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Creating competitive edge for the European **POLY**mer processing industry driving new added-value products with **COND**ucting polymers.

Instrument: INTEGRATED PROJECT for SMEs

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1st Periodic Report

Publishable executive summary

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Project coordinators: **Mark Gaddes** & **Gary Foster**

Project coordinator organisation name: **Rapra Technology Ltd**

Revision *1*

Confidential Technical Report
45994

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CREATING COMPETITIVE EDGE FOR THE EUROPEAN POLYMER PROCESSING INDUSTRY DRIVING NEW ADDED-VALUE PRODUCTS WITH CONDUCTING POLYMERS

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Large Projects

PolyCond 1st year

Publishable Executive Summary Report

Summary description of project objectives

The research is based on the compounding of engineering polymers and Inherently Conductive Polymers (ICPs) with improved conductivity, or hybrid systems of ICPs with conductive nanotubes. Innovative, eco-efficient processing, based on CO_2 assisted technologies specifically tailored to the new materials, will also be developed.

PolyCond's approach will provide:

- Plastic components with embedded EMI shielding functionality
- Weight reduction of at least 60%
- Total cost reduction of shielding components approaching 90%
- Reduction of production time by 80%, thus improving productivity

PolyCond will benefit plastic processors in the EU by developing new technologies and providing solutions to key long-term problems. A multidisciplinary and integrated approach includes technology transfer with training activities, thereby mobilizing EU and Regional funding.

The main challenges are:

- To enhance the conductivity of existing melt processable ICPs
- To extend the processing window of existing melt processable ICPs
- To improve the compatibility and dispersion of conductive nanofillers in complex matrices

Contractors involved

Nº	Participant name	Short name	Country
1	Rapra Technology Limited	Rapra	UK
2	Panipol Oy	Panipol	Finland
3	Promolding B.V	Promolding	The Netherlands
4	Faperin	Faperin	Spain
5	Colorex	Colorex	The Netherlands
6	Intermedic	Intermedic	Spain
7	Molespol	Molespol	Spain
8	Whitaker Technical Plastics	Whitaker	UK
9	TBA Textiles Ltd	TBA	UK
10	Compañía Levantina de Reductores	CLR	Spain
11	LABO Producer, Commercial and Provider Ltd	LABO	Hungary
12	Asociación de Investigación de Materiales Plásticos	Aimplas	Spain
13	Rondol Technology Ltd	Rondol	UK
14	European Plastic Converters	EuPC	European
15	British Plastic Federation	BPF	UK
16	MAGYAR VEGYIPARI SZÖVETSÉG	MAVESZ	Hungary
17	Dutch Society for Materials Science “Bond voor Materialenkennis”	BvM	The Netherlands
18	TNO	TNO	The Netherlands
19	VTT	VTT	Finland
20	Chemical Research Centre	CRC-HAS	Hungary

Coordinator's contact details

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Work performed

The work performed in year 1 of the PolyCond project has focused upon the development of the raw materials to be used in the polymer compounds. In work package 1, multi-walled carbon nanotubes (CNT) have been sourced and modified using novel chemical and physical modification techniques. The modified materials have been characterised using thermogravimetry / mass spectrometry, FTIR, Raman Spectroscopy, SEM, AFM, and TEM. The efficacy of these modifications has been determined using physical dispersion in media of differing chemical character. The performance of these materials as melt compounding additives is currently being assessed in work package 2. Hybrid modified nanotube / polyaniline materials have been synthesised and tested in work package 6.

In work package 2, the work has been focused on the practicalities of compounding carbon nanotubes at the lab and pilot plant scale. Steps have been taken to implement safety and handling procedures during compounding. Experiments have been undertaken to optimise processing conditions at the pilot plant scale. Alternative strategies to produce compounds have been investigated using various designs of mixing equipment. Steps have been taken to modify a twin-screw extruder for CO_2 assisted processing. Modifications to the screw elements, agitator configuration and the barrel has enhanced the pressure containing capability and allowed the injection of CO_2 through the barrel ports. Moreover, a side-stuffer has been modified to provide enhanced flexibility for feeding of conductive materials during compounding.

In work package 3, 35 combinations of plasticizer and doping agent candidate materials have been screened and 5 have been selected for scale-up trials. Pilot-plant scale production of new grades is currently underway.

In work package 5 extruder modifications have been designed and manufactured making a small 18 mm single screw extruder ready for CO_2 assisted processing trials. Preliminary trials were conducted to determine output rate data that was necessary for the design of an in-line capillary die.

In work package 6 alternative strategies to incorporate the nanotubes into conductive compounds have been investigated. Pre-processing of the nanotubes with flame-retardant oil has been tried. Addition of nanotubes during polyaniline preparation has been attempted.

The supporting work packages namely 9, 10, 13, 14 and 15 are up and running. Work packages 9 and 10 are feeding information into the research and development work packages concerning economic viability and environmental impact. Work package 14 has set up the PolyCond website (www.polycond.com) and a draft plan for using and dissemination knowledge has been prepared (**see Appendix 1**). An overall exploitation plan is being constructed.

Results achieved so far

Work package 1 has produced modified and characterised nanotubes. These have been supplied for mixing trials in work package 2 and the preparation of polyaniline / nanotube hybrid materials in work package 6. Early results suggest that hybrid materials with resistivities lower than 10^0 Ωcm may be obtainable.

A patent "NOVEL COMPOSITIONS AND METHODS FOR THE PRODUCTION THEREOF" was submitted by VTT / Panipol on February 23rd 2006. The patent describes the preparation of polyaniline / nanotube hybrids with resistivities of 10^0 Ωcm and lower.

In work package 2, optimisation of compounding trials have resulted in the pilot-plant scale production of materials with minimum resistivities in the order of 10^0 Ωcm. Equipment has been modified for development of the CO_2 assisted compounding processes.

In work package 3, results suggest that improvements in conductivity of two orders of magnitude over existing polyaniline grades will be obtained. The new formulae are sufficiently developed such that pilot-plant scale production of materials can be prepared for supply into work package 4. The first batches of scale up materials have been prepared and are currently being supplied to partners who will carry out the melt processing trials.

Work package 5 has developed the machinery hardware necessary for single screw extrusion and characterisation through in-line rheometry. Design and manufacture of the first stage of hardware development is complete ready for processing trials to commence.

Work package 6 has found that improvements in compound conductivity may be obtained if the nanotubes are pre-processed with an oil-based compounding additive or combined during the preparation of polyaniline.

Expected end results

The experimental work will lead to the optimal use of the nanotube and polyaniline raw materials. The required target conductivities will be obtained with minimal additive loadings and consequently minimised materials costs. A number of processes will be developed that will enable the conversion of the raw materials into products with specifications that satisfy the targeted end user's applications.

Intentions for use

Modifications to the nanotubes, matrix polymers, and processing conditions will permit the production of a range of materials with suitable combinations of electrical and physical properties with balanced costs. Improved polyaniline formulations will enable the doped and plasticized materials to be used in higher temperature applications and / or those in which higher levels of conductivity are required than can be satisfied with the present polyaniline formulation. The use of nanotube / hybrid materials will permit tailoring of the performance of conductive plastics compounds into more exacting applications.

Impact

PolyCond will develop a range of conductive materials and processes that will enable the consortium partners, and the eventually the wider EU community, to satisfy the demands of the expanding electronics industry by providing product specifications that are not currently available.

RAPRA TECHNOLOGY LIMITED UNITED KINGDOM
CONDITIONS OF BUSINESS

FORMATION OF CONTRACT

1.1 All quotations are made and all orders are accepted subject to the following conditions. All other terms, conditions or warranties whatsoever are excluded from any contract between the parties unless expressly accepted by Rapra Technology Limited ("Rapra") in writing.

1.2 Quotations shall be available for acceptance for a maximum period of 30 days from the dates thereof and may be withdrawn by Rapra within such period at any time by written or oral notice. "Work" shall mean the work and services that Rapra agree to provide in the quotation.

1.3 If any statement or representation has been made to the Client by Rapra, or its employees upon which the Client relies (other than in the documents enclosed with Rapra's quotation) then the Client must set out that statement or representation in a document to be attached to the return copy of the quotation and in any such case Rapra may accept or reject the same and/or submit a new quotation.

1.4 The supply of materials, products or information by the Client pursuant to the quotation shall constitute acceptance of these conditions where acceptance has not previously been communicated by the Client to Rapra.

PRICES

2.1 All prices are, unless otherwise stated, quoted net exclusive of VAT.

2.2 All requests for variations or addition to the Work must be made by the Client in writing. In the event of any variation or addition being so requested and agreed to by Rapra, Rapra shall be entitled to make an adjustment to the contract price fairly reflecting such variation or addition.

PAYMENT

3.1 Unless otherwise agreed by Rapra in writing the terms of payment shall be 30 days from receipt of invoice by the Client, which shall be deemed to be two working days after posting. Rapra may submit interim invoices in respect of each stage of Work completed for the Client.

3.2 No disputes arising under the contract nor delays beyond the reasonable control of Rapra shall interfere with prompt payment in full by the Client.

3.3 In the event of default in payment by the Client Rapra shall be entitled at its option to treat the whole contract as repudiated by the Client or to suspend all further work on any contract or contracts between Rapra and the Client without notice and to charge interest on any amount outstanding at the rate of 2% per annum above the Base Rate of National Westminster Bank plc in force at the time when payment was due.

COMPLETION

4.1 Time for completion of Work is given as accurately as possible but is not guaranteed. The Client shall have no right to damages or to cancel the order for failure for any cause to meet any time stated for completion of Work.

4.2 Any estimate of the date of completion of Work shall in every case be dependent upon prompt receipt of all necessary information, instructions or approvals from the Client. Variations or additions to the Work requested by the Client may result in delay in completion.

CANCELLATION

5. Either party may cancel the contract on 30 days written notice to the other on condition that all costs and expenses incurred by Rapra up to the time of cancellation and, where cancellation is at the insistence of the Client, all loss of profits and other loss or damage resulting to Rapra by reason of such cancellation, will be paid forthwith by the Client to Rapra.

LIABILITY

6.1 Rapra undertakes that it will indemnify and keep the Client indemnified against all liabilities, costs and expenses in respect of claims in relation to death or injury to persons or damage to tangible property to the extent that such death, injury, loss or damage is attributable to the negligent acts or omissions of Rapra, its officers, employees, agents or sub-contractors.

6.2 Save where Rapra is shown to have failed to exercise reasonable care in the performance of the Work and such failure results in death or personal injury, Rapra shall not be liable in respect of claims arising by reason of death or personal injury. Further, under no circumstances whatsoever shall Rapra be liable for consequential loss, loss of profits, damage to property or wasted expenditure.

6.3 Rapra's liability, whether in respect of one claim or the aggregate of various claims other than claims for death or personal injury due to negligence on the part of Rapra shall not exceed £500,000 in any Year and the Client agrees to insure adequately to cover claims in excess of such amount.

CONFIDENTIAL INFORMATION AND INDUSTRIAL PROPERTY RIGHTS

7.1 All data, information and reports are produced for the benefit of the addressee only. Rapra accepts no liability arising from unauthorised use of such information or reports by a third party.

7.2 The Client shall not reproduce or abstract for the purpose of advertising or otherwise any report or other information on the Work or use the name of Rapra either expressly or by implication in any of its advertising or sales promotional material without the prior written consent of the Company Secretary of Rapra.

7.3 All drawings, documents, confidential records, computer software and other information supplied by Rapra are supplied on the express understanding that copyright is reserved to Rapra and that the Client will not, without the written consent of Rapra, either give away, loan, exhibit or sell any such drawings, documents, records, software or other information or extracts therefrom or copies thereof or use them in any way except in connection with the Work in respect of which they are issued.

7.4 All intellectual Property Rights belonging to or otherwise in the control of either party prior to entering into the contract shall remain the property of the party owning such Intellectual Property Rights.

7.5 All title and ownership of, or relating to, any intellectual property, including, but not limited to ideas, inventions, discoveries, creations, improvements or any other property subject to patent protection or intellectual property rights as developed or resulting from work under this agreement, shall directly or indirectly be solely owned by Rapra Technology Ltd, unless otherwise agreed to in writing by all participating parties.

7.6 In the event that Rapra Technology Ltd does not wish to apply for or maintain patent protection for any invention owned by it in accordance with clause 7 herein, it will on request assign its rights in respect of that patent to the client but in any event Rapra Technology Ltd shall be granted a royalty free, irrevocable, non-exclusive, world-wide right to use such intellectual Property Rights assigned under this condition 7.6.

7.7 Rapra Technology Ltd will on request grant rights to the client for exploitation or patenting of the ideas, inventions, discoveries, creations, improvements arising from the work, in the client's traditional or defined new areas of business. In all other areas, rights remain vested with Rapra Technology Ltd.

SAMPLES

8. Rapra retains the right to return or dispose of the samples at the customers cost after a period of 6 months unless otherwise agreed with the client. Storage of the samples beyond the initial 6 month period will be charged for, invoiced in advance for the agreed period (minimum additional 6 months).

CUSTOMER'S INFORMATION

9.1 The Client shall be solely responsible for ensuring that all drawings, information, advice and recommendations given to Rapra, either directly or indirectly by the Client or by the Client's agents, servants, consultants or advisers, are accurate and sufficient for completion of the Work. Examination or consideration by Rapra of such drawings, information, advice or recommendations shall in no way limit the Client's responsibility hereunder unless Rapra specifically agrees in writing to accept responsibility.

9.2 Rapra shall not disclose to any third party any knowledge or information relating to the Work which is, on receipt by Rapra, marked 'confidential' by the Client unless and until such information becomes public knowledge.

INSOLVENCY

10. If either party shall become bankrupt or under the provisions of Section 123 of the Insolvency Act 1986 is deemed to be unable to pay its debts or compounds with creditors or in the event of a resolution being passed or proceedings commenced for its administration or liquidation (other than for a voluntary winding up for the purposes of reconstruction or amalgamation) or if a Receiver or Manager is appointed of all or any part of its assets or undertaking, the other party shall be entitled to cancel the contract in whole or in part by notice in writing without prejudice to any other right or remedy accrued or accruing to that party.

FORCE MAJEURE

11. In the event of the performance of any obligation accepted by Rapra being prevented, delayed, or in any way interfered with by direction of government, war, industrial dispute, strike, breakdown of machinery or plant, accident, fire or by any other cause beyond Rapra's control Rapra may at its option suspend performance or cancel its obligations under the contract without liability for any damage or consequential loss resulting therefrom, such suspension or cancellation being without prejudice to Rapra's right to recover all sums owing to it in respect of works performed and costs incurred prior to the date of suspension or cancellation.

ASSIGNMENT

12. This Contract is personal to the parties and may not be assigned or transferred without the prior written consent of the other party.

LEGAL

13. The contract shall be governed and interpreted exclusively according to the Law of England and shall be subject to the jurisdiction of the English Courts only.