for exploring tourism potential. (7) Promotion of multi-lateral finance for climate change adaption programmes is required in the IHR. (8) Facilitate the IHR States with 'Green Bonus' for conserving forests that act as carbon sinks. (9) Dedicated cells and nodal centres for climate change adaptation should be established in the IHR states.

The concluding session of the consultation meeting was chaired by Upendra Dhar, R. B. Singh and Kireet Kumar (GBPIHED, Almora). All the panellists agreed upon dissemination and replication of success stories/technologies that are related as well as efficient in combating the adverse effects of climate change in the IHR. In brief, the national consultation meet was successful in establishing a science and policy connection for the Himalaya through mutual dialogue among different stakeholders.

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MEETING REPORT

Metals and materials research*

The materials research is a fascinating field, as it continues to unravel the mystery of the existence of exotic materials, their novel structures and unique processing techniques. In view of increasing interest on the cutting-edge researches on materials, an international conference was recently organized. The conference began with the welcome address of T. A. Abinandanan (IISc, Bengaluru). V. S. Raja (IIT Bombay, Mumbai) highlighted the theme of the conference and urged the delegates to actively participate so that it could lead to a scientifically meaningful, enjoyable and beneficial meeting. Anurag Kumar (IISc, Bengaluru) inaugurated the conference and C. N. R. Rao (JNCASR, Bengaluru) delivered the inaugural lecture. On the evening of the first day, a felicitation function was organized to honor S. Ranganathan. During the function, his outstanding contributions to materials research, starting from grain boundary engineering, field ion microscopy, structural metallurgy, quasicrystals, metallic glasses, high entropy alloys and archaeometallurgy were well articulated by several distinguished scientists.

In addition to an inaugural lecture, there were six plenary talks and 67 invited oral presentations by eminent scientists and 45 poster presentations by senior research scholars and young researchers. There were 175 participants, with 22 overseas participants coming from various parts of the globe. The primary objective of this conference was to bring together eminent experts from academia and research institutions as well as practising engineers, young researchers and students to deliberate critically and evaluate the current progress and bring out the future challenges in the field of materials research. The conference covered a wide spectrum of materials with special focus on the topics of alloy design, advanced steels, archaeometallurgy, atomic resolution microscopy, grain boundaries and interfaces, bulk metallic glasses, quasicrystals, nanomaterials and high entropy alloys. Details of the conference and abstracts are available at www.icmr2016.net. Some of the important technical issues presented and deliberated during the conference are highlighted here.

Advanced materials and characterization

In his inaugural lecture, C. N. R. Rao elaborated on the synthesis of and developments in graphene and graphene-like materials such as MoS_2, WS_2, GaS and BN. He presented interesting results on few-layer metal chalcogenides and BN. It was shown that transistors and devices could be successfully fabricated using many of the few-layer inorganic materials. A new graphene-like material, viz. $B_xC_yN_z$ with high surface area and novel gas adsorptive properties was mentioned. A. L. Greer (Cambridge, UK) elaborated the optimizing principles for improvement of toughness of metallic glasses. The lack of tensile ductility is a major concern in using a metallic glasses in spite of they being high-strength materials. Controlled annealing of single-phase monolithic metallic glasses was shown to lead to a higher-energy rejuvenated state with improved ductility which could be retained. It was demonstrated that anisotropy could be induced for potential applications. A. Inoue (Japan) described the development of non-equilibrium metallic engineering materials, including bulk metallic glassy alloys and nanocrystalline alloys in various alloy systems by the effective combination of appropriate alloy components, unique preparation techniques and optimum preparation conditions. He presented the developmental history, structural features, fundamental properties, engineering characteristics, applications and future prospects of Al- and Cu-based metastable alloys. C. Barry Carter (University of Connecticut, USA) shared his experience while studying defects using transmission electron microscopy (TEM). He pointed out that data handling while recording them with high resolution and

*A report on the International Conference on Metals and Materials Research (ICMR-2016) held at the Indian Institute of Science (IISc), Bengaluru during 20–22 June 2016 and organized by the Bangalore Chapter and the Metal Sciences Division of the Indian Institute of Metals, and the Electron Microscope Society of India in collaboration with the Department of Materials Engineering, IISc, to coincide with the celebration of the 75th birth anniversary of Prof. S. Ranganathan (IISc).

precision is a challenge. He discussed the defect process occurring during lithiation using *operando* and video techniques in TEM and considered the future 4D studies of these defect processes. While discussing physical metallurgy of high-entropy alloys (HEAs), J. W. Yeh (National Tsing Hua University, Taiwan) discussed four core effects, i.e. high entropy, sluggish diffusion, severe lattice distortion and cocktail effects responsible for exhibiting unique properties compared to conventional alloys. Rajarshi Banerjee (University of North Texas, USA) studied a combinatorial assessment of laser-deposited $Al_xCrCuFeNi$ ($0 < x < 1.5$) HEAs using composition, microstructure, mechanical and magnetic properties, and developed a graded alloy. Such graded alloys are highly attractive candidates for investigating the influence of compositional changes on microstructural evolution and concurrent physical and mechanical properties in HEAs. B. S. Murty (IIT Madras) pointed out the challenges and opportunities in high-entropy alloy research in general. Processing of alloys for useful applications due to their unusual properties was suggested for full exploitation of these newly developed materials. Bikramjit Basu (IISc) discussed a new paradigm for development of multifunctional bioceramics and external field-stimulated cell with appropriate demonstration of a model system. Chandan Srivastava (IISc) elaborated biomedical imaging using fluorescent $CoFe_2O_4$-ZnO core shell nanoparticles and its underlying mechanisms.

Alloy development and materials processing

S. Banerjee (BARC, Mumbai) discussed the evolution of microstructures in laser-processed grey cast iron and showed that in the heat-affected zone pearlite matrix transforms into austenite without any significant dissolution of graphite flakes, whereas the fusion zone is characterized by complete dissolution of graphite flakes and the formation of dendrites of supersaturated austenite. The transformation paths in different regions were discussed in terms of thermodynamics and kinetics of the competing processes. K. Chattopadhyay (IISc) indicated various pathways for developing high-temperature alloys, including Ni-based complex inter-metallic ternary eutectics and a new class of Co-based superalloys. These classes of materials could substitute conventional Ni-based super alloys. He also highlighted the possible development of high-temperature Al-alloys by suitably exploiting ordered structures, complex chemistry and microstructure. Baldev Raj (NIAS, Bengaluru) brought out the importance of interdisciplinary measurements in a spectrum of applications related to frontier technologies. He further elaborated with examples how accuracy in measurements was crucial for applications involving nuclear reactors, nuclear recycle plants, fighter aircraft, space launch vehicles, submarines, missiles, fossil power plants, chemical industry and manufacturing industry requiring high precision components. S. Seetharaman (KTH, Sweden) discussed the history of iron (and steel) making in Sweden and showed that in 1990s, Sweden developed the Wilberg process and Kaldo process for newer steel technology, though currently the steel-making scenario is dominated by China. However, he claimed that Sweden is still holding a leading position with constant research support by Swedish Steel Producers Association. S. Mishra (Indian Steel Association, New Delhi) elaborated in detail the changes in steel and its processing in the last 50 years. It was pointed out that the introduction of microalloying and thermomechanical processing revolutionized the art of steel processing. He cited examples of a variety of steel products developed in the country. N. Eswara Prasad (DMSRDE, Kanpur) presented the development and current trends in Al–Li alloys for aerospace applications. He lucidly discussed the first and second generation of Al–Li alloys and then the third generation alloys which hold promise for aerospace applications. Samir Kamat (DMRL, Hyderabad) discussed the various futuristic materials for defence applications and also the challenges for meeting the technical requirements in harsh environments. S. N. Ojha (IIT-BHU) discussed improvements of mechanical properties of some aluminium alloys developed by spray deposition technique. Ravi Ravindran (Ryerson University, Canada) presented a procedure for *in situ* tracking of defects and an analysis of phase evolution in light alloys of magnesium and aluminum using neutron diffraction techniques. This approach revealed the solidification characteristics with inoculants and solute additions resulting in better castability. Alok Singh (NIMS, Japan) investigated the effect of quasicrystalline (QC) phase precipitates on the microstructure and mechanical properties of Mg-based alloys. Using advanced TEM techniques, Mg–Zn–Re alloys with desirable microstructure were developed through appropriate processing techniques. It was shown that QC phase modified the microstructure and texture by affecting the dynamic recrystallization during wrought processing. N. K. Mukhopadhyay (IIT-BHU, Varanasi) discussed the possible origin for grain-size softening, i.e. inverse Hall–Petch-like behaviour in Al–Fe–Cu nanoquasicrystals and Al–Fe nanointermetallics developed by high-energy ball-milling technique. K. Nagata (Tokyo Institute of Technology, Japan) revealed the thermodynamic mechanisms for the presence of oversaturated oxygen in steel in the era of pre-modern iron and steel-making, and presented evidence from old nails used in wooden shrines and temples in Japan. U. K. Mudali (IGCAR, Kalpakkam) highlighted the recent developments of high-nitrogen stainless steels for construction of engineering components in fast breeder reactors and associated reprocessing plants. Sharada Srinivasan (NIAS, Bengaluru) studied iron age high Sn bronzes from Tamil Nadu and demonstrated the Indian influence in developing Asian and South East Asian high Sn bronzes.

Phase stability and materials selection

S. Lele (IIT-BHU) presented the concept based on cluster expansion and cluster variation methods for obtaining accurate analytical formulations for configurational enthalpy and entropy of solution phases. This approach eliminates the requirement of solving the transcendental systems of equilibrium equations and considerably reduces the computational burden, making it comparable to the standard Calphad methods, without losing the description of short range order. Pradip (TRDDC, Pune) described the importance of integrated computational materials engineering framework for developing engineering materials and products. U. V. Waghmare (JNCASR) presented theoretical analysis on the prediction of robust non-centrosymmetric,

topological Dirac semi-metallic state in ternary half-Heusler compounds such as the LiMgBi model system. His work may open up tremendous possibilities of producing epitaxial heterostructures and interfaces that involve chirality, polarity, topology and correlations. T. A. Abinandanan (IISc) investigated morphological instabilities in cylindrical pores using phase field modelling by taking into account atomic transport through surface diffusion. The salient features of the model and implications of the stability of films and membranes with continuous pores were discussed. Indranil Manna (IIT Kanpur) discussed the size-dependent polymorphic phase transformation in early transition metals induced by mechanical attrition. The polymorphic/allotropic transformations (bcc/hcp $\rightarrow$ fcc) were demonstrated in Nb, Ti and Zr alloys, and structural instability was attributed to the negative hydrostatic pressure arising out of nanocrystallization or grain refinement. Wenzhang Zhang (Tsinghua University, China) proposed an integrated approach for understanding the morphologies of precipitates and its application to light metals. This theory was applied to Ti and Mg alloys to analyse the faceted interface of two phases irrespective of their orientation, unit cell size and structures. Chuang Dong (Dalian Institute of Technology, China) proposed the structures of several industrial alloys in terms of the building blocks, i.e. cluster-plus-glue atom configuration. Such local units could provide insights regarding the correlation between composition and properties, and this was demonstrated in case of low Young's modulus Ti-based, Zr-based alloys, stainless steel, Ni-based superalloys and high-entropy alloys. John Rodgers (Nanoholdings, USA) introduced the scheme for materials selection for extreme environments using property correlations and systematics with application to intermetallics and ceramic coatings. Mathematical methods such as correlation, systematics and estimation applied in the present context.

Hamish Fraser (Ohio State University, USA) demonstrated the formation mechanisms of various forms of ultrafine α microstructures in metastable β-Ti alloys with the help of aberration-corrected high-resolution electron microscopy technique. V. Jayaram (IISc) elaborated on the surface mechanical and structural characterization techniques to understand the domains of tribology in automotive engines. He demonstrated the critical role of high-resolution characterization techniques such as FIB, AFM and TEM for elucidating the mechanisms of material removal and in formulating models of wear in different ranges of pressure. Satyam Suwas (IISc) discussed recent trends in grain-boundary engineering and its importance for developing desirable strength and ductility. He demonstrated that in case of a particular grade of steel, grain boundary-engineered samples exhibited higher ductility compared to the conventionally processed samples. V. K. Vasudevan (University of Cincinnati, USA) studied bulk and surface grain boundary engineering for improved resistance to corrosion and stress corrosion cracking resistance of nuclear alloys. A clear correlation and mechanistic understanding relating the grain boundary character, sensitization, carbide precipitation and susceptibility to corrosion and stress corrosion cracking was observed. V. S. Raja (IIT Bombay) showed that 7010 Al alloy could be made to attain very high strength with a simultaneous improvement in resistance to stress corrosion cracking through an engineered microstructure. Chris Berndt (Swinburne University, Australia) investigated plasma-sprayed, yttria-stabilized zirconia coatings and established the microstructure–property relationship. A physical model was developed to optimize the plasma-spraying process leading to cheaper coatings of enhanced consistency, quality and durability for defence and commercial air fleets. Dheepa Srinivasan (GE Power, Bengaluru) discussed advanced materials technologies for structural component repair in gas turbine components, including welding, coatings and additive manufacturing. Larsen Miller parameter type of approach was shown to provide a good estimate of the residual life of coatings and also for exploring the possibility of extension of service life of coatings and components. M. S. M. Saifullah (Institute of Materials Research and Engineering, Singapore) discussed a process involving nano-imprint lithography which can be potentially incorporated during metal working process to impart hydrophobic and potentially super-hydrophobic behaviour without altering chemical purity of the metal. This surface appears to have potential for corrosion-resistant applications. R. K. Mandal (IIT, BHU) proposed a generalized form of Miller–Bravais indexing scheme for the hexagonal system beyond its classical form. A critical appraisal in terms of four-dimensional approaches was provided. R. Prasad (IIT Delhi) discussed some misconceptions in the models of crystal dislocations. He pointed out that the extra half plane in edge dislocations is not unique and helicoidal planes are associated not only with screw dislocations (which is an accepted fact) but also with edge dislocations. S. G. Srinivasan (University of North Texas, USA) discussed phase transition and anomalous diffusion in metastable β-Ti–Mo alloy. Using ab initio methods, a prototypical Ti–Mo system was studied to understand the effect of Mo distribution on the phase transformation mechanisms.

In conclusion, discussions among the delegates during oral and poster sessions and beyond the technical sessions were highly intense and stimulating. It was felt that the interactions initiated during this conference would lead to effective and beneficial collaborations among the delegates for future research activities in metals and materials.

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