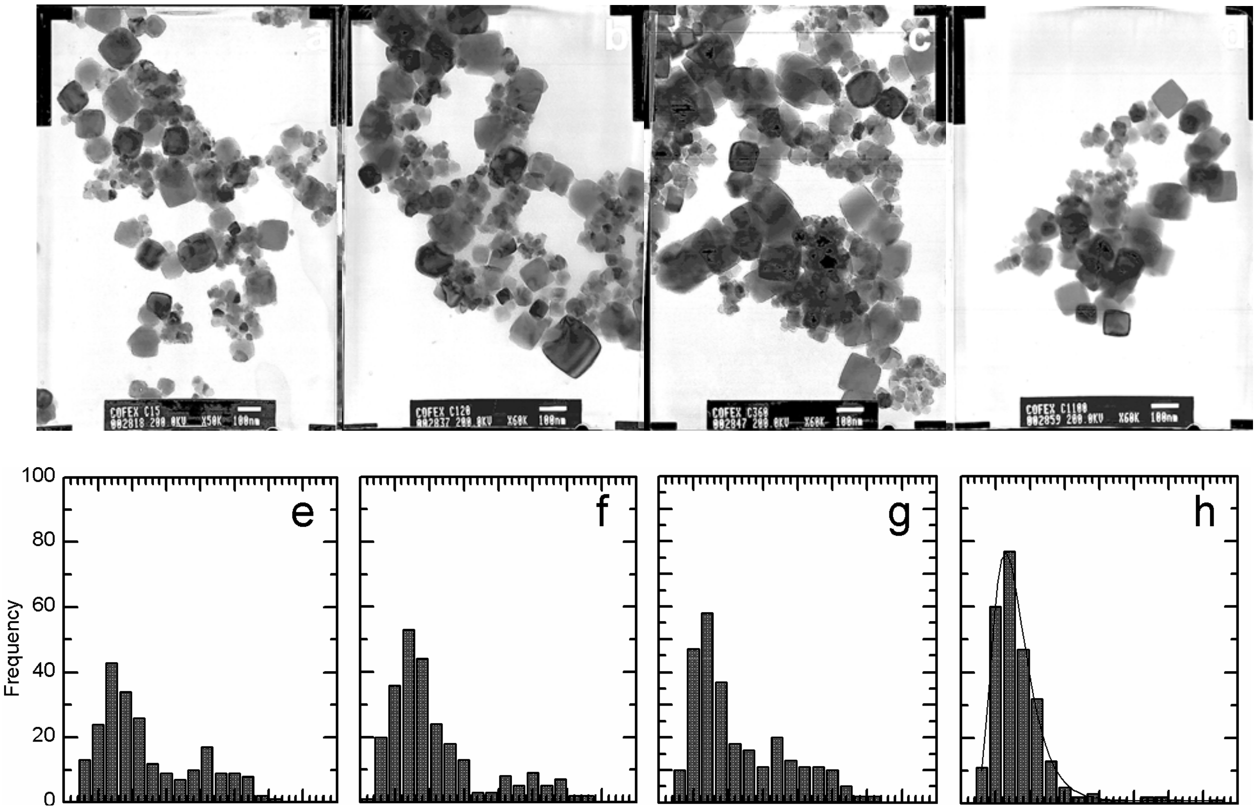
FOI-R--1524--SE
December 2004
ISSN 1650-1942

User report

S.J. Savage

Final report: nanocomposite materials



Ferrite nanoparticles and their size distributions

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FOI-R--1524--SE

December 2004

ISSN 1650-1942

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Issuing organization FOI – Swedish Defence Research Agency Sensor Technology P.O. Box 1165 SE-581 11 Linköping	**Report number, ISRN** FOI-R--1524--SE	**Report type** User report
	Research area code 74 Materials Technology	
	Month year December 2004	**Project no.** E3037
	Sub area code 74 Materials Technology	
	Sub area code 2	
Author/s (editor/s) S.J. Savage	**Project manager**	
	Approved by	
	Sponsoring agency	
	Scientifically and technically responsible	

Report title

Final report: nanocomposite materials

Abstract (not more than 200 words)

This report summarises the activities and results of the project: *nanocomposite materials* during the period 2000-2004. The report describes the various activities and reports produced in the project. The project has introduced nanocomposite materials and their potential for defence applications, of which there are many, particularly in applications demanding multifunctionality such as UAV's. Research activities have included synthesis and characterization of ferrite nanoparticles, their surface functionalization, dispersion in an epoxy matrix, and characterization of the microwave and mechanical properties of the nanocomposites produced. The latter charaterization will be completed and reported during the first two quarters of 2005, within a cooperating project: tunable signature materials.

The project has contributed greatly to improving the awareness of nanocomposites and their properties and applications within Swedish defence organisations, especially FMV and FOI.

It can be concluded that polymer matrix nanocomposites can be produced, and that they are likely to be used in defence materiel over a period stretching from the next few years to several decades in the future.

The project has created an extensive network of national and international cooperating partners.

Keywords

nanocomposites, final report, defence applications, materials technology

Further bibliographic information	**Language** English
ISSN 1650-1942	**Pages** 14 p.
	Price acc. to pricelist

Utgivare	Rapportnummer, ISRN	Klassificering
Totalförsvarets Forskningsinstitut - FOI Sensorteknik Box 1165 581 11 Linköping	FOI-R--1524--SE	Användarrapport
	Forskningsområde 7. Farkost- och rymdteknik	
	Månad, år December 2004	**Projektnummer** E3037
	Delområde 74 Materialteknik	
	Delområde 2	
Författare/redaktör S.J. Savage	**Projektledare**	
	Godkänd av	
	Uppdragsgivare/kundbeteckning	
	Tekniskt och/eller vetenskapligt ansvarig	

Rapportens titel (i översättning)

Slutrapport: nanokompositmaterial

Sammanfattning (högst 200 ord)

Rapporten sammanfattar de olika aktiviteter och resultat från projektet: *nanokompositmaterial* under perioden 2000-2004. Rapporten beskriver aktiviteterna och rapporter som har producerats inom projektet. Projektet har väckt intress och belyst nanokompositmaterial och deras egenskaper och tillämpningar av vilken det finns många, särskilt inom tillämpningar som kräver, p.g.a. volym och vikt begränsningar, multifunktionella material, t.ex i UAV's.
Forskningsaktiviteterna har inkluderat syntes och karakterisering av ferrit nanopartiklar, deras ytbehandling, metoder för dispergering i epoximatriser, och mätning av kompositernas mekaniska och mikrovågsegenskaper. Det senare kommer att färdigställas och publiceras under första halvåret 2005, inom ett samverkande projekt: styrbara signaturmaterial.
Projektet har gjort ett viktig bidrag för att väcka uppmärksamhet kring nanokompositer, och belyst deras egenskaper och aktuella och potentiella tillämpningar inom Svensk försvarsorganisationer, särskilt inom FMV och FOI.
En viktig slutsats är att polymermatris nanokompositer kan produceras under rimliga förhållandena och att det redan i dag finns försvarstillämpningar. Det är sannolik att ytterliggare tillämpningar kommer att utvecklas inom ett tidshorizont som sträckar sig från några få år framöver till ett antal decennier i framtiden.
Projektet har lyckats även utveckla ett omfattande nätverk av nationella och internationella samarbetande partners.

Nyckelord

nanokompositer, slutrapport, försvarstillämpningar, materialteknik

Övriga bibliografiska uppgifter	**Språk** Engelska
ISSN 1650-1942	**Antal sidor:** 14 s.
Distribution enligt missiv	**Pris: Enligt prislista**

Contents

Introduction

This report will summarise the activities and results from the project *nanocomposite materials*, during the period 2000-2004.

The main objective of this project has been to develop methods for the production and processing of polymer-based nanocomposite materials for microwave absorption combined with load carrying capability. Potential applications include ground vehicles and other weapon platforms, and UAV’s. The latter application is particularly attractive, as UAV’s will demand multifunctional materials due to their limited volume and weight limits. The project has been conducted in close cooperation with the Royal Institute of Technology (KTH), department of Fibre and Polymer Technology. Other departments at KTH which have cooperated include Casting of Metals and Materials Chemistry. In addition, we have cooperated internationally, with researchers in Germany and the People’s Republic of China.

Definition

The term nanocomposites as used in this report is taken to mean polymer-matrix materials containing particles (equiaxed or elongated), or fibres with at least one dimension in the 1 to 200 nanometre range. The particles or fibres may be inorganic (metal or ceramic, including semiconductors) or organic (e.g. polymer). This definition excludes metal-matrix nanocomposites, and similarly ceramic-matrix nanocomposites. This is not to suggest that these fields are unimportant, merely that they are not covered in this report.

Background

Prior to starting this report our knowledge and experience of producing and characterizing nanocomposite materials was extremely limited, although our limited awareness of their properties suggested a range of defence applications. An important stage in the project was therefore to create a network of contacts, particularly with civilian scientists in universities and research institutes.

It is relevant to note the particular characteristics of nanocomposites which distinguish them from conventional polymer-based composites and fibre-reinforced composites. Addition of particulate fillers to polymers (and elastomers) has been commonplace for many years. Polymers have, compared to metals and ceramics very low elastic modulus. This can be improved by adding fillers such as calcium carbonate (chalk), talc or mica. Quite large additions are required (several tens of volume percent), which increases the density of the polymer considerably. The particle size of these fillers is of the order of micrometres or larger. A consequence of adding the filler is that the mechanical properties of the polymer, particularly fracture toughness and strain to failure are drastically reduced. It is also common to add fillers such as aluminium trihydrate and antimony salts (also as micrometre-size particles) to reduce the flammability of the polymer.

Ferrite particles have also been added to polymers and elastomers as microwave absorbers as long ago as the 1940’s, again as micrometre-size particles. Such filler polymers have been applied as surface coatings, but have never been used to carry any mechanical loads.

It is apparent from the literature that by reducing the size of the filler from the micrometre regime to the nanometre regime several advantages can be achieved. The quantity of filler needed to achieve a significant improvement in elastic modulus can be reduced to a few volume percent, which will impose less of a density penalty, and the normal decreases in strain to failure and tensile strength can be avoided. In some cases (depending on the type of nanoparticles added) it is possible to obtain an improvement in tensile strength and fracture toughness. At the beginning of the project it was also thought that it should be possible to combine conventional, continuous fibre reinforcement (e.g. carbon fibre and glass fibre) with a polymer matrix reinforced with nanoparticles, i.e. a "composite within a composite." While this concept was not tested in the project recent reports indicate that this is indeed possible, and conventional production technology such as resin transfer moulding can be used.

Project summary

The project has contained four main activity areas:

- Synthesis and characterization of ferrite nanoparticles
- Surface functionalization of the nanoparticles
- Production of epoxy-based nanocomposites
- Characterization of the mechanical and microwave properties of the nanocomposites

Each activity will be described briefly. For a more detailed description of the methods and results the interested reader is referred to the scientific reports listed under "publications and reports" below.

Synthesis and characterization of ferrite nanoparticles

Ferrites have been studied in this project as this class of materials is known to have microwave absorbing properties, in addition to being useful in other, civilian applications e.g. in medicine and high frequency electronics. However, we have not attempted to optimize these properties, rather to develop and understand a method to synthesize ferrites reproducibly.

Synthesis and characterization of ferrite nanoparticles has been a major activity of the project. It is possible to purchase some ferrites in the form of nanoparticles from commercial sources (conventional micrometre-size ferrite powders are easily obtainable from the usual chemical suppliers). However, on investigation it was found that only very limited compositions were available, delivery times were uncertain and the provenance and reproducibility of those nanoparticles ferrites which were available could not be guaranteed. For these reasons it was decided to develop and optimize an in-house synthesis method.

There are several different methods to produce nanoparticle ferrites described in the literature, however the majority are capable of producing only very small quantities (<1 gram/run), which would be inadequate for the experiments planned in this project (10's to 100's of grams are required). For this reason, one method; the "chimie douce" method was chosen as the only realistic alternative, capable of being scaled up to 100's of grams/run. This method has the added advantage of using water-based solutions (no organic solvents required), which is an advantage from the environmental point of view. In principle the reaction is simple; solutions of mixed metal salts (e.g. cobalt chloride and iron sulphate to produce cobalt ferrite according to the equation below) are added to a solution of hydroxide, whereupon the ferrite is precipitated. The nanoparticles are separated from the liquid by magnetic decantation, washed and dried. The equation shown is greatly simplified.

$$Co^{(II)} + Fe^{(III)} \rightarrow CoFe_2O_4$$

Several ferrites have been produced as nanoparticles, including cobalt-, manganese- and nickel ferrites. These were chosen as having relevant properties for microwave absorption. In practice, it was found that many experimental parameters (often omitted from the methods reported in the literature) can affect the nanoparticle size, size distribution, morphology, composition, and density. Synthesis parameters which have been studied include the temperature; digestion time; metal salt concentrations; ratio of metal salt concentration to hydroxide concentration and stirring conditions.

An unexpected result was that density of the nanoparticles could be varied systematically from the stoichiometric value, and that the particle morphology varied with digestion time. Initially (after a few seconds) particles showed a hexagonal, plate-like morphology, which changed to a mixed cubic/spherical morphology. At longer digestion times (10's of minutes to 160 minutes) larger, cubic particles were observed to disappear, to be replaced by smaller cubic or spherical nanoparticles. This effect which is contrary to what is expected from Ostwald ripening theory, is unexplained although it has been suggested[1] that it is due to a phase transformation. This has not been confirmed.

From these experiments we now have a reproducible method to synthesis nanoparticle ferrites with reproducibility within 5 nm, within the range 40 to 80 nm. Both larger and smaller nanoparticles can be produced, however with lower reproducibility. It is likely that the synthesis method is generally applicable to other, non-magnetic nanoparticles (e.g. magnesium spinel, which has interesting optical properties). Results of this work have been presented at two international conferences (Nano 2004 and ICF-9), and submitted for publication. They also appear in a recently approved doctoral thesis.

Surface functionalization of the nanoparticles

Having synthesised the nanoparticle additions it is necessary to disperse them homogeneously in the polymer matrix, in this case an epoxy, chosen because epoxies are widely used in defence materiel, including fibre-reinforced composites. The surface of the (inorganic) nanoparticles must be functionalized to make it compatible with the (organic) epoxy. The interface between the nanoparticles and the matrix is of course important in determining the mechanical properties of the composite. It is relevant to note that in conventional, glass-fibre reinforced composites the surface of the glass fibre is also functionalized, for the same reason.

A series of different silanes were investigated for their influence on surface functionalization:

1. methyltrimethoxysilane
2. 3-aminopropyltriethoxysilane
3. [3-(2-aminoethylamino)-propyl]trimethoxysilane
4. 3-(trimethoxysilyl)propylarylate
5. γ-glycidoxypropyl-trimethoxysilane

These were coated on to the nanoparticles surfaces by dispersing the nanoparticles in water, ethanol and water/ethanol solutions of the silanes. The degree of coating was investigated by thermogravimetry and differential scanning calorimetry, to assess the amount of silane coating the nanoparticles. Infrared spectroscopy was used to give a qualitative analysis. Much

[1] Prof Rosenholm, Åbo University, Finland, 17 Dec. 2004

of this work was done by J. Deng from Northwestern University in China (sponsored by the Chinese Academy of Sciences), while a visiting scientist at KTH, together with Richard Olsson and Prof U. Gedde.

Preliminary results of this work have been presented at an international symposium on macromolecules (MACRO 2004). Results of these experiments are still being analyzed, and will be published during the first quarter of 2005. Initial experiments where different silanes were coated on the nanoparticles were found to have a significant influence on the mechanical properties of the epoxy nanocomposite.

Production of epoxy-based nanocomposites

Non-coated nanoparticles were mixed in the epoxy by high intensity ultrasonic dispersion combined with high speed mixing. Prior to this a number of experiments were performed to develop an epoxy/hardener system which hardened within a few minutes when heated to 60 °C. Below this temperature the system is stable for long periods, allowing nanoparticle dispersion to occur. This system would also be compatible with e.g. resin transfer moulding for fibre-reinforced composite production. Despite the high intensity ultrasound/high speed stirring it was found that agglomerates of nanoparticles remained in the composite after hardening. This is undesired, and will lead to deteriorated mechanical properties. In spite of this, some preliminary measurement of microwave absorption and transmission have been made.

Failure to achieve complete dispersion was not entirely unexpected, as this is a major problem when working with nanoparticles. The high surface energy of the nanoparticles acts to create agglomerates, and, once formed it is very difficult to decompose the agglomerates into individual particles again. Experiments with various silane treatments to improve the chemical compatibility between the inorganic nanoparticles and the organic matrix are ongoing, and preliminary results appear promising. Simple dispersion tests in aqueous solutions show that silane coated nanoparticles can be made to have hydrophilic or hydrophobic properties, but it remains to test these in the epoxy in a systematic way. This work is ongoing, and will be reported during 2005.

Commercial nickel nanoparticles[2] were used to test the feasibility of adapting the mechanical alloying technique for obtaining a homogeneous dispersion. Mechanical alloying is a method developed to produce oxide dispersion strengthened high temperature alloys (superalloys), and has been used for this purpose for some 30 years or more. The method has until recently not been applied to polymer-based materials. Simply described, the two immiscible components (ferrite and polymer particles) are ball-milled together under controlled temperature conditions. Normally, the particle size of both components is reduced, sometimes dramatically. In the present case however it was expected that the ferrite agglomerates would be reduced, without the nanoparticles of which the agglomerates were composed being affected. To damage the nanoparticles the milling media (balls) would need to come into contact on the nanometre scale which is very difficult to achieve. A small project was initiated in cooperation with the department of Metal Casting at KTH, to test the mechanical alloying concept in this way. For convenience, a simple, amorphous polymer; PMMA (poly(methyl methacrylate)) was used, although in principle any polymer, including epoxy is possible. The nickel ferrite nanoparticles were used untreated in the as-received state. After

[2] Nanostructured and Amorphous Materials, Inc., Los Alamos, NM, USA

milling for several hours, the composites produced were compacted dynamically, and examined by transmission electron microscopy (TEM). It was seen that the nanoparticle agglomerates had been removed and individual nanoparticles dispersed homogeneously throughout the PMMA matrix. It was found to be possible to disperse large amounts (up to 50 wt%) of ferrite in the polymer. By comparison, conventional mixing of such large amounts of ferrite particles in an epoxy would be very difficult due to increase in the viscosity. The limited time available for this project did not allow the mechanical properties of the mechanically alloyed composite to be studied. This has been submitted as a diploma project (sv. Examensarbete) at KTH, October 2004.

Characterization of the mechanical and microwave properties of the nanocomposites

A series of nanocomposites have been prepared using non-functionalized cobalt and manganese ferrites. These nanoparticles were prepared under conditions designed to give a range of compositions and densities by varying the metal:hydroxide concentration ratio during synthesis. Although the composites do contain nanoparticle agglomerates these are currently being characterized with respect to microwave absorption and transmission in the G; C; J; X; P; K; and Ka bands. It is not expected that the presence of agglomerates will greatly influence the microwave characteristics. However, mechanical properties are likely to be reduced, so that further materials will be prepared using surface functionalized nanoparticles.

Preliminary results indicate that the magnetic losses in the ferrites are low, i.e. they are not particularly effective as microwave absorbers. This is not unexpected, although disappointing. What is clear from measurements of magnetic properties is that the static magnetic properties (coercivity, saturation and remanance) do vary quite considerably with composition and synthesis conditions. It is hoped that further analysis of the magnetic properties may be continued outside this project via a cooperation planned with a research group in Spain.[3]

Summary

Much attention has been paid to developing and understanding how to synthesis ferrite nanoparticles, and how to treat them to obtain a homogeneous dispersion in a polymer matrix. We now have a good understanding of these techniques. It remains to relate the surface functionalization to mechanical properties of the composite, and this work is on-going. It will be reported during the first two quarters 2005.

The microwave properties of the nanoferrite particles synthesized are not particularly promising for radar absorption, which is disappointing but not unexpected. Development of highly effective radar absorbers was not a major objective of the project, and would not have been possible to combine with the level of national and international cooperation needed to conduct this project with the resources available.

Cooperating partners

National

The main cooperating partner in the project has been the department of Fiber and Polymer Technology at the Royal Institute of Technology (KTH). A postgraduate student has been

[3] Dr Salazar-Alvarez, Universitat Autònoma de Barcelona, Spain

employed through the project, under the supervision of Prof U. Gedde. The department of Materials Chemistry (Prof M. Muhammed) has also been involved in the project. After the first year of the project the student left the project and was replaced by the present doctoral candidate (R. Olsson). The change in personnel did cause some delay in the plan of work, which has been largely recovered.
The department of Casting of Metals (Prof H. Fredriksson), has cooperated in supervising a diploma student (R. Sathees) investigating the mechanical alloying method to prepare nanocomposite materials from agglomerated nanoparticles. This work has been submitted to KTH in partial fulfilment of the requirements for a Master of Science degree (FOI-S--1609--SE).

International

During the project we have been successful in cooperating internationally. A visiting student from the University of Ilmenau (Germany) spent the period April to October 2003 at the Department of Fibre and Polymer Technology at KTH. A. Pönicke, a final year student conducted an independent research project on synthesis of ferrite nanoparticles and surface functionalization of the same. His work was presented in the form of a seminar at FOI Linköping, and his report has been submitted to the University of Ilmenau as part of the formal requirements for the award of a Master of Science degree (FOI-S--1610--SE).

During the period January to October 2004 a visiting scientist from the People's Republic of China worked at the Department of Fibre and Polymer Technology at KTH, researching the surface functionalization of ferrite nanoparticles. Dr Yinglan Deng was sponsored by the Chinese Academy of Science. Her work *Surface treatment of Macromolecules* was presented at the 40th IUPAC Symposium on Macromolecules (6-9 July, 2004, Paris, France), (FOI-S--1505--SE). An extended version is being prepared for publication in 2005, under the title: *Silanization of ferrite nanoparticles: an assessment of the thickness of silane layer coating* (J. Deng, R.T. Olsson, S.J. Savage, M.S. Hedenqvist, U.W. Gedde). This will be submitted to the journal: Polymer Testing during the first quarter 2005.

Publications and reports

This project has resulted in a number of publications, conference contributions (both poster and oral) and other reports. These are listed below. Included are also articles which are under preparation and which will be submitted during the first half of 2005.

Published, accepted or submitted for publication.

1. *Defence applications of new forms of carbon* (S.J. Savage, FOI-R--1103--SE, December 2003). An introduction to the fullerenes and carbon nanotubes, and their defence applications, particularly in multifunctional materials.
2. *Nanotechnology - A Revolution in Material Affairs?* (S.J. Savage, FOI-S--1276--SE, April 2004, published in Swedish Journal of Military Technology, #1, 2004 pp. 6-12). A popular scientific overview of nanotechnology, including nanocomposites, from the defence point of view.
3. *Synthesis of cobalt ferrite nanoparticles* (R.T. Olsson, G. Salazar-Alvarez, M.S. Hedenqvist, M. Muhammed, U.W. Gedde, A. Pönicke, S.J. Savage, FOI-S--1506--SE, December 2004. Poster presentation at 7th International conference on Nanostructured Materials, 20-24 June, 2004, Wiesbaden, Germany. No proceedings published). Describes the synthesis of cobalt ferrite nanoparticles, including their variation in density with mass balance (ratio of metal ion to hydroxide ion) during the reaction.

4. *Synthesis and characterization of cubic cobalt ferrite nanoparticles* (R.T. Olsson, M.S. Hedenqvist, U.W. Gedde, G.Salazar-Alvarez, M. Muhammed, S.J. Savage, FOI-S--1504--SE, December 2004. Oral presentation at the 9th International Conference on Ferrites, 22-27 August 2004, San Francisco, USA, and accepted for publication in Transactions of the American Ceramics Society). Presents the synthesis of large quantities of cobalt ferrite nanoparticles by precipitation from aqueous solutions, and the relation between synthesis conditions and nanoparticles size and size distribution.
5. *Surface treatment of ferrite nanoparticles* (J. Deng, R.T. Olsson, S.J. Savage, M.K. Hedenqvist, U.W. Gedde, FOI-S--1505--SE, December 2004. Poster presentation at the 40th IUPAC Symposium on Macromolecules, MACRO 2004, 4-9 July, 2004, Paris, France. No proceedings published). Describes the investigation of surface functionalization of manganese ferrite nanoparticles prepared within the project, and a method to quantify the degree of functionalization.
6. Mechanical alloying of polymer nanocomposites (R. Sathees, FOI-S--1609--SE, December 2004). Describes preliminary studies of the mechanical alloying process applied to polymer-matrix systems using commercial, highly agglomerated nickel-ferrite nanoparticles. It was shown that the nanoparticles could be homogeneously dispersed in a poly (methyl methacrylate) matrix, despite the initial agglomeration, which is very difficult to achieve by other methods.
7. A new polymer composite based on $CoFe_2O_4$ and $MnFe_2O_4$ nanoparticles for radar absorption (A. Pönicke, traineeship report submitted to University of Ilmenau, 2004. FOI-S--1610--SE). Describe the synthesis and surface functionalization of two ferrites as nanoparticles, and preliminary results on their microwave absorption.
8. *Defence applications of nanocomposite materials* (S.J. Savage, FOI-R--1456--SE, December 2004). Reviews selected applications for nanocomposite materials which are either already in use, under evaluation or have potential in defence systems.
9. *Controlled synthesis of near-stoichiometric cobalt ferrite nanoparticles* (R.T. Olsson, M.S. Hedenqvist, U.W. Gedde, G. Salazar-Alvarez, F. Lindberg, S.J. Savage, submitted to Chemistry of Materials, and also included in the doctoral thesis of Salazar-Alvarez, KTH, December 2004). Describes and analyses the synthesis of cobalt ferrite nanoparticles using the "chemie douce" method by precipitation from aqueous solution. The size and size distribution can be controlled to within narrow limits (5 nm) in the range 40 to 80 nm. The influence of synthesis conditions, including the digestion time, on morphology was also investigated. Particle morphologies obtained included spherical, plate-like hexagonal, rod-like and cubic.

To be submitted for publication

1. *Silanization of ferrite nanoparticles: assessment of thickness of silane layer coating* (J. Deng, R.T. Olsson, S.J. Savage, M.S. Hedenqvist, U.W. Gedde, to be submitted to Polymer Testing). Describes the surface functionalization of cobalt and manganese ferrites with a series of silanes containing varying active groups. This objective of this work is to elucidate the optimum groups for the epoxy polymer matrix being used in the project.
2. *Surface functionalization and its influence on mechanical properties* (J. Deng, R.T. Olsson, U.W. Gedde, et al. Under preparation for submission to Polymer Testing). Describes the influence of nanoparticles surface functionalization using four different silanes chosen to influence the degree of chemical bonding between the nanoparticles and the epoxy polymer matrix. Preliminary results indicate that the active group has a significant influence on the mechanical strength of the nanocomposite.

3. *Magnetic properties of cobalt ferrite nanoparticles* (G. Salazar-Alvarez, R.T. Olsson, et al. Journal not yet decided). Will describe the variation in magnetic properties with nanoparticles composition and synthesis conditions.
4. *Synthesis and properties of nanocomposites for mechanical properties and microwave absorption* (R.T. Olsson, licenciate thesis, to be submitted to KTH, April/May 2005). Will describe and analyze the synthesis and influence of synthesis conditions, including surface functionalization, on the mechanical and microwave properties of epoxy-based nanocomposites.

Information dissemination

The main method for disseminating the results and experience gained from this project has been through the normal channels of internal reports, publications in scientific journals and contributions to scientific conferences. In addition, an open seminar day was organised and held at KTH on 10 June. The programme and a list of invitees are given in Appendix 1, and the programme, which contained six presentations describing the science, technology and applications (current and potential) of polymer nanocomposites. The seminar day was attended by about 30 persons from industry, academia and FMV/FOI. A CD containing the presentations is available from FOI.

Recommendations for further work

As with most research projects, there remain many questions to be answered before it can be said that all uncertainties have been resolved. Not unexpectedly, since this project has explored a new area where experience of nanocomposites in the Swedish defence organisations was previously extremely limited, there are several areas which should be explored more thoroughly. These include the following:

Surface functionalization: this is clearly a critical area for obtaining optimized mechanical properties. However, this should be approached with a particular application or group of applications in mind. In some applications maximum fracture toughness may be required, whereas in others maximum tensile or compressive strength. To optimize the final material properties it will be necessary to treat the nanoparticle functionalization, *together* with the monomer/hardener as a system, not as individual components in the general approach which has been taken in this project.

Microwave absorbing nanoparticles: this project has studied ferrites, a class of materials known to have relevant properties for microwave absorption. However, we have not devoted much effort to optimizing the microwave absorption properties, as this is not appropriate in a project where the cooperation must of necessity be open, and the results published. To achieve a practical load-carrying microwave absorber will require further studies. Some approaches to this are indicated in the reports on *Defence applications of new forms of carbon*, and *Defence applications of nanocomposite materials.*

Acknowledgements

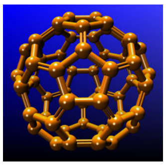
The contributions of Prof U.W. Gedde and Richard Olsson are particularly acknowledged, in addition to many others who have cooperated in this project. Funding from the Swedish Armed Forces Headquarters is gratefully acknowledged.

Appendix 1 Seminar day programme and distribution list

Försvarets materielverk (FMV) Rolf Dahlberg Karl Lychou Patrik Persson Rickard O. Lindström Kenth Henningsson Erik Prisell Anders Brandt Martin Borgh Ola Dickman Curt Eidefeldt Carina WikanderBjörk Håkan Hinsefeldt Björn Jonsson Karl-Gunnar Lövstrand Hans Norinder Anders Lönnö Anders Grop Gert Lidö Jan Lindström Magnus Eriksson KC Farkost sjö Pontus Björk Staffan Lundin Carl-Martin Larsson Ulf Örberg Bengt Wikander Elisabeth Behm Fredrik Hyllengren **Högkvarteret (HKV)** Gunnar Brodin Christian Artman Hans-Ove Görtz Christer Ramstedt Fritz Eriksson Henrik Nerpin STRA UTVS Stefan Silfverskiöld	**Försvarshögskolan (FHS)** Daniel Hagstedt Martin Nylander C.-G. Svantesson Hans Liwång **FOI** Anders Callenås Staffan Harling Nils Roman Eric Berglund Gunnar Hovmark Linus Fast Sören Svensson Michael Jacob Torbjorn Tjärnhage Lars Österlund Ola Claesson Magnus Oskarsson Lars Holmberg Lena Klasén Eva-Lotta Kraft Madelene Sandström Staffan Rudner Cecilia Looström Jan Fogelin Åke Sellström Stefan Rantzer Monica Dahlén Helena Bergman

Industri

Åkers Protection	Anders Nilsson
Aerotech Telub	Christer Larsson
Vinnova	Eva Lindenkrona, Anders Marén
Volvo Aero	Dennis Lundström
Packforsk_STFI	Mikael Gällstedt
CSM Materialteknik	Mikael Östensson, Anette Järneteg
SP	Petra Andersson
Kockums	Kenneth Håkansson
Saab (Linköping)	Pontus Nordin
Chelton Applied Composites	Tord Arding, Sören Poulsen
Saab Barracuda	Peter Edman, Lars Karlsson
Hägglunds	Mikael Georgsson, Tore Gustafsson



2004-05-17

FOI och KTH – Program 10 juni 2004

FUNKTIONELLA NANOKOMPOSITER OCH POLYMERER FÖR FÖRSVARETS OCH INDUSTRINS BEHOV

Polymerkompositer har som bekant ett antal fördelaktiga egenskaper jämfört med de separata komponenter eller faser som ingår i komposit, och de används i allt större utsträckning inom försvarets materiel och i industriella produkter. Det som kommer att belysas under seminariedagen är de ytterligare egenskapsförbättringar som möjliggörs när man kombinerar nanoteknik med polymerer och polymerkompositer. Under förmiddagen presenteras och diskuteras ett antal materialtekniska faktorer relevanta för framställning och karakterisering av dessa material, och under eftermiddagen presenteras ett antal utvalda exempel på befintliga och potentiella tillämpningar.

	Tid	Titel	Föredragshållare
(Nano)Materialteknik	0845-0900	Registrering	
	0900-0905	Presentation	Steven Savage
	0905-0950	**Introduktion till nanokompositer** Översikt om vad som menas med nanokompositer, historik, egenskapsförbättringar som har uppnåtts, m m.	Steven Savage
	0950-1000	Paus	
	1000-1045	**Matriser och tillsatser** Termoplast, härdplast och nanopartiklar (silikater, konstgjorda nanopartiklar, fibrer, m m)	Lars Berglund
	1045-1130	**Framställning av nanokompositer** Ytfunktionalisering av tillsatser, interkalering, tillverkningstekniker, m m	Richard Olsson
	1130-1200	**Översikt karakteriseringsmetoder** DSC, DTA, DMTA, TEM, m m	Ulf Gedde
	1200-1300	Lunch OBS! Föranmälan krävs!	
Försvars- och industriella tillämpningar	1300-1345	**Rundvandring i labb, demonstration av nanokompositttillverkning**	Richard Olsson
	1345-1600 (inkl 15 min paus)	**Smakprov på aktuella och potentiella tillämpningar av funktionella polymerer och nanokompositer** • Temperatur- och brandbeständiga polymernanokompositer i fartyg och fordon – **Petra Andersson, SP** • Elektriska ledande polymerer för styrbara signaturanpassning **- Hans Kariis, FOI** • Diffusionsbarriärer inom matransons förpackningar – **Mikael Gällstedt, Packforsk/Stfi** • Polymernanokompositer i flygtillämpningar - **Pontus Nordin, Saab** • ”Shear thickening fluids” i styrbara ballistiska skydd - **Steven Savage, FOI** • Reptåliga transparenta polymer i sensorfönster - **Mamoum Muhammed, KTH** • Multifunktionella material för miniatyriserade system - **Hans Norinder, FMV** • Polymernanokompositer med hög värmeledningsförmåga för elektronik och elektriska komponenter **Johan Liu, IVF**	**10-15 min/inlägg**
	1600- ca 1630	Diskussioner	