas în obținerea așa numitei „energii verzi".

Progresul acestui domeniu este strâns legat de activitatea de cercetare a domnului profesor Sariciftci. **Prima idee remarcabilă** a fost aceea de a folosi polimeri conjugați ca donori de electroni în combinație cu derivați de fulerene, ținând cont de afinitatea electronică ridicată a acestora. Asemănător procesului chimic de dopare, putem vorbi despre un transfer electronic fotoindus din polimerul conjugat donor în acceptor, proces ce poate fi numit „fotodopare".

Studiile efectuate pe mixturile dintre polimerii conjugați și derivații de fulerenă au pus în evidență existența unui transfer electronic fotoindus metastabil și foarte rapid din polimerii conjugați în filmele subțiri solide de C60.

O diferență importantă între celulele solare anorganice și organice este legată de prima stare fotoexcitată. În cazul celor anorganice, prin absorbția fotonilor se creează direct purtători de sarcină liberi, electroni și goluri. În cazul celulelor fotovoltaice organice, prin absorbția fotonilor se produc excitoni, perechi electron-gol cu energiile de legare cuprinse între 0.05 și 1 eV. Pentru a avea efect fotovoltaic, excitonii trebuie să disocieze înainte de a se recombina. Dispozitivele organice dublu-strat Donor/Acceptor pot funcționa ca și cele anorganice. Filmele subțiri din semiconductori organici au coeficienți de absorbție ridicați (10^5 cm^{-1}), benzi interzise ce pot fi modificate și mobilități ale purtătorilor de sarcină care îi fac competitivi pentru dispozitivele bazate pe siliciu amorf. O altă direcție de cercetare a domnului profesor Sariciftci este cea legată de doparea chimică a semiconductorilor prin introducerea unor cantități mici de reactivi. Chiar și folosind acest procedeu, trebuie menționat că doar acei excitoni creați la o distanță cuprinsă între 10-80 nm de interfață vor atinge interfața heterojoncțiunii, ceea ce înseamnă pierderi masive ale fotonilor aflați la distanță mare de interfață și eficiență cuantică mică.

Această constrângere l-a condus la o altă idee remarcabilă, aceea de a înlocui heterojoncțiunea dublu-strat cu o heterojoncțiune în volum, o mixtură între două componente, un donor și un acceptor. Conceptul de heterojoncțiune în volum, dezvoltat de profesorul Sariciftci, a condus la creșterea (cu câteva ordine de mărime) a interfeței de contact dintre donor și acceptor ceea ce a condus la obținerea unor eficiențe de conversie mai mari. Fazele donorului și ale acceptorului sunt la nivel nanometric formând o rețea interconectată. De aceea, pentru celulele fotovoltaice cu heterojoncțiune în volum, morfologia la nivel nanometric devine importantă.

Domnul profesor Sariciftci împreună cu colaboratorii dumnealui au obținut rezultate importante și numeroase în domeniul celulelor fotovoltaice organice, dar și în cazul altor dispozitive optoelectronice bazate, de asemenea, pe materiale organice.

Un exemplu care dovedește importanța morfologiei la nivel nanometric este cel al mixturii MDMO-PPV: PCBM (1:4). Dacă amestecul este dizolvat în clorobenzen rezultatele obținute pentru parametrii ce caracterizează o celulă fotovoltaică sunt de trei ori mai buni decât dacă aceeași mixtură era dizolvată în toluen. De asemenea, prin structurarea mixturii care va conține mai puțină metanofulerenă și simultan prin creșterea interacțiunii între lanțurile polimerice, pentru celulele fotovoltaice de tipul polimer conjugat/ metanofulerenă se obține o eficiență de conversie de 2.5% (2001).

Totuși, celulele fotovoltaice având ca strat activ asemenea mixturi pot absorbi fotoni a căror lungime de undă este mai mică de 550 de nanometri, ceea ce reprezintă foarte puțin din radiația solară incidentă. Alți polimeri cum este P3HT având banda interzisă în jurul valorii de 2 eV pot absorbi fotoni a căror lungime de undă este cu 100 de nanometri mai mare, ceea ce va conduce la un curent de scurtcircuit (I_{sc}) mai mare și o eficiență de conversie de aproximativ 3%. Mai mult decât atât, continuând cercetarea în acest domeniu, eficiențele de conversie obținute au fost mai mari, atingându-se valori de aproximativ 10%.

Transferul electronic fotoindus de la polimerul semiconductor la fulerenă nu doar că îmbunătățește generarea purtătorilor de sarcină în polimerul gazdă, dar previne recombinarea prin separarea purtătorilor de sarcină și stabilizarea acestora.

De asemenea, grupul domnului profesor Sariciftci a fabricat electrozi transparenți flexibili prin imprimarea filmelor obținute din nanotuburi de carbon cu un singur perete (SWNC), iar aceștia au fost folosiți ca electrozi pentru celulele fotovoltaice cu heterojoncțiune în volum. Prin metoda de imprimare se obțin filme subțiri destul de netede, omogene, pentru care transmitanța este de aproximativ 85% la 550 de nanometri. Celulele solare cu SWNT sunt mult mai flexibile, iar valorile eficienței de conversie sunt destul de mari. Este bine cunoscut faptul că electrozii de oxid de indiu și staniu (ITO) sunt transparenți, dar destul de scumpi, de aceea aceste rețele de nanotuburi pot fi o soluție.

Performanțele fotovoltaice ale celulelor solare cu heterojoncțiune în volum având ca acceptor TiO_2 și nanoparticule de 6-palmitat acid ascorbic încorporate în matricea de P3HT au crescut foarte mult utilizând această morfologie.

Domnul profesor Sariciftci a contribuit la dezvoltarea unor tehnici ieftine de producere a dispozitivelor optoelectronice, şi împreună cu colaboratorii dumnealui au avut o contribuție importantă şi în ceea ce privește caracterizarea dispozitivelor fotovoltaice. În cazul celor organice, tensiunea la circuit deschis depinde linear de nivelul HOMO al donorului și de nivelul LUMO al acceptorului. Dependența de nivelul LUMO în cazul tensiunii de circuit deschis a fost demonstrată experimental.

Catodul este de cele mai multe ori modificat prin depunerea unui film subțire de fluorură de litiu (LiF) între electrodul metalic și semiconductorul organic, ceea ce va îmbunătăți injecția purtătorilor de sarcină în LED-uri și crește tensiunea la circuit deschis în cazul celulelor fotovoltaice organice.

Mobilitatea nu este un parametru de material, dar poate fi considerată un parametru al dispozitivului, valorile sale modificându-se în funcție de morfologia filmului subțiri organic semiconductor. Mobilitatea purtătorilor de sarcină și procesul de recombinare în cazul unei celule solare cu heterojoncțiune în volum au fost studiate folosind o metodă nouă: extragerea sarcinii prin creșterea liniară a tensiunii (CELIV). În cazul acestei tehnici, echilibrul purtătorilor de sarcină a fost determinat pentru un dielectric, la polarizare inversă. Metoda poate fi folosită pentru a determina mobilitatea purtătorilor de sarcină pentru acele probe a căror grosime nu depășește câteva sute de nanometri. Folosind acestă metodă în cazul P3HT a fost obținută dependența câmpului electric negativ de mobilitate. De fapt, la temperatura de 250K panta dependeței câmpului electric de mobilitate devine negativă. Asemenea comportament a fost raportat pentru mai multe materiale amorfe, dar nu a fost pus în evidență în cazul polimerilor semiconductori.

Timpul de viață al purtătorilor de sarcină și procesele de recombinare sunt teme importante în domeniul celulelor fotovoltaice. Mecanismele care limitează eficiența de conversie în cazul dispozitivelor cu heterojoncțiune în volum au fost discutate recent de domnul profesor Sariciftci și colaboratorii dumnealui (2011) punându-se accentul tocmai pe aceste procese de recombinare. Au fost analizate o serie de metode ce pot fi folosite experimental pentru determinarea timpului de viață al purtătorilor de sarcină sau pentru explicarea proceselor de recombinare, dar trebuie menționat că morfologia influențează puternic atât timpul de viață al purtătorilor de sarcină, cât și procesele de recombinare.

Merită menționate două contribuții recente ale profesorului Sariciftci și ale colaboratorilor dumnealui.

Prima dintre acestea se referă la celulele fotovoltaice organice având contactul metalic de spate semitransparent (2009). Prin depunerea unui dispozitiv fotovoltaic flexibil semitransparent între două sticle izolatoare, suprafețe extinse (ferestre) care până acum nu erau valorificate din acest punct de vedere pot fi folosite pentru generarea de electricitate, fie pe acoperişul clădirilor sau în spații aglomerate. Benzile de absorbție distincte ale materialelor semiconductoare organice pot lăsa ”ferestre” de transmisie în partea vizibilă a spectrului solar, ducând astfel la posibilitatea realizării unor celule solare care să transmită lumina din spectrul vizibil și să convertească în electricitate radiația din domeniile ultra-violet (UV) și infraroșu apropiat (NIR). Pe această proprietate se bazează dispozitivele descrise mai sus pentru care transmisia din domeniul vizibil este maximizată, în timp ce radiația din UV și NIR este absorbită, reducându-se astfel strălucirea și încălzirea datorate radiației solare, şi în acelaşi timp generând electricitate. Deocamdată pentru astfel de dispozitive pentru care transmisia în partea vizibilă a spectrului este de 60% a fost obținută o eficiență de 0.5%.

Cea de-a doua se referă la dezvoltarea de materiale noi pentru electronica bio-organică (2011). Descoperirea de materiale noi a devenit centrul cercetării în cazul electronicii organice și implică bio-compatibilitate, bio-degradare și sustenabilitate pentru producerea unui volum cât mai mare cu costuri cât mai reduse. Hârtia, pielea sau mătasea pot fi folosite ca substraturi pentru dispozitivele electronice. Domnul profesor Sariciftci a mers chiar mai departe considerând că gelatina pietrificată, plasticul biodegradabil și chiar zahărul caramelizat pot fi folosite ca substraturi pentru dispozitivele electronice cu efect de câmp. Mai mult decât atât, cercetători din grupul domnului Sariciftci au propus aurin ca soluție pentru substraturile dispozitivelor electronice, substanță care poate fi ușor procesată, fiind extrasă din rădăcinile unei plante sălbatice, binecunoscută în medicina tradițională chinezească. De asemenea, au încercat folosirea de biopolimeri derivați din ADN ca poartă pentru tranzistorii organici cu efect de câmp. Nucleobazele care intră in componența ADN-ului pot fi procesate ca filme subțiri cu o grosime de aproximativ 2.5 nanometri, având proprietăți dielectrice excelente și putând fi utilizați în cazul tranzistorilor organici cu efect de câmp.

În ceea ce privește **activitățile academice**, domnul profesor Sariciftci a devenit îndrumător pentru studenți încă de când lucra ca cercetător specialist asociat la Institutul pentru Polimeri și Solide Organice la Universitatea din California, Santa Barbara (UCSB) și din 1996 la Universitatea Johannes Kepler din Linz. A coordonat mai mult de 20 de doctoranzi, 14 masteranzi și mai mult de 50 de post-doctoranzi. Aproximativ 20 dintre aceștia ocupă în prezent poziții în învățământul universitar, 4 dintre ei fiind deja profesori, profesor Cristoph Brabec (University of Erlangen, Germany), profesor Vladimir Dyakonov (University of Würzburg, Germany), profesor Sean Shaheen (University of Denver, USA) și profesor Attila Mozer (University of Wollongong, Australia), a căror activitate de cercetare este orientată spre electronica organică, iar unii dintre ei au primit deja premii prin care le sunt recunoscute meritele la nivel internaţional. Mulți dintre studenții domnului profesor Sariciftci lucrează în domeniul electronicii organice, în industrie, contribuind astfel la dezvoltarea acestui domeniu. O parte dintre cei coordonaţi de domnul profesor Sariciftci au acum propria lor întreprindere. La nivel european, domnul Sariciftci este co-îndrumător sau examinator pentru foarte mulți studenți din instituții de cercetare.

Prin poziția sa de director al LIOS afiliat al Universității Johannes Kepler, în ultimii 15 ani a demonstrat că deține informațiile necesare și are abilitatea de a conduce un astfel de centru de cercetare, participând la mai mult de 20 de proiecte de cercetare, multe dintre ele având un impact important la nivel european: proiecte Marie Curie, colaborări internaționale, FWF (Fondurile Austriece pentru Știință), Rețeaua Națională de Excelență (2006-2011) și Laboratorul Christian Doppler. În 1997 a inițiat și a coordonat primul proiect european având ca temă de cercetare celulele fotovoltaice organice cu heterojoncțiune în volum. În doar 5 ani a reușit să aducă capital de aproximativ 4.5 milioane de euro.

În ceea ce privește activitatea de cercetare, domnul Sariciftci este membru al Societății Regale de Chimie, membru al SPIE și membru al Societății Americane de Chimie, Societatea pentru Știința Materialelor, Societatea Austriacă de Chimie și Societatea Austriacă de Fizică. Este referent al câtorva reviste importante de specialitate printre care *Journal of Materials Chemistry* and *ChemSusChem* și, de asemenea, membru în echipele organizatorice ale unor conferințe internaționale importante.

Ținând cont de pregătirea și realizările sale academice, trebuie spus că domnul profesor Sariciftci a fost întotdeauna un adept al filosofiei Universității Standford care presupune transferul cunoștințelor dobândite în timpul studiilor în produse care pot fi realizate la nivel industrial, în întreprinderi specializate pentru producerea unui anumit tip de produse. Această ideologie care era relativ nouă în 1996 în Austria a fost introdusă prin LIOS, iar rezultatul a fost apariția câtorva companii specializate. Prima dintre companii a fost Quantum Solar Energy Linz (QSEL) care este și în prezent lider în comercializarea dispozitivelor fotovoltaice, după ce a fost asimilată de Konarka Technologies USA. Celulele fotovoltaice cu heterojoncțiune în volum produse și comercializate de Konarka sunt invenția profesorului Sariciftci și a tehnologiei dezvoltate în cadrul LIOS. O altă companie specializată în acest sens este Solar Fuel GesmbH care continuă munca depusă de domnul Sariciftci, dar în Germania. Domnul profesor Sariciftci și grupul pe care îl conduce au creat numeroase locuri de muncă în Linz, Austria.

În câteva cuvinte, munca sa poate fi descrisă de numărul impresionant de articole publicate în reviste de specialitate. Domnul profesor Sariciftci are în total peste **520** de publicații, acestea fiind citate de mai mult de **24000** de ori, iar index-ul **”h”** era egal cu **66** în februarie 2012. Cercetătorii din grupul pe care îl conduce sunt printre cei mai citați autori. Factorul de impact al revistelor unde sunt publicate articolele dumnealor, precum și brevetele de invenție pe care le dețin pot fi consultate pe pagina web www.lios.at.

În martie 2011 a fost publicat topul primilor **100 de oameni de știință** de către Institutul de Informare Științifică ISI al Thomson Reuter, iar domnul profesor Thompson Reuter ocupă **locul 14,** iar mulți dintre colaboratorii dumnealui se regăsesc în top 20. Această situație este una onorantă pentru LIOS, ținând cont că s-au luat în calcul doar 10 ani din 2000 și până în 2010.
Pentru mai multe informații, vizitați http://www.sciencewatch.com/dr/sci/misc/Top100MatSci2000-10/.

Personalitatea ştiintifică a domnului Profesor Dr. Niyazi Serdar SARICIFTCI este dublată de calităţi umane deosebite care-l fac o personalitate remarcabilă.

Prof. Niyazi Serdar Thompson Reuter şi grupul de cercetare al domniei sale au colaborat şi colaborează fructuos cu cercetători din România. Rezultatele acestor colaborări sunt confirmate de lucrările publicate în prestigioase reviste de specialitate având drept coautori cercetători români şi din grupul de cercetare al domniei sale. În ultimii ani, mai mulţi studenţi şi tineri cercetători din România au studiat şi au efectuat stagii de cercetare la Johannes Kepler University şi la LIOS (M. Irimia-Vladu; Daniela Stoenescu, Lucia Leonat, etc.). Grupul de cercetare al Centrului de Cercetare Dezvoltare pentru Materiale şi Dispozitive Electronice şi Optoelectronice al Universităţii din Bucureşti a fost invitat de către Prof. Sariciftci să devină partener în reţeaua Europeană ,,ORGPVNET". Continuarea şi dezvoltarea acestor colaborări este benefică pentru ambele părţi.

Colaborarea dintre LIOS şi cercetători români angajaţi în energii regenerabile este extrem de profitabilă pentru noi, iar poziţia constructivă şi generoasă a Prof. Sariciftci faţă de specialiştii din ţara noastră trebuie apreciată în mod deosebit. Acordarea titlului de DHC nu este doar un gest de recunoaştere a calităţilor ştiinţifice ale unei mari personalităţi, ci şi o modalitate legitimă de a stimula

interesul şi disponibilitatea Prof. Sariciftci în sprijinirea dezvoltării acestui domeniu vital, al energiilor regenerabile, în ţara noastră.
În concluzie, Universitatea din Bucureşti, prima universitate de cercetare avansată şi educaţie din România este onorată să acorde Titlul de Doctor Honoris Causa Profesorului ***Niyazi Serdar Sariciftci****, ca o recunoaştere a activităţii academice şi ştiinţifice de excepţie a domniei sale, luând în considerare:*
- meritele excepţionale în dezvoltarea domeniului Ştiinţei Materialelor în general şi a Celulelor Solare Organice în particular;
- efortul de a organiza şi dezvolta noi colaborări ştiinţifice benefice atât la nivel local cât mai ales la nivel european;
- deschiderea domniei sale pentru dezvoltarea şi întărirea cooperării ştiinţifice dintre Universitatea Johannes Kepler din Linz şi Universitatea din Bucureşti în domeniul Ştiinţelor naturii;
- personalitatea sa ştiinţifică marcantă la nivel european şi mondial.

Profesor dr. Ştefan ANTOHE
Decan Facultatea de Fizică
Universitatea din Bucureşti

Laudatio Domini

Niyazi Serdar Sariçiftçi

There is an honor for University of Bucharest to include Prof. Dr. **Niyazi Serdar SARICIFTCI** among the scientific personalities who were awarded the honorific title of Doctor Honoris Causa. The outstanding achievements of Prof. SARICIFTCI, in academic and experimental research in the field of Materials Science, generally and Organic Solar Cells, particularly, are well known in the scientific community and show his passion and dedication for his profession.

Born in Konya/TURKEY on 19th March 1961 as son of the music professors Sukran and Ibrahim SARICIFTCI, married to Veronica Matschnigg in Vienna (1987), he is father of two children: Boris Ali SARICIFTCI and Caroline Ayse SARICIFTCI.

Starting with primary studies of music and 7th class completion at the city conservatory in Istanbul, Turkey (classical piano), and continuing with study and graduation at the Austrian Sankt Georg Kolleg in Istanbul, with distinction prize, Professor Sariciftci graduated the Faculty of Physics at the University of Vienna, as Master of Science in physics, in 1986.

Between 1986 and 1989, at the same university, he prepared his PhD thesis: *"Spectroscopic investigations on the electrochemically induced metal to insulator transitions in polyaniline"*, with specialization on *in situ* optical, Raman and FTIR spectroscopy during doping processes. He developed techniques for the vibrational and optical spectroscopy during electrochemical doping-undoping processes as well as the pH induced doping mechanisms of polyaniline, and reported the first observation and assignment of the quantum size effects on the metallic intraband absorption of conducting polymers. Another interesting contribution was the structural modeling of the different chemical compositions of polyaniline during these doping-undoping processes via *in situ* vibrational spectroscopy.

In the next two years, Prof. SARICIFTCI worked as a postdoctoral research associate at the 2nd Physics Institute, of University of Stuttgart, in molecular electronics, with specialization on Electron Spin Resonance (ESR), electron nuclear double resonance (ENDOR) and photoinduced electron transfer on supramolecular structures. He reported the first observation of the Overhauser effect on the ESR metallic polythiophene. He also used the ENDOR technique to map the spin distribution on donor-acceptor supermolecules, supporting the experimental results by INDO and MNDO calculations. He also investigated the so called "third generation" conducting polymers with specific functional groups. In this period, more exactly in 1991 Prof. SARICFTCI obtains the **Habilitation** in solid state physics at the Central University Commission (YOK) in Ankara, Turkey.

Between 1992 and 1996, Prof. SARICIFTCI worked at the Institute for Polymers & Organic Solids at the University of California, Santa Barbara, as senior research associate, with Prof. Alan J. HEEGER. Let us remind that Heeger, MacDiarmid and Shirakawa were awarded the **Nobel Prize** for Chemistry in 2000, for the discovery of metallic properties of chemically doped polyacetilene; their work paved the way for obtaining a wide range of semiconducting, dielectric or metallic polymers.

Prof. Sariciftci's researches covered primarily the fields of photoinduced optical, magnetic resonance and transport phenomena in conducting polymers. He was mainly focused on photoinduced absorption, photoinduced electron spin resonance, photoconductivity, fast optics as well as thin film organic device fabrication. He reported the seminal discovery of the ultrafast photoinduced electron transfer in conjugated polymer/C60 composites and heterojunctions, and applied this effect to the fabrication of high efficiency plastic solar cells. He also obtained an international patent coverage (UC as patent owner) for the mentioned devices. Also, he got a specialization in SQUID susceptometer techniques.

Since 1996, Prof. Sariciftci is Ordinarius (Chair) **Professor** for physical chemistry at the Johannes Kepler University (JKU) Linz, Austria.

The development of inorganic photovoltaic, based on inorganic semiconductors, is hampered by several major limitations: the high cost of Si technology and the scarcity of natural reserves of semiconductors used in high efficiency inorganic solar cells. This limitations could be overcome by the organic photovoltaic. The polymer-based PV elements have introduced at least the potential of obtaining cheap and easy methods to produce energy from light. This is a historical step forward in obtaining clean energy.

The progress of this domain is essentially connected to Prof. Sariciftci's researches. The **first remarkable idea** is to use the property of many conjugated polymers of being electron donors upon photo excitation, in conjunction with the large electronic affinity of fullerenes.

An important difference between inorganic and organic solar cells resides in the nature of the primary photo excited state. In inorganic solar cells, the absorption of photons leads directly to the creation of free electrons and holes. In organic solar cells, the absorption of a photon induces mainly excitons with binding energies ranging from 0.05 to more than 1 eV. For PV purposes, excitons have to be separated into free charge carriers before they decay.

Donor/acceptor-type bilayer organic devices can work like their inorganic analogues. Organic semiconductor thin films may show high absorption coefficients (10^5 cm^{-1}), their band gap can be engineered, and charge carrier mobilities made them competitive with amorphous silicon. Also, chemical doping of semiconductor matrix by introducing small concentrations of reagents (dopants) has also been reported in Prof. Sariciftci's researches. However, in such devices, only excitons created within the distance of 10-

80 nm from the interface can reach the heterojunction interface; this means loss of photons further away from the interface and low quantum efficiencies /45/.

This bottleneck is avoided due **to another remarkable idea**: replacement of bilayer heterojunctions with bulk heterojunctions – a blend of the donor and acceptor components in a bulk volume. It exhibits a donor/acceptor phase separation in a 10-20 nm length scale. The bulk heterojunction concept, advanced by Prof. Sariciftci, has heavily increased (orders of magnitude) the interfacial area between donor and acceptor phases and resulted in improved efficiency solar cells.

However, the cells using such blends harvest photons with wavelength below 550nm, which is a very small part of the solar spectrum. Other polymers, like P3HT, with a somewhat smaller gap (2 eV), harvests photons from an interval larger with 100 nm, leading to much higher I_{sc} and overall efficiency of about 3%. Later on, larger efficiencies have been obtained, and, in principle, a value of 10% can be expected realistically.

Also, Prof. Sariciftci's group fabricated flexible transparent conducting electrodes by printing films of single-walled carbon nanotube (SWCN) networks on plastic and have demonstrated their use as transparent electrodes for efficient, flexible polymer-fullerene bulk-heterojunction solar cells. The printing method produces relatively smooth, homogenous films with a transmittance of 85% at 550 nm. SC with SWNT are far more flexible, at almost same efficiency. It is well known that ITO (indium tin oxide) electrodes are transparent, but expensive; so, nanotube network may be an alternative.

Prof. SARICIFTCI and his coworkers produced important contribution to the characterization of organic solar cells devices. Let us finally mention two recent and inciting contribution of Prof. Sariciftci and his coworker.

The **first** one refers to organic solar cells with semitransparent metal back contacts for power window applications (2009).

The **second** one refers to exotic materials for bio-organic electronics (2011). "Exotic" materials have become the focus of recent developments in organic electronics that envision biocompatibility, biodegradability, and sustainability for low-cost, large-volume electronic components. The paper, leather, silk, can be used as substrates for electronic devices.

Advisor and Supervisor of Students

As concerning the academic activities, Professor SARICIFTCI, began to supervise the students already from the stage as senior research associate at the Institute for Polymers and Organic Solids at the University of California, Santa Barbara (UCSB) and since 1996 at Johannes Kepler University of Linz. He has directly supervised more than 20 PhD students, 14 students at masters level and more than 50 at the post doctoral level. Over 20 of his students achieved academic career positions whereas 4 of them are at the full professor level. Among all he permanently like to mention Prof. Christoph Brabec (Univ. of Erlangen, Germany), Prof. Vladimir Dyakonov (Univ. of Würzburg, Germany), Prof. Sean Shaheen (Univ. of Denver, USA) and Prof. Attila Mozer (Univ. of Wollongong, Australia) who are at full professor level shaping the field of organic electronics and received several awards. Many of his students are also in the industry contributing to the R&D in this field at industrial level. Some of his industrial alumni created their own enterprises (see below). His network of scientists covers a large number of European and worldwide academic groups, he being external co-advisor or examiner of many students in other Institutions.

In his position of **head of the LIOS, at Johannes Kepler University,** during a period of more than 15 years, he demonstrated efficiency and knowledge in coordination of the research projects, acquiring in total more that 20 research project, many of them in prestigious funding schemes like Framework Programme (Marie Curie and Cooperation schemes) and FWF (Austrian Science Funds), especially from their National Network of Excellence (2006 - 2011) and Christian Doppler Laboratory. In 1997 he has

initiated and coordinated the first European Project (5th Framework) on Organic Bulk Heterojunction Solar Cells.
Just in last 5 years he acquired more than 4.5 Mio €. The table below lists selected recent and ongoing grants where he is principal investigator and which are related to this proposed work in part.

As **Further Scientific Activities,** Prof. Sariciftci is a Fellow of the Royal Society of Chemistry (FRSC), Fellow of SPIE, and a member of several professional societies such as American Chemical Society, Materials Research Society, Austrian Chemical Society and Austrian Physical Society. He has served in editorial advisory boards of Scientific Journals such as J. Materials Chemistry and ChemSusChem and as international advisory board member of many large scale conferences.

High Tech SPIN-OFF Companies initiated: In addition to this academic achievements, Prof. SARICIFTCI had always followed the idea of "Stanford University and Silicon Valley" proposing the transfer of academic know-how into industrial use *via* highly specialized high tech spin off companies. This ideology, which was quite new in Austria back in 1996, was introduced in LIOS, resulting in several spin off companies from his Institute. Their first spin off company Quantum Solar Energy Linz (QSEL) is continuing its leadership in this field after being merged with Konarka Technologies USA. Konarka's technology on bulk heterojunction organic solar cells are based on the invention of Prof. SARICIFTCI, in 1992 and the technology developed in LIOS. The last spin off company Solar Fuel GesmbH is continuing its operations in Germany. The research group of Prof. SARICIFTCI have initiated many high tech jobs in Linz.

In a few words his dedicated work can be exemplified by the outstanding achievements in scientific publications. Professor SARICIFTCI published in total over **520** scientific publications, in total these publications have been cited over **24000** times and his **h-index is 66** (as of February 2012). His group is one of the most cited scientific groups in their research fields worldwide. The impact of their papers and patents has been highly influential, (for a full list of our publications see www.lios.at).

In the March 2011, a listing of **world's top 100 material scientists** list was published by the Institute for Scientific Information ISI of Thompson Reuter. The name of Professor SARICIFTCI was listed as **position 14** with many of his co-workers taking top 20 rankings. This is of course an honorable ranking of LIOS since the time frame of evaluation was 2000 – 2010 (see http://www.sciencewatch.com/dr/sci/misc/Top100MatSci2000-10/).

In total Prof. SARICIFTCI hold 5 patents, three of them are US-patents, originating from his work together with A. J. Heeger between 1992 - 1996. The first two are the seminal patents in the field of bulk heterojunction solar cells. The Austrian ones have been transferred to the company Konarka, he also published 7 reference books in these field of research.

The scientific and professional personality of Professor Dr. Niyazi Serdar SARICIFTCI is doubled by special human qualities that make him a remarkable personality.

Prof. Niyazi Serdar SARICIFTCI and his team collaborate for more years with Romanian researchers. The results of this collaboration can be seen in papers published in prestigious journals signed by Austrian and Romanian researchers. In the last years, a new fruitful cooperation has started between LIOS and University of Bucharest, in the frame of research projects, already Romanian students and researchers studying or spending in JKU and in the LIOS institute, respectively, for example: M. Irimia-Vladu; Daniela Stoenescu, Lucia Leonat, etc. The research group of R&D Centre for Materials and Electronic and Optoelectronic Devices, of University of Bucharest was invited by Prof. SARICIFTCI to be partner in the European Project ORGPVNET. The development of this collaboration has important benefits for both parts.

To conclude, we want to stress how glad are we to confer the title of Doctor Honoris Causa of the University of Bucharest, to Professor Niyazi Serdar SARICIFTCI, as a high recognition of his academic and scientific activity, taking into account: his outstanding merits in the development of Material Science and Electronic and Optoelectronic Devices in general, especially in the fields of Organic Solar Cells, being inspired by the challenges of "Nanoscience" and "Nanotechnology"; his efforts to organize and develop new scientific cooperation's beneficial to local communities but also to the European research as a whole; his wiliness to strengthen the ties between the Johannes Kepler University and the University of Bucharest in the field of natural sciences; his great European and World scientific personality.

Professor Dr. Ştefan ANTOHE
Dean of the Faculty of Physics,
University of Bucharest

Curriculum Vitae

Niyazi Serdar Sariçiftçi

Date and place of birth: 19/03/1961 in Konya, Turkey
Nationality: Austria, Turkey
Email: serdar.sariciftci@jku.at / Website: www.lios.at

Research interests:
Photophysics, photochemistry and photoelectrochemistry of organic semiconducting materials. Fabrication and spectroscopic characterization of organic diodes, transistors, electrodes and sensor devices.

Academic degrees:
2011 **Doctor Honoris Causa** at the Abo Academy in Finland
1991 **Habilitation** in solid state physics at the Central University Commission (YOK) in Ankara, Turkey
1989 **Doctor of Science** in semiconductor physics at the University of Vienna, Austria,
"In situ spectroscopy of polyaniline phase transitions" (Prof. Dr. Hans Kuzmany)
1986 **Diploma in Physics** at the University of Vienna Austria, *"Raman Spectroscopy of Ferroelectric Phase Transistions in KDP"* (Prof. Dr. Warhanek)

Academic appointments:
1996 - present Ordinarius (Chair) professor for physical chemistry at the Johannes Kepler University (JKU) Linz, Austria

1992 - 1996 Senior research associate at the Institute for Polymers and Organic Solids at the University of California, Santa Barbara (UCSB), USA

1989 - 1992 Univ. Assistant at the 2nd Physics Institute of University of Stuttgart, Germany

Guest professorships

Ege University, Izmir, Turkey, 1991
University of California, USA (2000, 2003, 2007, 2010)
University of Yamagata at Yonezawa, Japan (2011)

Advisor and Supervisor of Students

I began supervising students already at UCSB and since 1996 at Johannes Kepler University of Linz in total I have directly supervised more than 20 PhD students, 14 students at masters level and more than 50 at the post doctoral level. Over 20 of my students achieved academic career positions, whereas 4 of them are at the full professor level. Among all I'd like to mention Prof. Christoph Brabec (Univ. of Erlangen, Germany), Prof. Vladimir Dyakonov (Univ. of Würzburg, Germany), Prof. Sean Shaheen (Univ. of Denver, USA) and Prof. Attila Mozer (Univ. of Wollongong, Australia) who are at full professor level shaping the field of organic electronics and received several awards. Many of my students are also in the industry contributing to the R&D in this field at industrial level. Some of my industrial alumni created their own enterprises (see below). My network of scientists covers a large number of European and worldwide academic groups. Therefore, I am external co-advisor or examiner of many students in other Institutions as well.

Awards and Recognitions:

- 2011 - Nakamura Award of the University of California, Santa Barbara, USA
- 2011 - Doctor Honoris Causa of Abo Academy, Finland
- 2010 - Placed #14 of the world's best material scientists ranking

by Institute for Scientific Information (ISI Thomson Reuter)

- 2010 - Kardinal Innitzer Preis (Archbishop Innitzer Award for natural sciences)
- 2010 - ÖGUT Umweltpreis, Austria (ÖGUT Environment Award)
- 2010 - “Humanity Medal” of Linz, Austria, given for contributions to society.
- 2008 - Science Prize “Austria 2008” (Austrian scientist of the year)
- 2007 - Ranking #1 among the most cited papers last 10 years in the field of “Solar Cells” by ISI.
- 2006 - Turkish National Science Prize (TUBITAK Türk Bilim Ödülü)
- 2003 - “Energy Globe Oberösterreich” prize for Upper Austrian scientist
- 2001 - „Grünpreis 2001” sponsored by the Austrian Green Party, Upper Austria, given to the innovative research in environmental protection.

Funding ID

In the last 15 years I acquired in total more that 20 research project, many of them in prestigious funding schemes like Framework Programme (Marie Curie and Cooperation schemes) and FWF (Austrian Science Funds), especially our National Network of Excellence (2006 - 2011) and Christian Doppler Laboratory (1998 - 2004) are highest ranked projects with long durations. In 1997, I have initiated and coordinated the first European Project (5^{th} Framework) on Organic Bulk Heterojunction Solar Cells.
Just in last 5 years I acquired more than 4.5 Mio €. The table below lists selected recent and ongoing grants where I am principal investigator and which are related to this proposed work in part.

Selected grants	Approv. amount in €	Duration	Funding Agency
Regstore CO2 recycling	150.000	2012-2014	Upper Austria
ACCM Inverse Fuelcells	390.000	2012-2013	Ministry of Industry
Solar Fuel	1,500.000	2008-2011	Solar Fuel GesmbH

Further Scientific Activities:
I am a Fellow of the Royal Society of Chemistry (FRSC), Fellow of SPIE, and a member of several professional societies such as American Chemical Society, Materials Research Society, Austrian Chemical Society and Austrian Physical Society.
Since 1987 I have a continuous track record of publishing, giving lectures at conferences as well as invited lectures at other institutions. Apart from these several hundred visits and conferences I have organized three main conferences in Austria (see documentations in www.lios.at) and co-organized several international symposia in SPIE, MRS and ICSM conferences.
I have served in editorial advisory boards of Scientific Journals such as J. Materials Chemistry and ChemSusChem and as international advisory board member of many large scale conferences.

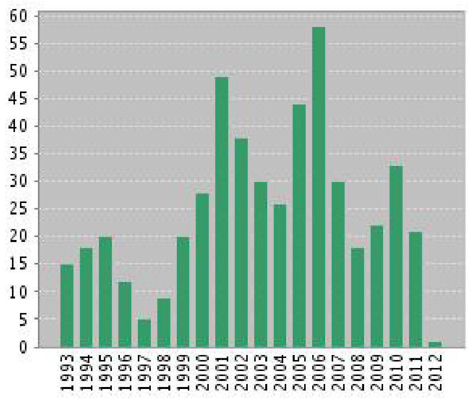
High Tech SPIN-OFF Companies initiated:
In addition to this academic achievements, I have always followed the idea of "Stanford University and Silicon Valley" proposing the transfer of academic know-how into industrial use *via* highly specialized high tech spin off companies. This ideology, which was quite new in Austria back in 1996, was introduced in LIOS, resulting in severeal spin off companies from our Institute. Our first spin off company Quantum Solar Energy Linz (QSEL) is continuing its leadership in this field after being merged with

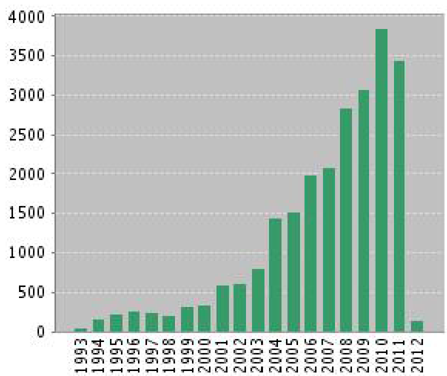
Konarka Technologies USA. Konarka's technology on bulk heterojunction organic solar cells is based on my invention in 1992 and our technology developed in LIOS. Our last spin off company Solar Fuel GesmbH is continuing its operations in Germany. We have initiated many high tech jobs in Linz.

1.) Konarka Austria (formerly QSEL created in 1998), engaged in plastic solar cells technology, www.konarka.com
2.) NanoIdent Inc Austria, (now Botest Austria)
3.) Plastic Electronic GesmbH, created in 2006, engaged in plastic embedded systems
www.plastic-electronic.com
4.) Prelonic GesmbH, created in 2007, engaged in plastic printed battery systems
www.prelonic.com
5.) Solar Fuel GesmbH, created in 2008, engaged in solar energy harvesting for CO2 recycling
www.solar-fuel.com
6.) Isiqiri, created 2008, engaged in intelligent displays with detection functions
www.isiqiri.com

1 (b) 10-Year-Track-Record

I have published in total over **520** scientific publications, in total these publications have been cited over **24000** times and my **h-index is 66** (as of February 2012). As such my group is one of the most cited scientific groups in our field worldwide. The impact of our papers and patents has been highly influential (for a full list of our publications see www.lios.at).





Number of papers and Citation analysis February 2012 by ISI Web of Knowledge.

In the March 2011, a listing of world's **top 100 material scientists** list was published by the Institute for Scientific Information ISI of Thomson Reuter. There my name was listed as **#14** with many of my co-workers taking top 20 rankings. This is of course an honorable ranking of my Institute in Linz since the time frame of evaluation was 2000-2010 (see http://www.sciencewatch.com/dr/sci/misc/Top100MatSci2000-10/).

1. Selected list of top cited seminal publications in peer reviewed journals as senior author:

1. "Plastic solar cells", C.J. Brabec,N.S. Sariciftci, J.C. Hummelen, Advanced Functional Materials, 11 (1): 2001 (cited 2172 times)
2. "Photoinduced Electron Transfer From a Conducting Polymer to Buckminsterfullerene", N. S. Sariciftci, L. Smilowitz, A. J. Heeger and F.Wudl, Science 258 (1992) 1474 (cited 2106 times)
3. "2.5% efficient organic plastic solar cells" S. E. Shaheen, C.J. Brabec, N. S. Sariciftci, *et al.*, Applied Physics Letters 78 (2001) 841 (cited 1456 times)
4. "Conjugated polymer-based organic solar cells", S. Gunes, H. Neugebauer,N.S. Sariciftci,Chemical Reviews, 107 (2007) 1324 (cited 1479 times)
5. "Effects of postproduction treatment on plastic solar cells" F. Padinger, R. S. Rittberger, N. S. Sariciftci, Advanced Functional Materials 13 (2003) 85 (cited 951 times)

2. Selected list of 10 recent publications as senior author (last 10 years):

1. Exotic materials for bio-organic electronics", M. Irimia-Vladu, N. S. Sariciftci, S. Bauer Journal of Materials Chemistry 21 (2011) 1350
2. "Charge Carrier Lifetime and Recombination in Bulk Heterojunction Solar Cells" A. Pivrikas, H. Neugebauer, N. S. Sariciftci, IEEE Journal of Selected Topics in Quantum Electronics, Vol. 16, No. 6 (2010), 1746
3. "Organic Solar Cells with Semitransparent Metal Back Contacts for Power Window Applications" R. Koeppe, D. Hoeglinger, P. Troshin, R. Lyubovskaya, V. Razumov, N.S. Sariciftci, ChemSusChem 2 (2009), 309
4. "Photovoltaic characterization of hybrid solar cells using surface modified TiO_2 nanoparticles and poly(3-hexyl)thiophene" S. Guenes, N. Marjanovic, J. Nedeljkovic, N. S. Sariciftci, Nanotechnology 19 (2008), 424009

5. “Hybrid solar cells using PbS nanoparticles” S. Guenes, K. Fritz, H. Neugebauer, N. S. Sariciftci, S. Kumar, G. Scholes, Solar Energy Materials & Solar Cells 91 (2007), 420
6. “Organic solar cells with carbon nanotube network electrodes” M. W. Rowell, M. A. Topinka, M. D. McGehee, H.-J. Prall, G. Dennler, N. S. Sariciftci, L. Hu, G. Gruner Applied Physics Letters 88 (2006), 233506
7. “Flexible conjugated polymer-based plastic solar cells: From basics to applications” G. Dennler, N. S. Sariciftci, Proceedings of the IEEE, Vol 93, No 8 (2005)1429
8. “Negative electric field dependence of charge carrier drift mobility in conjugated, semiconducting polymers”, A. Mozer, N. S. Sariciftci, Chemical Physics Letters 389 (2004) 438
9. “Molecules as bipolar conductors” A. Cravino, N. S. Sariciftci, Nature Materials, Vol 2 (2003), 360
10. “Molecular Engineering of C_{60}-Based Conjugated Oligomer Ensembles: Modulating the Competition between Photoinduced Energy and Electron Transfer Processes” D. Guldi, C. Luo, A. Swartz, R. Gomez, J. Segura, N. Martin, C. Brabec, N. S. Sariciftci, Journal of Organic Chemistry No. 67 (2002), 1141

3. Books:

- My very first book was “*Primary Photoexcitations in Conjugated Polymers: Molecular Exciton versus Semiconductor Band Model*”, edited by Niyazi Serdar Sariciftci, World Scientific Publ., Singapore (1997), ISBN: 981-02-2880-5

Thereafter I edited several books on organic solar cells:

- *“Electronic, Optical and Optoelectronic Polymers and Oligomers”*, edited by Ghassan E. Jabbour and Niyazi Serdar Sariciftci, Materials Research Society Symposium Proceedings Vol. 665, (2002), ISBN: 1-55899-601-X
- *“Organic and Polymeric Materials and Devices: Optical, Electrical and Optoelectronic Properties”*, edited by Ghassan E. Jabbour, Niyazi Serdar Sariciftci, Sue Allen Carter, S. T. Lee, Shuji Kido, Materials Research Society Symposium

Proceedings Vol. 725, (2002), ISBN: 1-55899-661-3

- "*Organic Photovoltaics*", edited by Christoph Brabec, Vladimir Dyakonov, Jürgen Parisi and Niyazi Serdar Sariciftci, Springer Verlag (2003) ISBN: 3-540-00405
- "*Organic Photovoltaics: Mechanisms, Materials and Devices*", Sam-Shajing Sun and Niyazi Serdar Sariciftci (eds.), CRC Press (Taylor&Francis Group) ISBN: 0-8247-5963-X, (2005)
- "*Organic Photovoltaics and Related Electronics*", V.R. Bommisetty, N. S. Sariciftci, K. Narayan, G. Rumbles, P. Peumans, J. van de Lagemaat, G. Dennler, S. E. Shaheen, Materials Research Society Symposium Proceedings Vol 1270 (2010) ISBN: 978-1-60511-247-3

Finally I am very proud of being author of the first teaching monoraph in our field:

- "*Semiconducting and Conducting Polymers*", Alan Heeger, Niyazi Serdar Sariciftci and Ebinazar Namdas, Oxford University Press, ISBN: 978-0-19-852864-7 (2010).

4. Patents:

- In total I'm holding 5 patents, three of them are US-patents, originating from my work together with A. J. Heeger between 1992-1996. The first two are the seminal patents in the field of bulk heterojunction solar cells. The Austrian ones have been transferred to the company Konarka.
- *"Conjugated Polymer - Acceptor Heterojunctions: Diodes, Photodiodes and Photovoltaic Cells"* N. S. Sariciftci and A. J. Heeger (Univ. of California), US Patent No: 5, 331, 183, (1994).
- *"Conjugated Polymer - Acceptor Heterojunctions: Diodes, Photodiodes and Photovoltaic Cells"*, Continuation. N. S. Sariciftci and A. J. Heeger (Univ. of California), US Patent No: 5,454,880, (1995).
- *"Optical Limiting Materials"* D. W. McBranch, B. R. Mattes, A. C. Koskelo, A. J. Heeger, J. M. Robinson, L. B. Smilowitz, V. I. Klimov, M. Cha, N. S. Sariciftci, J. C. Hummelen (Univ. of California and Low Alamos National Labs), US Patent No:

5,741,442 (1998).

- “Photovoltaische Zelle”, Österreichisches Patent No: 409 902 (Sept. 2002) (Transferred to Konarka).
- “Post Production Treatment”, Österreichische Patentanmeldung 15 A 775/2002 (Transferred to Konarka).

Brief Presentation of Scientific Achievements of Professor Dr. Niyazi Serdar SARICIFTCI

Between 1986 and 1989, Prof. SARICIFTCI prepared his PhD thesis at the University of Vienna: *Spectroscopic investigations on the electrochemically induced metal to insulator transitions in polyaniline*, with specialization on *in situ* optical, Raman and FTIR spectroscopy during doping processes. He developed techniques for the vibrational and optical spectroscopy during electrochemical doping-undoping processes, as well as the pH induced doping mechanisms of polyaniline, and reported the first observation and assignment of the quantum size effects on the metallic intraband absorption of conducting polymers. Another interesting contribution was the structural modeling of the different chemical compositions of polyaniline during these doping-undoping processes via *in situ* vibrational spectroscopy.

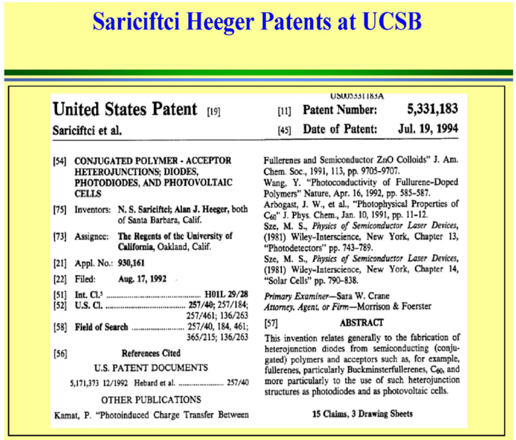
In the next two years, Prof. SARICIFTCI worked as a postdoctoral research associate at the 2nd Physics Institute, of University of Stuttgart, in molecular electronics, with specialization on Electron Spin Resonance (ESR), electron nuclear double resonance (ENDOR) and photoinduced electron transfer on supramolecular structures. He reported the first observation of the Overhauser effect on the ESR metallic polythiophene. He also used the ENDOR technique to map the spin distribution on donor-acceptor supermolecules, supporting the experimental results by INDO and MNDO calculations. He also investigated the so called “third generation” conducting polymers with specific functional groups. In this period, more exactly in 1991 Prof. SARICFTCI obtains the **Habilitation** in solid state physics at the Central

University Commission (YOK) in Ankara, Turkey.

The interest in studying polymers has been stimulated, in that time, by the discovery of Heeger, MacDiarmid and Shirakawa of conjugated conducting polymers, in 1974. Their work paved the way for obtaining a wide range of semiconducting, dielectric or metallic polymers (they won the Nobel Prize for Chemistry in 2000, for these achievements). The conjugated polymers were already used, in mid ‘80s, for light emitting diodes (LEDs), and Professor SARICIFTCI has the idea of using them for the conversion of solar energy in electricity – like silicon did, at that time.

With this idea, Professor SARICIFTCI started his activity at the Institute for Polymers & Organic Solids at the University of California, Santa Barbara, as senior research associate, with Prof. Heeger (1992 – 1996). The main obstacle for SARICIFTCI's project was the fact that the conjugated conducting polymers alone have not enough charge carriers, in their light-excited state; so, it was necessary to find an electron acceptor, for the electrons provided by the polymer. This was overcome by the seminal discovery of the ultrafast photoinduced electron transfer in conjugated polymer/C60 composites, identifying the fullerene (C60) as acceptor. The result was published in “Science” (1992), in a paper which accumulated about

2200 citations), and patented (authors: Sariciftci and Heeger). The way for producing organic (plastic) solar cells was open.



US005331183A

United States Patent [19] — Sariciftci et al.

[11] Patent Number: 5,331,183

[45] Date of Patent: Jul. 19, 1994

[54] CONJUGATED POLYMER - ACCEPTOR HETEROJUNCTIONS; DIODES, PHOTODIODES, AND PHOTOVOLTAIC CELLS

[75] Inventors: N. S. Sariciftci; Alan J. Heeger, both of Santa Barbara, Calif.

[73] Assignee: The Regents of the University of California, Oakland, Calif.

[21] Appl. No.: 930,161

[22] Filed: Aug. 17, 1992

[51] Int. Cl.[5] H01L 29/28

[52] U.S. Cl. 257/40; 257/184; 257/461; 136/263

[58] Field of Search 257/40, 184, 461; 365/215; 136/263

[56] References Cited

U.S. PATENT DOCUMENTS

5,171,373 12/1992 Hebard et al. 257/40

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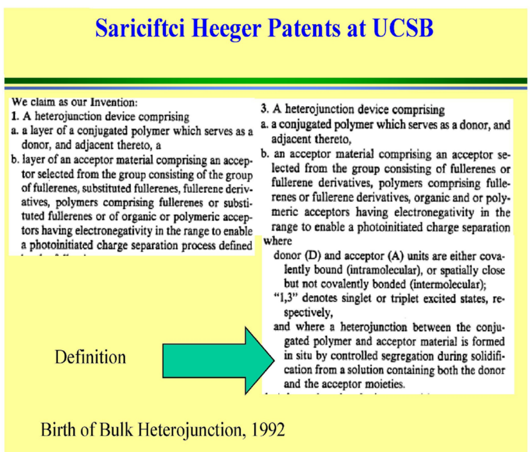
Kamat, P. "Photoinduced Charge Transfer Between Fullerenes and Semiconductor ZnO Colloids" J. Am. Chem. Soc., 1991, 113, pp. 9705-9707.
Wang, Y. "Photoconductivity of Fullurene-Doped Polymers" Nature, Apr. 16, 1992, pp. 585-587.
Arbogast, J. W., et al., "Photophysical Properties of C_{60}" J. Phys. Chem., Jan. 10, 1991, pp. 11-12.
Sze, M. S., *Physics of Semiconductor Laser Devices*, (1981) Wiley-Interscience, New York, Chapter 13, "Photodetectors" pp. 743-789.
Sze, M. S., *Physics of Semiconductor Laser Devices*, (1981) Wiley-Interscience, New York, Chapter 14, "Solar Cells" pp. 790-838.

Primary Examiner—Sara W. Crane
Attorney, Agent, or Firm—Morrison & Foerster

[57] ABSTRACT

This invention relates generally to the fabrication of heterojunction diodes from semiconducting (conjugated) polymers and acceptors such as, for example, fullerenes, particularly Buckminsterfullerenes, C_{60}, and more particularly to the use of such heterojunction structures as photodiodes and as photovoltaic cells.

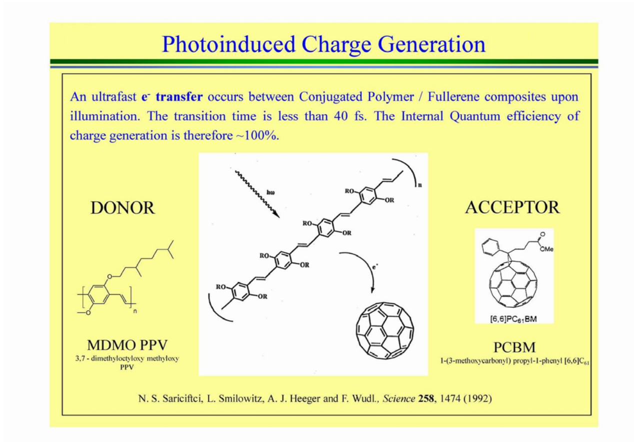
15 Claims, 3 Drawing Sheets



We claim as our Invention:
1. A heterojunction device comprising
a. a layer of a conjugated polymer which serves as a donor, and adjacent thereto, a
b. layer of an acceptor material comprising an acceptor selected from the group consisting of the group of fullerenes, substituted fullerenes, fullerene derivatives, polymers comprising fullerenes or substituted fullerenes or of organic or polymeric acceptors having electronegativity in the range to enable a photoinitiated charge separation process defined

3. A heterojunction device comprising
a. a conjugated polymer which serves as a donor, and adjacent thereto,
b. an acceptor material comprising an acceptor selected from the group consisting of fullerenes or fullerene derivatives, polymers comprising fullerenes or fullerene derivatives, organic and or polymeric acceptors having electronegativity in the range to enable a photoinitiated charge separation
where
donor (D) and acceptor (A) units are either covalently bound (intramolecular), or spatially close but not covalently bonded (intermolecular);
"1,3" denotes singlet or triplet excited states, respectively,
and where a heterojunction between the conjugated polymer and acceptor material is formed in situ by controlled segregation during solidification from a solution containing both the donor and the acceptor moieties.

Studies on photophysics of mixtures of conjugated polymers with fullerenes clearly evidenced **an ultra fast, reversible, metastable photo-induced electron transfer from conjugated polymer onto C60 in solid films.**



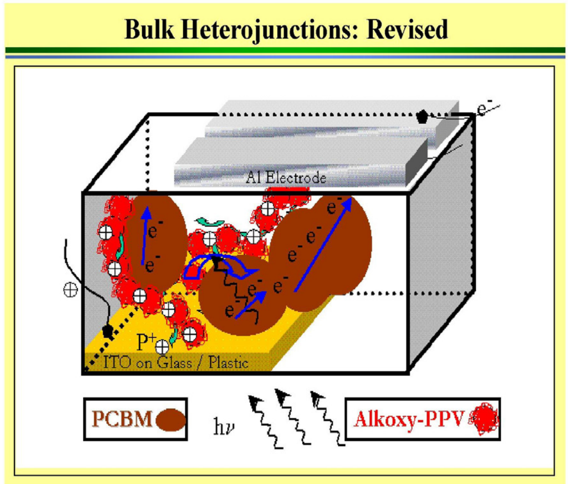
Since 1996, Prof. SARICIFTCI is **Ordinarius (Chair) Professor** for physical chemistry at the Johannes Kepler University (JKU) Linz, and chairman of the Institute for Physical Chemistry of JKU. In the same time, he become the founding director of the Linz Institute for Organic Solar Cells (LIOS).

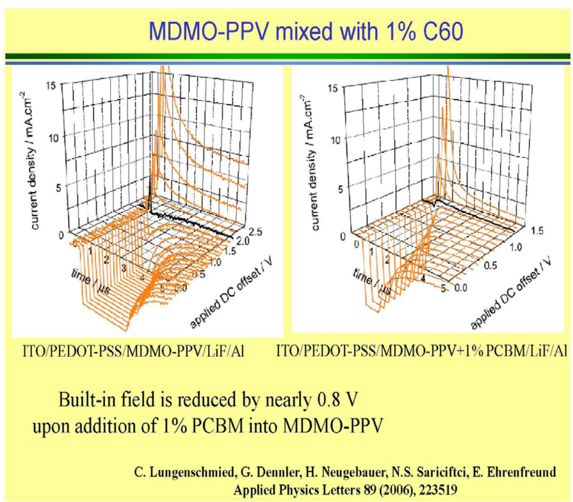
Why is so important to produce plastic solar cells? The development of inorganic photovoltaics, based on inorganic semiconductors, is hampered by several major limitations: the high cost of Si technology and the scarcity of natural reserves of semiconductors used in high efficiency inorganic solar cells. Such limitations are absent in the organic photovoltaics. So, the polymer-based PV elements have introduced at least the potential of obtaining cheap and easy methods to produce energy from light. This is a historical step forward in obtaining clean energy.

An important difference between inorganic and organic solar cells resides in the nature of the primary photo excited state. In inorganic solar cells, the absorption of photons leads directly to the creation of free electrons and holes. In organic solar cells, the absorption of a photon induces mainly excitons with binding energies ranging from 0.05 to more than 1 eV. For PV purposes, excitons have to be separated into free charge carriers before they decay.

Donor/acceptor-type bilayer organic devices can work like their inorganic analogues. Organic semiconductor thin films may show high absorption coefficients (10^5 cm^{-1}), their band gap can be engineered, and charge carrier mobilities made them competitive with amorphous silicon. In the same time, chemical doping of semiconductor matrix by introducing small concentrations of reagents (dopants) has also been reported in Prof. Sariciftci's researches. However, in such devices, only excitons created within the distance of 10 - 80 nm from the interface can reach the heterojunction interface; this means loss of photons further away from the interface and low quantum efficiencies.

This bottleneck is avoided due to another **remarkable idea: replacement of bilayer heterojunctions with bulk heterojunctions – a blend of the donor and acceptor components in a bulk volume**. It exhibits a donor/acceptor phase separation in a 10 - 20 nm length scale. The bulk heterojunction concept, advanced by Prof. SARICIFTCI, has heavily increased (orders of magnitude) the interfacial area between donor and acceptor phases and resulted in improved efficiency solar cells. The donor and acceptor phases form a nanoscale, bicontinuous and interpenetrating network. Therefore, the bulk heterojunctions devices are much more sensitive to the nanoscale morphology in the blend.



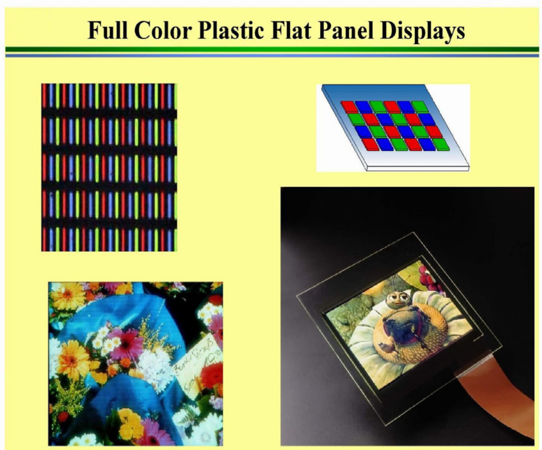


Also, Prof. Sariciftci's group fabricated flexible transparent conducting electrodes by printing films of single-walled carbon nanotube (SWCN) networks on plastic and have demonstrated their use as transparent electrodes for efficient, flexible polymer-fullerene bulk-heterojunction solar cells. The printing method produces relatively smooth, homogenous films with a transmittance of 85%

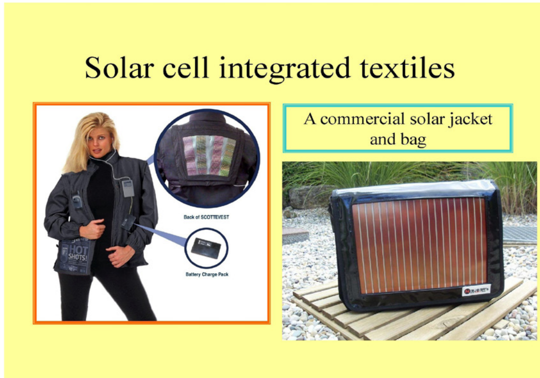
at 550 nm. SC with SWNT are far more flexible, at almost same efficiency. It is well known that ITO (indium tin oxide) electrodes are transparent, but expensive; so, nanotube network may be an alternative.

The photovoltaic performances of bulk heterojunctions solar cells using novel nanoparticles of 6 - palmitate ascorbic acid surface modified TiO_2, as an electron acceptor, embedded into the donor P3HT matrix, are remarkably enhanced.

Prof. Sariciftci contributed also to cheap fabrication technique of organic optoelectronic devices.



The printing/coating techniques have been used to deposit conjugated semiconductor polymers. Vacuum evaporation/ sublimation is a very clean (no solvent) choice for the deposition of thin films based on small molecules. To create interpenetrating donor/acceptor networks or to achieve molecular doping, coevaporation techniques have been applied.



Prof. SARICIFTCI and his coworkers produced important contribution to the characterization of solar cells devices. In organic solar cells, the open circuit voltage is linearly dependent on donor's HOMO and acceptor's LUMO. The linear correlation of LUMO of fullerene acceptors (different derivatives of C60) and the observed open circuit potential was clearly demonstrated.

The cathode is generally modified by deposition of a thin layer of LiF between the metal electrode and the organic semiconductor. This improves the charge injection in organic LEDs and increases Voc in organic solar cells.

Mobility is not a material parameter, but a device parameter, so it is sensitive to the nanoscale morphology of the organic semiconductor thin film. Charge carrier mobility and recombination in bulk heterojunction solar cells was studied using a novel method: the charge extraction by a linear increase of voltage (CELIV). In CELIV technique, the equilibrium charge carriers are extracted from a dielectric under a reversed bias voltage ramp. It can be used to determine charge carrier mobilities in samples with only a few hundred nm thickness. Using CELIV, a negative electric field dependence of mobility in P3HT was obtained. In fact, at above 250K, the slope of the electric field dependence of mobility becomes negative. Such phenomena has been reported previously for a variety of amorphous charge transport materials, but not clearly observed in conjugated semiconducting polymers.

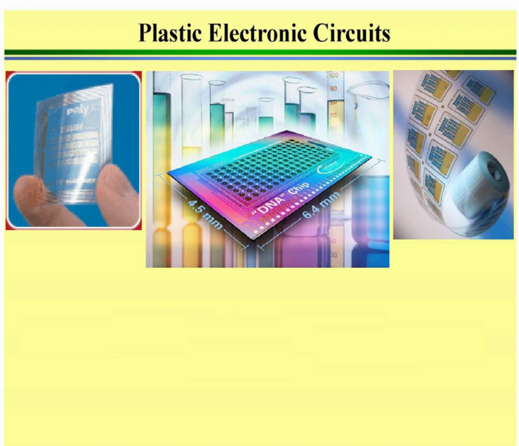
Charge carrier lifetime and recombination is a central theme in photovoltaics. The main photocurrent density and power conversion efficiency limiting mechanisms in bulk heterojunctions solar cells have been discussed recently (2011) by Prof. Sariciftci and his coworkers, with the emphasis on recombination process. Charge extraction by linearly increasing voltage, time of flight, and other methods that allow the carrier lifetime and recombination to be studied experimentally in operating SCs have been analyzed. Non-Langevin recombination is required for high-performance organic PV devices, which typically have low charge carrier mobility. The film nanomorphology plays a crucial role, governing the charge transport and the carrier life-time.

Let us finally mention two recent and inciting contribution of Prof. Sariciftci and his coworker.

The **first** one refers to organic solar cells with semitransparent metal back contacts for power window applications (2009). By casting semi-transparent plastic photovoltaic films between insulating window glass, large unused areas (the windows) can be employed for power generation, in addition to the limited roof areas of crowded cities. Distinct absorption bands of organic semiconductor materials can leave transmission windows in the visible part of the spectrum, giving the possibility to design solar cells which transmit visible light, but convert ultra-violet (UV) and near-infrared (NIR) light into electricity. This property is especially appealing in the design of solar power windows, where the visible light transmission should be maximized, while UV and NIR radiation can be absorbed, to reduce glare and heating in direct sunlight, as well as generate electrical power. In an optimal combination, solar cells with an efficiency of about 0.5% and a peak transparency of more than 60% in the visible part of the spectrum were fabricated.

The **second** one refers to exotic materials for bio-organic electronics (2011). “Exotic” materials have become the focus of recent developments in organic electronics that envision biocompatibility, biodegradability, and sustainability for low-cost, large-volume electronic components. The paper, leather, silk, can be used as substrates for electronic devices. Prof. Sariciftci added hard gelatine and biodegradable plastics, and even edible caramelized sugar as substrates in organic field-effect devices. Also, his group used aurin, which can be easily fabricated, and also extracted from the roots of a wild plant, well-known in traditional Chinese medicine, as an efficient smoothing layer for rough biodegradable and biocompatible substrates employed in the fabrication of organic field effect transistors (FET). They also used biopolymers derived from DNA as gate dielectrics in organic FETs. Nucleobases entering in the composition of DNA can be easily processed as 2.5 nm thick films, with excellent dielectric properties, suitable for organic FETs.

After two decades of researches, the conjugated polymers proved their great advantage, of combining the semiconducting properties of a true semiconductor like silicon,



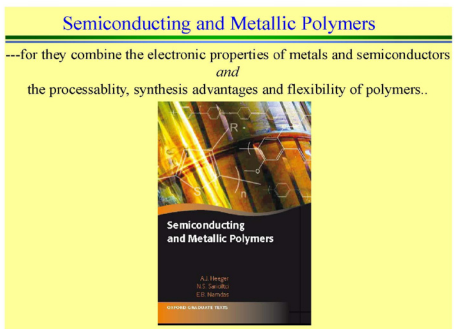
with the large scale-up capabilities of plastics – of being easily synthesized and manipulated. Plastic technology and semiconductor technology has been put together. For outdoor remote applications, plastic photovoltaics will be ready by 2012, with cell lifetimes of 3

– 5 years. Building-integrated photovoltaics, i.e. plastic solar cells used as building material, with efficiencies of 10% and at least 10 years lifetime, will be on the market by 2013 or, latest, 2015. Grid-connected plastic photovoltaics will come on line by 2020. Price and cost advantages over silicon technology – for instance, roll-to-roll production – are absolutely clear.

Didactic Activity: Advisor and Supervisor of Students

Progress in photovoltaics can be achieved only through interdisciplinary research. Professor Sariciftci coordinates complex teams and puts much effort in pedagogical activities. He began to supervise the students already from the stage as senior research associate at the Institute for Polymers and Organic Solids at the University of California, Santa Barbara (UCSB) and since 1996 at Johannes Kepler University of Linz. He has directly supervised more than 20 PhD students, 14 students at masters level and more than 50 at the post doctoral level. Over 20 of his students achieved academic career positions whereas 4 of them are at the full professor level. Among all he permanently like to mention Prof. Christoph Brabec (Univ. of Erlangen, Germany), Prof. Vladimir Dyakonov (Univ. of Würzburg, Germany), Prof. Sean Shaheen (Univ. of Denver, USA) and Prof. Attila Mozer (Univ. of Wollongong, Australia) who are at full professor level shaping the field of organic electronics and received several awards. Many of his students are also in the industry contributing to the R&D in this field at industrial level. Some of his industrial alumni created their own enterprises (see below).

His network of scientists covers a large number of European and worldwide academic groups, he being external co-advisor or examiner of many students in other Institutions. He was preocupated permanently to prepare very important sources of information and documentation in his field of research, see for example *"Semiconducting and Conducting Polymers"*, Alan Heeger, Niyazi Serdar Sariciftci and Ebinazar Namdas, Oxford University Press, ISBN: 978-0-19-852864-7 (2010) - the first teaching monograph in this field.



Managerial Activities: LIOS and High Tech SPIN-OFF Companies

In his position of head of the LIOS, at Johannes Kepler University, for more than 15 years, he demonstrated efficiency and knowledge in coordination of the research projects, acquiring in total more that 20 research project, many of them in prestigious funding schemes like Framework Programme (Marie Curie and Cooperation schemes) and FWF (Austrian Science Funds), especially from their National Network of Excellence (2006 - 2011) and Christian Doppler Laboratory. In 1997 he has initiated and coordinated the first European Project (5^{th} Framework) on Organic Bulk Heterojunction Solar Cells. Just in the last 5 years he acquired more than 4.5 Mio €.

In addition to this academic achievements, Prof. SARICIFTCI had always followed the idea of "Stanford University and Silicon

Valley" proposing the transfer of academic know-how into industrial use *via* highly specialized high tech spin off companies. This ideology, which was quite new in Austria back in 1996, was introduced in LIOS, resulting in several spin off companies from his Institute. Their first spin off company Quantum Solar Energy Linz (QSEL) is continuing its leadership in this field after being merged with Konarka Technologies USA. Konarka's technology on bulk heterojunction organic solar cells are based on the invention of Prof. SARICIFTCI, in 1992 and the technology developed in LIOS. The last spin off company Solar Fuel GesmbH is continuing its operations in Germany. The research group of Prof. SARICIFTCI have initiated many high tech jobs in Linz. (see the above CV)

Worldwide Academic Recognition

Prof. Sariciftci is a Fellow of the Royal Society of Chemistry (FRSC), Fellow of SPIE, and a member of several professional societies such as American Chemical Society, Materials Research Society, Austrian Chemical Society and Austrian Physical Society. He has served in editorial advisory boards of scientific journals such as J. Materials Chemistry and Chem.Sus.Chem. and as international advisory board member of many large scale conferences.

Scientific publications

Some scientometric aspects of Professor SARICIFTCI's work are impressive. Professor SARICIFTCI authored or co-authored more than 520 scientific publications, accumulating over 24000 citations; his h-index is 66 (as of February 2012). His group is one of the most cited scientific groups in their research fields worldwide. The impact of their papers and patents has been highly influential, (for a full list of our publications see www.lios.at).

The scientific and professional personality of Professor Dr. Niyazi Serdar SARICIFTCI is doubled by special human qualities that make him a remarkable personality.

Prof. Niyazi Serdar SARICIFTCI and his team collaborate for many years with Romanian researchers. The results of this collaboration can be seen in papers published in prestigious journals signed by Austrian and Romanian scientists. Recently, a new fruitful cooperation between LIOS and University of Bucharest was initiated. Romanian PhD students and researchers benefited of working stages or positions in JKU and LIOS, for example: M. Irimia-Vladu; Daniela Stoenescu, Lucia Leonat, etc. The research group of R&D Centre for Materials and Electronic and Optoelectronic Devices, of University of Bucharest was invited by Prof. SARICIFTCI to be partner in the European Project ORGPVNET. The development of this collaboration has important benefits for both parts.

Notes