STAND-ALONE PROJECT – FINAL REPORT

Project number: P-19379

Project Title: The influence of the interface in the copper-diamond system

Project leader: Ao. Univ. Prof: Dr. Christoph Eisenmenger-Sittner

Project Website:
http://www.ifp.tuwien.ac.at/forschung/duenne_schichten/english/index_e.htm

1. Summary for public relations work

English:

Heat generation in high power electronic components, machining equipment or large scale integrated circuits has become a major issue because of the tremendous increase of power density which was achieved during the last decades. This poses high requirements to new materials in respect to the combination of thermal conductivity and thermal expansion behavior. Heat removal is essential for preventing thermal overload. A low or tunable coefficient of thermal expansion is paramount to prevent mechanical stresses caused by cyclic heating and cooling during operation, which, in the long run, can lead to mechanical failure. Promising material combinations in this respect are copper based composites reinforced with diamond particles. Thermal conductivities of 600 W/mK have been achieved, but the issue of the modification of the thermal transport across the copper/diamond interface has not been studied systematically.

Within the present project intermediate layers which optimize the thermal transport between copper and diamond were studied. A wide group of carbide forming materials (B, various borides, Cr, Mo, W and Nb) was intensively investigated on planar diamond or vitreous carbon substrates. Heat transfer across the thermal interface between copper and carbon was studied by infrared radiometry. The connection between the quality of the thermal interface and the morphological evolution of copper under heat treatment was investigated by various experimental techniques. The chemical composition of the interface bearing the interlayers was characterized with high chemical sensitivity and spatial resolution by secondary ion mass spectroscopy and electron energy loss spectroscopy, respectively. Cross correlating the experimental results allowed for the identification of B and Nb as optimum interlayer materials. It could be shown that only very thin interlayers are needed to significantly improve the thermal transfer and that, to a certain degree, results obtained from vitreous carbon samples can be transferred to diamond.

Finally, the optimized interlayers were also applied to diamond granulate and copper diamond composites were manufactured. Here pure boron yielded the best results, if it is located at the copper diamond Interface. Therefore, the detailed scientific investigation of possible interlayer materials led to a reliable method to optimize the thermal conductivity in copper diamond composites.

Deutsch:

Die Wärmebelastung in Hochleistungselektroniken, Werkzeugen oder hochintegrierten elektronischen Schaltkreisen ist aufgrund der in den letzten Jahrzehnten erzielten Steigerungen der Leistungsdichte zu einem volkswirtschaftlich relevanten Thema geworden. Sie stellt hohe Anforderungen an Wärmeleitfähigkeit und thermische Ausdehnung neuer Materialien. Eine effiziente Wärmeabfuhr ist wichtig, um thermischer Überlastung vorzubeugen. Ein geringer oder gezielt einstellbarer Wärmeausdehnungskoeffizient ist unerläßlich, um mechanische Spannungen, welche durch thermisches Zyklieren während des Betriebes entstehen und die auf lange sicht zu mechanischem Versagen führen können, abzupuffern. Materialien, welche diese Eigenschaften verbinden, sind Kupfer-Diamant Komposite. In Einzelfällen wurden thermische Leitfähigkeiten von bis zu 600 W/mK erzielt, aber der thermische Transport über die Grenzfläche zwischen Kupfer und Diamant wurde noch nicht systematisch untersucht.

Gegenstand dieses Projektes waren Zwischenschichten zur Optimierung des thermischen Transportes zwischen Kupfer und Diamant. Eine große Gruppe von karbidbildenden Materialien (B, verschiedene Boride, Cr, Mo, W und Nb) wurden intensiv an planaren Diamantsubstraten sowie an glasartigem Kohlenstoff erforscht. Der Wärmeübergang von Kupfer auf Kohlenstoff wurde mittels Infrarot-Radiometrie untersucht. Der Zusammenhang zwischen dem Wärmeübergang über die Grenzfläche und der morphologischen Entwicklung von Kupfer unter Wärmebehandlung wurde mittels verschiedener experimenteller Techniken quantifiziert. Die chemische Zusammensetzung der durch die Zwischenschichten modifizierten Grenzfläche wurde mit hoher chemischer Sensitivität und örtlicher Auflösung mittels Sekundärionenmassenspektroskopie und Elektronenenergieverlustspektroskopie charakterisiert. Durch die Kreuzkorrelation der experimentellen Ergebnisse war es möglich, Bor und Niob als optimale Zwischenschichtmaterialien zu identifizieren. Es konnte gezeigt werden, dass bereits sehr dünne Zwischenschichten signifikanten Einfluß auf den Wärmetransport über die Grenzfläche haben und dass Ergebnissse, die für glasartigen Kohlenstoff erzielt worden sind, bis zu einem gewissen Grad auf Diamant übertragen werden können.

Die optimierten Zwischenschichten wurden schlußendlich auf Diamantgranulat aufgebracht. In diesem Falle lieferte Bor die besten Ergebnisse, wenn sichergestellt werden kann, daß die Zwischenschicht im Komposit erhalten bleibt. Die gezielte wissenschaftliche Aufarbeitung des Themas führte daher zu einer Methode, Kupfer Diamant Komposite mit hoher Wärmeleitfähigkeit herzustellen.

2. Brief Project Report

2. 1. Report on the scientific work

2. 1. 1. Information on the development of the research work

Copper Diamond Metal Matrix Composites (MMC) may act as heat sinks in high power or high performance electronic devices because of their high thermal conductivity and low Coefficient of Thermal Expansion (CTE). The aim of this project (end: February 2012) was to optimize the thermal interface between diamond and copper by carbide forming interlayers. For this task three approaches were chosen:

- Deposition of interlayer and copper on planar diamond substrates by magnetron sputtering
- Determination of mechanical, thermal and chemical properties of the plane samples
- Deposition of interlayers on diamond granulate by magnetron sputtering with control of thickness and thickness uniformity

All points could be realized. Plane synthetic diamond substrates manufactured by SUMITOMO Inc. (4x4x0.5 mm^3) were used to characterize the mechanical and thermal interface. Vitreous carbon (SIGRADUR G, manufactured by HTW Germany, 20x20x2 mm^3) served as a second carbon based substrate to check if results obtained from vitreous carbon substrates could be transferred to diamond. The choice of interlayer materials was guided by their ability to form carbides. B, Cr, Mo, Nb and Ti were investigated. The mechanical properties of the interface were characterized by the observation of de-wetting after heat treatment (usually 30 min at 800°C under high vacuum conditions, except stated otherwise) and by mechanical pull off testing. The thermal interface properties were characterized by Infrared Radiometry (IR) in collaboration with the Ruhr University Bochum and the Université de Reims Champagne-Ardenne. Interface chemistry and diffusivity of the interlayer material were investigated by Time of Flight Secondary Ion Mass Spectrometry (TOF-SIMS). Detailed investigations of the interface were performed with Transmission Electron Microscopy (TEM) and Electron Energy Loss Spectroscopy (EELS). A deposition set-up which allows the coating of granular materials was developed. With this system it was possible to coat sufficient amounts of diamond granulate to enable the production of copper diamond MMCs. All tasks defined in the proposal were performed and even additional tasks (e. g. developing a prototype system for the determination of film thickness on granulates) could be tackled within the framework of the project.

2. 1. 2. Important results of the project

The most important results of the project will be presented in relation to the main topics defined in the project proposal:

Over- all goals of the project proposal:

- *Reduction of the Thermal Contact Resistance (TCR) between Cu and diamond by suppression of dewetting effects of Cu coatings during heat treatment [1,3,6,7,9]*

  Coated plane diamond samples as well as coated samples of Sigradur G which contained interlayers of various materials and thicknesses were subjected to heat treatments of different durarion [1,7,9]. The surfaces of the coated samples were investigated in respect to morphology and adhesion by Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and, where possible, by mechanical pull-off Testing. A correlation between the recrystallization and de-wetting behavior of the Cu coating and the adhesion strength could be established. Results obtained for Sigradur G

could be transferred to diamond [9]. This may be suitable to evaluate interlayer properties on less expansive substrates than synthetic diamond.
The temperature treated samples were investigated in respect to their chemical composition by dynamic SIMS. Interdiffusion and carbide formation between carbon/interlayer/copper were observed. Form the cumulative results of morphological and chemical investigation Boron and Niobium were identified as the most promising interlayer materials. Boron was found to diffuse far into the Cu layer, while Nb remains at the interface and forms a carbide only after prolonged thermal treatment [9].
Samples containing different interlayers were investigated by IR radiometry. From these investigations a cooperation between the Thin Film Group at the Vienna University of Technology and the Groups of Prof. J. Pelzl at the Ruhruniversität Bochum and Mihai Chirtoc at the Université de Reims Champagne-Ardenne evolved. The small diamond samples posed a great challenge for the IR radiometry experiments, but measurements in reflection identified Nb and B as the interlayer materials which reduced the Thermal Contact Resistance (TCR) of the interface to the highest extent [9]. These materials were chosen as interlayers which were applied to diamond granulate in the next step of the project.

- *Transfer of knowledge from plane substrates to diamond particle coating [2,4,5,8]*

  On plane samples the deposition of interlayers with defined thickness could be realized by Direct Current (DC) magnetron sputtering. For coating granulates, during the whole duration of the project a special inset for the vacuum chamber was designed and optimized [4] which allows the deposition of coatings on granular materials with diameters from approx. 10 µm to 500 µm. Also methods to determine the film thickness of the interlayers were developed [2]. A crucial point proved to be the proper intermixing of the granular material. Approaches based on container geometry or special diverting elements were pursued. Finally, a set-up described in [5] was found to yield the best results. With this device it is possible to coat up to 60 cm³ of granulate. The deposition of multilayers or gradient materials is possible because containers may be located beneath different sources. The deposition rate on the granulate could be estimated by a numerical simulation [8] with reasonable accuracy.
  Diamond granulates were coated with Nb and Boron interlayers. For the deposition of the metallic Nb DC magnetron sputtering could be employed, while for depositing B Radio Frequency (RF) sputtering had to be chosen due to the low electrical conductivity of B.

- *Preparation of a composite with small particle size [2]*

  Diamond granulates with grain sizes from 30 µm to 400 µm could be coated with good reproducibility. The interlayer thickness was determined either by the optical method described in [2] or by Focused Ion Beam (FIB) cross sections performed on selected diamond particles. Copper diamond composites were manufactured by RHP Technology GmbH by rapid hot pressing. Thermal conductivities were measured on macroscopic composites in collaboration with PROFACTOR GmbH. The highest thermal conductivities of about 500 W/mK could be achieved with the B coated granulates. It is in fact not necessary to coat the granulate, but admixture of B to the Cu powder used for hot pressing is sufficient to improve the thermal conductivity.

Methods and results of thermal and mechanical interface characterization:

- *Scanning Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) [1,3,6]*

  Conventional non-contact mode AFM and SEM has been applied for the study of the surface topography of heat treated Cu coatings on plane SIGRADUR G and synthetic diamond substrates. These measurements yielded valuable results about the process of recrystallization and de-wetting of copper observed for different interlayer materials.

- *Dynamic Secondary Ion Mass Spectroscopy (dynamic SIMS) [3,6,7,9]*

  Synthetic diamond substrates containing different interlayers were subjected to dynamic SIMS. Two effects were observed as a consequence of heat treatment: (i) diffusion of material from the interlayer into the Cu-matrix and (ii) carbide formation of the interlayer material at the diamond substrate. It was found that it is necessary to have carbide formation in the vicinity of the diamond surface to unfold an influence onto the thermomecanical interface [9] before the interlayer dilutes into the matrix.

- *Infrared Radiometry (IR-radiometry) [6,7,9]:*

  IR-radiometry measurements in reflection mode were performed on SIGRADUR G substrates and synthetic diamond samples. The experimental results were fitted by theoretical models of thermal wave propagation within layered media [6,7]. The interlayer could be considered as thin enough to not be regarded as separate material of finite thickness. In this case the effect of the interlayer is only mirrored in a change in TCR. IR radiometry proved that thin interlayers of approx. 5 nm thickness can considerably lower the TCR in the case of plane samples [6,7,9].

- *Cross sectional Transmission Electron Microscopy (X-TEM) and Electron Energy Loss Soectroscopy (EELS)*

  To quantify the chemical processes at the Copper Diamond interface TEM cross sections of plane samples were manufactured by FIB. In contrary to SIMS this method yields high spatial resolution in the nm range. EELS makes it possible to detect B, which is difficult for other methods as e. g. Energy Dispersive X ray analysis (EDX). During heat treatment B immediately forms a carbide while carbide formation with Nb is slower. Both materials, however, remain close to the interface and therefore reduce theTCR as it was observed by IR radiometry.

Synopsis of basic physico-chemical processes at the thermomechanical interface:

- *Carbide formation in intermediate layers [6,7,9]*

  The thermomechanical properties improve if the interlayer material remains located at its initial position within the model sample (i. e. between the Cu top layer and the diamond-substrate) after heat treatment. Adhesion is increased by the formation of a carbide of the interlayer material. This was the case for B and Nb interlayers. Ti and Cr migrated away from the interface due to heat treatment thus leading to a depletion of the interlayer material and therefore canceling the positive effects of carbide formation. By cross sectional TEM, the detailed mechanisms of carbide formation and diffusion for B and Nb could be observed at the nanometer scale. Thermal treatment has to be optimized in a way that (i) interlayer material does not excessively diffuse into the Cu matrix and (ii) has to be sufficient to allow the formation of the carbide. Under these conditions the thermomechanical properties of the interface are improved. Carbide formation was found to be faster for B than for Nb, which may play a crucial role for using these interlayer materials for the production of Cu diamond composites.

- *Solid state de-wetting [1,3,6,7,9]*

  Apart from carbide formation a key mechanism in relation to the thermomechanical interface is de-wetting of the Cu film from the modified substrate. De-wetting can nicely be observed by SEM and AFM [1,3]. The degree of de-wetting can be determined by e. g. counting the numbers of holes or voids in the coating [6]. Within the present project a correlation between this quantity and adhesion as well as TCR could be established [6,7,9]. Since these methods (especially SEM) are easily accessible, the observation of de-wetting can be regarded as a first indicator if a selected interlayer positively influences the thermomechanical interface.

- *The thermomechanical interface in the composite*

  As the measurement of the thermal conductivity in Cu diamond composites has shown, the positive effect of Nb is not fully retained in the composite. The reason for this is likely to be the diffusion of Nb away from the interface into the Cu-Matrix before a carbide can be formed. B addition, however, significantly increases the thermal conductivity, even if B is not applied to the diamond granulate as a coating, but just admixed to the Cu powder. In this case B is likely to diffuse through the matrix because of its high mobility, until it is stopped at the diamond surface where the carbide is rapidly formed. It can be concluded that B is a suitable material for the improvement of the thermal properties of Cu-diamond composites.

2. 1. 3. Information on the running of the project and on deviations from the original proposal

The Project started on March 01. 2007. The project was elongated for 24 months without additional costs until Feb. 29. 2012. This rather long additional period of the project was mainly caused due to delays in the availability of DI Johannes Hell which were caused (i) by a delay in the finishing of his master thesis which was concluded in 2009 and not, as anticipated, in early 2008 and (ii) by a serious injury which had to be treated for several months. Nonbetheless the work of Mr. Hell, especially in relation to the construction of the device for coating granulates, was outstanding and will be a significant part of his PhD thesis which is due to be finished in late 2012. In addition two major pieces of equipment which were not included into the initial proposal could be bought by a diversion of financial means: (i) an active vibration damping for Atomic Force Microscopy in 2010 which significantly improved the experimental throughput and image quality in respect to the characterization of plane samples related to de-wetting and (ii) a dedicated Radio Frequency (RF) generator in 2011 with which is now solely used to deposit non conducting interlayers on granulates.
Within the Project 3 master theses were granted. Their topics were:

- Master thesis 1: Interface Optimization in the Copper Carbon System
- Master thesis 2: Numerical Calculation of coating rates on granular materials in a magnetron sputter plant
- Master thesis 3: Characterization of the interface properties in metal diamond composites

Initially the project contained financial support for 4 master theses. The financial means for one of these proposed theses were diverted and consumed by the prolongation of the project as well as for buying the equipment mentioned above.
The initial goals of the project could be pursued during the whole duration, no large shift in focus is reported. The project leader takes full responsibility for the reported delays.

2. 2. Personnel development

All participants of the project could acquire significant knowledge concerning the topics of compound materials, interface modification, wetting phenomena and characterization of complex materials and interfaces. In addition the topic of coating granular materials gained momentum so far that the methodology developed in the project could be used for different other of applications. This progress was documented by frequent visits of the participating persons to international congresses and several publications in reviewed scientific journals as well as the master theses which are given in the appendix to this report.
The accumulated know-how in the above fields triggered several national and international co-operations which dealt with problems related to the above research but which employed techniques which were not readily accessible to the project leader. The collaboration between the project participants and the groups of Prof. Josef Pelzl (Ruhruniversität Bochum) and Mihai Chirtoc (Université de Reims Champagne-Ardenne) resulted in research vistis of two master students employed in the project and yielded vital results for their work.

Finally, the knowledge gained about the coating of granular materials spawned two applications for Austrian Science Fund Projects which were both granted in the meantime. The Translational Project TRP 6, "Optical thickness determination on transparent granulates", Tscan, deals with the reliable thickness determination of coatings on large samples of transparent granulates and originated from the work done on thickness determination and calculation [2,8] in the present project. The FWF Project P-22718, "Thin films on hollow micro glass spheres", CatSphere, deals with the deposition of catalytic coatings on micro glass spheres. Both projects would not have been initiated without the present one.

2. 3. Effects of the project outside the scientific field

Results of the project concerning the de-wetting processes occurring in thin films upon heat treatment were incorporated in a lecture cycle on thin film growth given by the project leader.
Other areas of the society might be affected by the two FWF projects mentioned in the previous sections which touch the fields of high throughput powder characterization, pattern recognition and image processing (TRP-6) as well as energy harvesting and storage (P-22718).

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	1	3	non-scientific co-workers	0	0
diploma students	1	1	diploma students	3	36
PhD students			PhD students	1	36
post-doctoral co-workers			post-doctoral co-workers	0	0
co-workers with “Habilitation” (professorial qualifications)			co-workers with “Habilitation” (professorial qualifications)	0	0
professors			professors	0	0

4. Attachments

List 1

1.a. Scientific publications

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

[1] H. Steiner, C. Eisenmenger-Sittner, B. Schwarz
Temperature induced recrystallization of copper coatings deposited on adhesion promoting molybdenum interlayers
Journal of Physics: Conference Series 100 (2008) 082032

[2] Determination of the thickness of metal coatings on granular diamond materials by spatially resolved optical methods
M. Horkel, H. Mahr, J. Hell, C. Eisenmenger-Sittner, E. Neubauer
Vacuum, 84(1) (2009) 57-60

[3] Suppression of de-wetting of copper coatings on carbon substrates by metal (Cr, Mo, Ti) doped boron interlayers
D. Schäfer, J. Hell, C. Eisenmenger-Sittner, E. Neubauer, H. Hutter, N. Kornfeind
Vacuum, 84(1) (2009) 202-204

[4] Construction and characterization of a sputter deposition system for coating granular materials
J. Hell, M. Horkel, E. Neubauer, C. Eisenmenger-Sittner
Vacuum, 84 (2010) 453 – 457

[5] Optimization of a container design for depositing uniform metal coatings on glass microspheres by magnetron sputtering
G. Schmid, C. Eisenmenger-Sittner, J. Hell, M. Horkel, M. Keding, H. Mahr
Surface & Coatings Technology 205 (2010) 1929 – 1936

[6] Characterization of the mechanical and thermal interface of copper films on carbon substrates modified by boron based interlayers
D. Schäfer, C. Eisenmenger-Sittner, Mihai Chirtoc, P. Kijamnajsuk, N. Kornfeind, H. Hutter, E. Neubauer, M. Kitzmantel
Surface and Coatings Technology, 205 (2011) 3729–3735

1.a.2. Non peer-reviewed publications (journals, contribution to anthologies research reports, working papers, proceedings, etc.)
NONE

1.a.3. Stand-alone publications (monographies, anthologies)
NONE

1.b. publications for the general public and other publications such as films, exhibitions, preparation of a home page etc. with an indication of the status (published, submitted / in preparation)

NONE

List 2 project-related participation in international scientific conferences (with an indication of the conference date) – 4 subunits:

2.1. Conference participations - invited lectures

1st Austrian Symposium on Carbon Based Coatings, 19.-20. Mai 2010, Congress Leoben (Austria)
Grenzflächenmodifikation in Kupfer-Diamant Kompositen als Mittel zur Beeinflussung der mechanischen und thermischen Eigenschaften/The effect of interface modification on the mechanical and thermal properties of Copper Diamond composites
C. Eisenmenger-Sittner, J. Hell, K. Zellhofer, E. Neubauer, M. Kitzmantel

6th Vacuum and Surface Sciences Conference of Asia and Australia (VASSCAA-6), October 9-13, 2012 Islamabad, Pakistan
Thin Film Deposition on Uncommon Substrates: Deposition and Possible Application of PVD Coatings on Granulates (Plenary Talk, scheduled Oct. 2012)

2.2.Conference participations - lectures

14th International Conference on Thin Films & Reactive Sputter Deposition 2008 (ICTF 14 & RSD 2008), 17. 11-20. 11. 2008, Ghent, Belgium
SPATIALLY RESOLVED THICKNESS DETERMINATION OF METAL AND OXIDE COATINGS USING OPTICAL CONSUMER ELECTRONIC COMPONENTS
M. Horkel, H. Mahr, J. Hell, C. Eisenmenger-Sittner, E. Neubauer*

Joint Vacuum Conference 13 (JVC 13), 20.-24.06.2010, Štrbské Pleso, Slovakei
Pull-off test-, SEM-, AFM-, SIMS- and heat stage ESEM investigation of sputter deposited boron- and metal doped boron interlayer in the Cu-C system
K. Zellhofer, J. Hell1, D. Schäfer, C. Eisenmenger-Sittner, E. Neubauer, S. Puchner, H. Hutter

Tagung: 15th International Conference on Thin Films (ICTF 15) 08. 11-12. 11. 2011, Kyoto (Japan)
Interface modifications in the Cu-Diamond system
J. Hell, M. Chirtoc2, C. Eisenmenger-Sittner, P. Kijamnajsuk, M. Kitzmantel, E. Neubauer, K. Zellhofer

2.3. Conference participations - posters

Joint Vacuum Conference 12, JVC-12, Balatonalmadi, Ungarn, 22.09-26.09.2008
SUPPRESSION OF DE-WETTING OF COPPER COATINGS ON CARBON SUBSTRATES BY METAL (Cr, Mo, Ti) DOPED BORON INTERLAYERS
D. Schäfer, J. Hell C. Eisenmenger-Sittner, E. Neubauer*

Joint Vacuum Conference 12, JVC-12, Balatonalmadi, Ungarn, 22.09-26.09.2008
DETERMINATION OF THE THICKNESS OF METAL COATINGS ON GRANULAR DIAMOND MATERIALS BY SPATIALLY RESOLVED OPTICAL METHODS
M. Horkel, H. Mahr, J. Hell, C. Eisenmenger-Sittner, E. Neubauer*

15th International Conference on Thin Films (ICTF 15) 08. 11-12. 11. 2011, Kyoto (Japan)
Assessment of the requirements for PVD systems for coating granular materials
C. Eisenmenger-Sittner, J. Hell, M. Keding, G. Schmid

2.4. Conference participations - other

NONE

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

N	**E**	**D**	**Collaboration partner / content of the collaboration**
N	E3	D	1) Name: Michael Kitzmantel Title: DI. Institution: RHP-Technology GmbH & Co. KG Content: Rapid Hot Pressing of Composites
E	E3	D	2) Name: Josef Pelzl Title: Dr. Institution: Ruhruniversität Bochum Content: Characterization of thermal interface, IR radiometry
E	E3	D	3) Name: Mihai Chirtoc Title: Dr. Institution: Université de Reims Champagne-Ardenne Content: IR Radiometry in reflection
			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 Theses:

4.1 PhD Theses

D. I. Johannes Hell
Interface modifications in the Cu-Diamond system
PhD Thesis TU Wien, due late 2012

4.1 Master Theses

[7] David Schäfer
Optimierung der Grenzfläche in Kupfer – Kohlenstoff Systemen
Master Thesis TU Wien, 2009

[8] Harald Mahr
Numerische Berechnungen zur Beschichtung granularer Materialien in einer Magnetron-Sputteranlage
Master Thesis TU Wien, 2009

[9] Katharina Zellhofer
Charakterisierung der Grenzflächeneigenschaften von Metall-Diamant-Verbundwerkstoffen
Diploma Thesis TU Wien, 2010

List 5 Effects of the project outside the scientific field:

5.1. Organization of scientific events
NONE

5.2. Particular honours, prizes etc.
The award "For Encouragement of Research in Thin Films" was given to D. I. Johannes Hell for his presentation "Interface Modifications in the Cu-Diamond System" at the 15th International Conference on Thin Films (ICTF 15) 08. 11-12. 11. 2011, Kyoto (Japan).

5.3. Information on results relevant to commercial application
NONE

5.4. Other effects beyond the scientific field
NONE

5.5. Relevance of the project in the organization of the relevant scientific discipline
NONE

List 6 Applications for follow-up projects:

6.1. Applications for follow-up projects (FWF-Projects)

TRP 6, Translational Project, "Optical thickness determination on transparent granulates", Tscan, approved 06. 2010

P-22718, "Thin films on hollow micro glass spheres", CatSphere, approved 04. 2011

6.1. Applications for follow-up projects (Other national Projects)

NONE

6.1. Applications for follow-up projects (International-Projects)

NONE

5. Zusammenarbeit mit dem FWF

Sie werden gebeten folgende Aspekte der Zusammenarbeit mit dem FWF zu bewerten. **Anmerkungen (Ausführungen)** unter Verweis auf den entsprechenden Referenzpunkt bitte auf Beiblatt.

Skala
-2 sehr unzufriedenstellend,
-1 unzufriedenstellend;
0 angemessen;
+1 zufriedenstellend;
+2 sehr zufriedenstellend.
X nicht beansprucht

Regelwerk
(Richtlinien für Programm, Antrag, Verwendung, Bericht) **Wertung**

Antragsrichtlinien	Umfang	**+2**
	Übersichtlichkeit	**+2**
	Verständlichkeit	**+2**

Verfahren (Einreichung, Begutachtung, Entscheidung)

	Beratung	**+2**
	Dauer des Verfahrens	**+1**
	Transparenz	**+2**

Projektbegleitung

Beratung	Verfügbarkeit	**+2**
	Ausführlichkeit	**+2**
	Verständlichkeit	**+2**

Durchführung Finanzverkehr (Überweisungen, Gerätebeschaffungen, Personalwesen)	**+2**

Berichtswesen/ Prüfung/ Verwertung

	Aufwand	**+2**
	Transparenz	**+2**
	Unterstützung bei Öffentlichkeitsarbeit/ Verwertung	**X**

Anmerkungen zur Zusammenarbeit mit dem FWF:

Der FWF als Fördergeber ist extrem kooperativ. Anfragen bei Unklarheiten werden rasch und kompetent abgearbeitet. Auch die Dauer der Begutachtungsverfahren hat sich tendenziell verkürzt. Eine Abwicklung von Einzelprojekten wie früher mit eigenen Projektleiterkonten wäre wünschenswert, um sich die behäbige universitäre Finanzbürokratie, die oft zu finanziellen Einbussen führt (verlorene Skonti etc.), zu ersparen. Dies liegt aber sicher nicht in der Hand des FWF.