Try not to become a man of success but rather to become a man of value.

- Einstein.

### THE NICHE AREAS

Research activities in the School are centred around five niche areas:

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The following capture the research highlights of each of the niche areas.

#### THE NICHE IN POLYMER COMPOSITES

Research activities on advanced materials, particularly in polymer composites at USM were started in early 1990s. Over the years, the research areas have grown to encompass different types of polymer composites ranging from micro- to nano-composites targeted for automotive, structural and dental applications. The group is comprised of several academic staff of the School; Professor Dr. Hamzah Ismail, Professor Dr. Zainal Affin Mohd. Ishak, Assoc. Prof. Dr. Azlan Ariffin, Assoc. Prof. Dr. Azhar Abu Bakar, Assoc. Prof. Dr. Hazrul M. Aiki, Assoc. Prof. Ir. Dr. Mariati Jasir, Assoc. Prof. Dr. Azura A. Rashid, Assoc. Prof. Dr. Chow Wen Shiang, Assoc. Prof. Dr. Zulkifli Mohamad Ariff, Assoc. Prof. Dr. Zulkifli Ahmad, Dr. Razzina Mat Tai, Dr. Nadzim Othman and Dr. Zuraini bin Abdul Hamid.

The group has an impressive directory of infrastructure and expertise which are dedicated to cover three important areas of research namely polymer compounding, rheology and processing for different polymer matrix systems such as plastics, rubbers, blends, etc. The research facilities include a variety of techniques for characterization of microstructure-processing-property relationships, durability, design and performance of polymer composites. To name a few, these include twin-screw extruder, pultrusion, resin transfer molding, injection molding, dynamic mechanical thermal analyzer, differential scanning calorimetry, thermal gravimetric analysis, acoustic emission tester, VP-field emission scanning electron microscope, atomic absorption spectrophotometry, titration tester, accelerated weathering chamber, etc.

The group consists of 50-70 graduate students, working on a variety of research projects, most of which are sponsored by government or industrial grants. The research group has a track record of attracting funding from the Construction Industry Development Board (CIDB), Malaysia Tertiary Science Foundation (MTSF), AUN/SEED-Net, UICA, British Council, to cite a few. In terms of research output, about 150 publications have been published in the refereed journals since 1993. The research group has strong collaboration links with international universities such as Kaiserslautern University of Technology, Budapest University of Technology and Economics, Kyoto Institute of Technology, to name a few. Researchers in this research group also received many consultations and conducted testing services for the industries. They have also actively participated in conducting trainings/short courses for the related industries. The research group has great interests in collaborating with academia, governmental organizations, national and international companies in research, knowledge transfer and consultancy in the area of composite materials.

Current research focus of the group is to develop locally planted kenaf fibers for various structural and non-structural applications. The utilization of kenaf fibers which has been identified by the Malaysian Government to be the next commodity plant will help to add value to the locally produced kenaf fibers. Composite materials with high specific mechanical properties, low cost, lightweight, high corrosion resistance and environmental friendly are targeted as the final products. This current focus of the group has eventually led to the establishment of the Cluster for Polymer Composites (CPC). The main objective of the newly formed CPC is to foster interdisciplinary research into the scientific and technological endeavour in processing, properties, design and fabrication associated with polymer composites.
THE NICHE IN BIOMATERIALS

Biomaterials refer to synthetic materials that are synthesized or fabricated for use in the human body either as implants, fillers, scaffolds, carriers, etc. At the School of Materials & Mineral Resources Engineering, Universiti Sains Malaysia, research and development in biomaterials have been actively pursued via a multi-pronged approach, viz. in terms of materials, processing, and the varied applications in mind.

In terms of materials, the thrust has always been on ceramic calcium phosphates (such as doped and undoped hydroxyapatite (HA), Sr-tricalcium phosphates, hydroxyapatite/calcium phosphate, etc.), calcium phosphate glasses, ceramic dental porcelains, biocomposites based on nanotubes, metal-composites, polymer-HA composites, and bone cements. In the last 2-3 years, the work on hydroxyapatite has shifted to carbonated (c-HA) and silicated (Si-HA) hydroxyapatites, whilst the focus on ceramics has been extended to polycrystalline ceramics, as well as hydrogel or as polymer composites.

These reformulated materials are synthesized or produced by various processing techniques, such as powder pressing, wet precipitation, spray forming, gel-casting, sol-gel, hydrothermal and mechanical activation methods. The novelty being sought for has always been the reformulation of the compositions as opposed to the much-reported world-wide materials of similar make-ups.

The driving forces for these mushrooming interests in Biomaterials are equally diverse. These include dental porcelain, dental fillers, orthopaedic implants, maxillofacial implants, artificial kidney systems, cosmetics, bone cements, biodegradable latex/polymers, as well as porous, microporous and mesoporous HA/HAp. Continuous rejuvenation of ideas in Biomaterials has always been the guiding beacon in inculcating the expertise of the senior members of staff with the enthusiasm of the younger staff.

Research and development within the realm of biomaterials in the School of Materials & Mineral Resources Engineering and in fact at Universiti Sains Malaysia or even within Malaysia, can be traced back as far as the mid-1990s with the pioneering work of Professor Radzali Othman. In those early days, where the scenario in terms of numbers of academic staff, research grants and postgraduate students were very much different from what they are today. In the last 5-6 years, the zeal for research work on Biomaterials has spawned to the younger bloods in the School.

Research work on Biomaterials would not have been as rigorous and as meaningful had it not been a one-man show on Materials per se. The intimate collaboration with our colleagues from the School of Dental Sciences, Kubang Kerian augments well for the niche multidisciplinary platform we have created at Universiti Sains Malaysia. The diversity of materials, processes, applications and number of researchers that transcend campuses and disciplines, are testaments to the viability and sustainability of the niche area in Biomaterials that we have carved at the School of Materials & Mineral Resources Engineering, Universiti Sains Malaysia. Let’s the accomplishments that we had achieved so far speak for itself. The Biomaterials Group adheres to the philosophy that we do not merely bask in the glory of the past but enthuses to the challenges and promises of the future.

The list of research projects are as vibrant as they are varied and inter-disciplinary. Up to now there are 25 research projects undertaken by the lecturers that were and still are being supported by various funding agencies within and outside Malaysia. The manifestations of these projects have been translated into 104 final year dissertations (from 1999 to 2011) and 60 M.Sc./Ph.D. theses (1999-2011).

THE NICHE IN NANOMATERIALS

Nanotechnology can be defined as any technology done on a nanoscale that has applications in the real world. There is currently an extraordinary amount of interest in nanotechnology as it has enormous consequences on the design and engineering of everything from common consumer products to more sophisticated nanosystems that support numerous applications especially in electronics, information technology, biology, medicine and energy. Hopes exist for being able to make things smaller, more efficient, greener, or work better than is possible with conventional devices. The field of nanotechnology is clearly an emerging state. But its potential is evident and how to move forward perhaps lies on constant development of nanomaterials. Nanomaterials are in fact, enabling component of nanotechnology. Nanomaterials are however not undiscovered materials, but nanoscale forms of well-known materials: semiconductors, metals and ceramics. At the School, research, development and innovation on nanomaterials have been carried out since the emergence of this science in early 2000s. As to allow the research works on the topic of nanomaterials to progress efficiently, a group was created in 2004: Nanomaterials Initiative Group (NanOmic).
THE NICHE AREAS

Since its establishment, the group has been very active especially in organising seminars, short courses and workshops to promote, educate and develop further understanding on nanomaterials and nanotechnology to interested parties. The group (or individuals within the group) was approached by several research institutions in Malaysia to provide seminars and courses. Experts from all over the world have been invited to share their experience and knowledge for these seminars and courses. Moreover, training programmes are provided for industries, research institutions, academics and members of the public to bring transparency and awareness to this far-reaching and emerging science to them. Every year the group has taken an initiative to exhibit outstanding research findings and products at an annual event organised by the Materials Research Society Malaysia. The group has also been appointed as Technical Committee-229 for Standardisation of Nanotechnology under the International Standard Organisation (ISO).

At a more international level, the group has organised various activities for, example for, the participants of the 2010 Asia Nano Camp for Asia Nano Forum. Several of the members of the group have also been invited to give invited talks at international conferences and to organise symposium on nanomaterials in various conferences. Sufficient to say, those actively involved in research on nanomaterials at the School are dynamic and energetic. They have excellent track records and possess specific technology know-how required to either in the formation (or synthesis) colloidal, nanocomposites, nanomaterials, nano fibres, thin film, meso and macroscopic or on how to apply the nanomaterials. Their strength can be illustrated by the vast number of publications accumulated to be more than 60 publications in indexed journals: fundamental and applied science published since 2004 and the numbers are increasing as new findings are being discovered from the laboratories in the School. The articles published have been continuously cited showing the impact of the publications to the enhancement of knowledge in materials science and engineering in the world and directly portraying the quality of the research at our School is at par if not better than other renowned research institutions in the world. Apart from publications, several members of the group have also looked into commercialising their research products and patenting their research findings. To date more than 5 patents have been filed bearing the word nanomaterials or related science since 2008.

The group has also established networking within industries in Malaysia and internationally through various schemes. For example, the Centre for Research and Teaching (CORT), IIT, Malaysia and the Centre for Research and Development in Nanotechnology (COST), IIT, Malaysia and the Centre for Research and Development in Nanotechnology (COST), IIT, Malaysia. Collaborations are also taking place with the University of Technology Malaysia and the University of Technology Malaysia and the University of Technology Malaysia. The group has also worked closely with other Schools and departments within USM in order to create healthy, multidisciplinary and translational research activities.

Progress on the active research and development of the staffs of the School working on nanomaterials has also been acknowledged through prestigious awards from national and international bodies. Most of these are brought about by the United Kingdom Prime Minister's Award for the development of nanomaterials. The Japan on the development of nanomaterials as well as the Japanese Ministry of Education, Science, Sports and Culture: Cooperation - The Academy of Sciences for the Developing World, Women Research Grant on women related research in nanomaterials. At the national level, several researchers have been awarded with the Malaysian Technology Research Grant (or grants on related research in nanomaterials). Research in Priority Areas (RPA) Grant members received with research funds for the fabrication and characterisation of nanomaterials and nanodevices by scanning probe microscopy (SPM). The term 'structural materials' is defined to be any material or material 'system' whose primary function is to be load or stress bearing (induced either mechanically, thermally or a combination of both), often under extreme environmental conditions. In PPKSBM, this niche on Structural Materials focuses on the relationships between the chemical and physical structure of materials and their properties and performance. The development of the material class metallic, ceramic, polymeric or composite, an understanding of the structure-property relationships provide a scientific basis for developing engineering materials for advanced applications. Fundamental and applied research in this field responds to an ever-increasing demand for improved or better-characterized materials.

Of all material classes, structural materials make a significant contribution to employment and GDP of many countries in the world. They represent a highly diverse and strongly multidisciplinary area, with links to numerous industrial sectors such as aerospace, energy, construction, automotive, leisure, security and defence. Structural materials comprise a number of classes such as metals (ferrous and non-ferrous), composites (e.g. ceramic, metal and polymer matrix), construction materials (e.g. glass, concrete, steel, ceramics, wood) and others such as structural & refractory ceramics and polymers. While the range of materials may be diverse, many common technical challenges have been identified:

- The need for materials to withstand more aggressive environments e.g. Extreme temperatures, stresses, impact and weather conditions.
- The requirement to reduce environmental impact both in their production, end-use and recyclability.
- The need to understand complete materials 'systems' (e.g. coated components, sandwich structures, composites, joints)
- The need to improve the modeling of materials through the whole life cycle (alloy design, production, processing, manufacture and end use) including lifetime prediction.
- The requirement for better condition monitoring and NDE of structural materials and their manufacturing processes.
- The drive for lower cost through innovative production and processing methods.
- The need for technology transfer between materials sectors and the implementation of novel alternative uses.

Research in Structural Materials is not a new activity at the School of Materials and Mineral Resources Engineering. Most of the academic staff is actively engaged with related research of the Structural Materials. Their researches vary much from each other and supported with grants and postgraduate students. This has been achieved through grants for research activity of the same period of time. In recent years, the structural materials research has been focused on the development of high performance materials for extreme environments, including high temperature, high pressure and extreme mechanical loads. The focus has been on the development of composite materials for aerospace and automotive applications, and on the development of new materials for energy conversion and storage. The research in Structural Materials has been successful in terms of the number of publications, the impact of research activities and the number of students involved in the research.
THE NICHE AREAS

The outcome of these researches can be seen from the vast number of papers published in citation index from each of the publications. Within the area, teams of researchers have also been actively involved in Products Exhibition, accumulating Gold, Silver and Bronze awards in various exhibitions in Malaysia and internationally.

Within this area, a group was initiated to enhance the research, development, innovation, consultation and training specifically on metallurgy to the industries. The group: metallurgy research and interest group was established in 2009 comprising of academic staff, tutors and postgraduate students of PPKBSM. The group has linkages with Southern Steel, Malaysian Iron and Steel Industrial Federation (MISIF), SIRIM Malaysia and other steel industries in Malaysia. The group also actively involved in formulating, deliberating and publishing for Malaysia Standard (MS) under the International Standard Committee-M, TC-5 and TC-7 (Metal Casting) Malaysian Standard.

THE NICHE IN STRATEGIC MINERALS

The mining and quarrying has always being viewed as the fundamental foundation towards further enhancement of any nation worldwide striving for further national development and industrial development programme. The increasing demand for high quality minerals for construction, manufacturing, ceramic, glass, water treatment and petrochemical industries has greatly assisted in the rapid growth of the Malaysian mineral resource industry. Malaysian mineral resources span a wide and multipurpose range of minerals with multiple application: Announcing to the Minerals and Geoscience Department Malaysia, there are some 30 types of minerals in this country. Some of these mineral include gold, tin, coal, silica sand, clay, limestone and iron.

These mineral resources are important not only as raw materials by themselves but also as essential elements for the manufacturing of several mineral based products. The use of these local deposits will definitely reduce the overall economic costs for the manufacturing process of the high tech chemical, ceramic and other metallurgical industries.

Malaysia is well endowed with vast rock and mineral deposits that support quarrying, mining, processing and extraction activities. The Malaysian mineral sectors can broadly divide into Metallic ore industry, Industrial Mineral – Non Metallic, Industrial Mineral – Rock Based Industry and Energy Minerals – Coal.

The rock based industry related to block and rock aggregate production through quarrying consist of manufacturing of marble dimension stone, granite dimension stone and aggregate, quicklime, cement, terrazzo and limestone grits and powder, where limestone accounts for more than 60% of the resources. Non-metallic mineral are generally taken to include any rock or mineral or any naturally occurring substance of economic value; industrial minerals are valued for their diverse physical and/or chemical properties exhibited either in their natural state or in their subsequent use after modification by selective mining and/ or mineral processing. Other than rock based minerals, the most common categories of these minerals are several industrial clays and earth materials (ball clay, kaolin, earth and rare earth mineral), feldspar, silica sand, mica (sericite), slate, feldspar (pegmatite and feldspar-sand) and bauxite. Other minerals normally related to tin mining are ilmenite, corundum, monazite, xenotime, zircon, rutile, columbite and other rare earth minerals.

The bottom category application of industrial minerals also includes sand and gravel; the basic materials used in the construction industry. Sand and gravel are obtained mainly from mine tailing dumps, river beds, beach and offshore areas, with small amount derived from alluvial washing.

For the last few years, Malaysian mineral industry focus on non-metallic minerals due to the low price of metal based minerals such as tin, gold and iron. Recent record high metal prices namely gold, tin, iron ore, copper and others have greatly encouraged the state governments to open more land for mining. The country has seen a sudden surge in new application for mining leases and also the opening of new mines in addition to the resumption of old mines.

Research in mineral resources engineering at PPKBSM is based on the concept of “from mine to mill” to end-user product whilst encompassing three keystones; to improve productivity (particularly energy efficiency), enhance competitiveness particularly adding maximum value to products and strengthen environmental performance. Generally, current and future research projects in mineral resources engineering are focussed in four main areas, including exploration and resources characterization, safe and efficient mining/quarrying, safe and efficient processing and extraction metallurgy, and environment. The work is strategized on minerals (metallic or non-metallic) that are high in demand and have a variety of applications. Value adding of the raw material for identified application will definitely enhance production and sale value. Importantly, the whole research direction is in line with the sustainability theme under Sustainable Mineral Development.

Identified key research areas are as follows:

1) Construction Materials – Aggregate and Manufactured Fine Aggregate (MFA)
   Production of high quality aggregate in terms of controlled shape and size, including manufactured fine aggregates (MFA), that will contribute to overall concrete and asphalt performance improvement.

2) Value adding of local mineral resources for industrial application
   Research on value adding of local mineral resources include mineral such as limestone, silica, clay and iron ore is being carried out extensively. The goal of this research area is to maximize the value adding of the local minerals and to fulfill the stringent demand by the manufacturing industries in order to enhance the markability of the value and marketability of the resources.

3) Modelling and simulation of mineral processing systems
   Computer simulation is now becoming a very powerful tool in the design and optimization of mineral processing plants. Simulation techniques allow the engineers and metallurgists to better control their plants with optimum operating conditions. The great power of simulation as optimization, and indeed design, tool is its ability to explore many different scenarios quickly and efficiently. The technology was well implemented in dry and wet grinding circuit and has brought large economic benefit.

4) Evaluation of Malaysian Mineral Resources for High Technology Applications
   This is one of the key area that is being developed to generate complete database for Malaysian mineral resources and their potential applications. The database is essential to evaluate the suitability of the local resources to be mined and value added to feed the local construction and manufacturing industries besides exporting high quality raw materials.