TIFR Swarnajayanti Fellow to study plasticity for better design of materials

Dr. Smarajit Karmakar, Associate Professor at Tata Institute of Fundamental Research, Hyderabad, one of the recipients of Swarnajayanti Fellowship of the Department of Science and Technology will study plasticity in amorphous solids at bulk and nano-scale. This can lead to design of more efficient plastic materials. It will also help understanding of super-cooled liquids which may help bio-preservation like preservation of fossils in resin, as well as pharmaceutical industry.

Plasticity enables a solid to undergo permanent deformation without rupture under the action of external forces. Many food items like ketchups; cosmetic products; toothpaste etc. and metallic glasses are examples of glassy materials whose flow and deformation properties matter in our daily life. For example toothpaste will not be extruded until a certain pressure is applied to the tube. However, the plastic properties of amorphous structures evolve in response to applied physical stresses, temperature gradients and other perturbations and under physical aging conditions.

Better understanding of plasticity in these materials will lead to development of better materials for future use such as industrial and bio-preservation use. For example, proteins and biomolecules seem to show very different dynamical properties in glassy matrix and for this reason glassy matrix is used to enhance stability or preserve functionality of proteins and bio-molecules. Thus a better understanding of stability of proteins and bio-molecules in glassy matrix will help us better preserve these biomaterials using glassy systems.

Besides, many important devices are becoming smaller and smaller in size and devices at nano-scales are becoming essential in life. Nanomoulding with metallic glasses is reshaping the device fabrication at nano-scale. But it is rather unclear how plasticity in these materials at nano-scale will affect the mechanical stability of the material. Dr Karmakar's study may lead to development of such understanding.

He will study the plasticity in amorphous solids at nano-scale samples. His study of plasticity at nano-scale is a novel idea and will be relevant for industrial applications. In particular, the study on nano-size metallic glass will have direct impact on nano-technology.

Apart from this, he will probe dynamical and flow and deformation properties of disorder systems via inclusions in the form of impurity pinning sites and rod-shaped molecules. Besides, Dr Karmakar will focus on how these systems at small-scale yields under uniaxial elongation or compression.

The role played by glassy dynamics in bio-preservation is also an urgent problem that needs attention for its immense importance in food and drug industry apart from fundamental curiosity. Thus, detailed understanding of glassy dynamics and the plasticity in glassy solids are of general interest amongst the physics community as well as in industry. Dr. Karmakar's group tries to understand some of the puzzles of the glass transition and mechanical properties of amorphous solids within the framework of statistical physics.

In his recent work he has demonstrated that one can tune the yielding phenomena in amorphous solids from being heterogeneous to homogeneous by embedding inclusions which have relaxation timescales much larger than that of the amorphous matrix.

Dr. Karmakar's team showed that by tuning the inclusion concentration, the solid can not only become more rigid, but also yield later and that too in a ductile manner, due to the increasing localization of plastic activity and the homogeneous nature of local yielding.

His recent works have also played an important role in understanding some of these puzzles in glasses where he looked at the physics of glass transition in systems with medium range crystalline order (MRCO) and proposed that these glasses probably belong to a different category of glassy systems with metallic glasses may be a good example of it. He believes that glass transition in this second category of glasses is different than other generic glasses.

He also showed a direct relation between short and long time dynamical relaxation processes in glass-forming liquids. Short time relaxations are assumed to be one of the main mechanisms for ageing and rejuvenation in glassy solids as well as an important component to understand bio-preservation. Thus his works will have definitive impact on further understanding of glassy dynamics and its role in various physical phenomena.

Tuning the nature of the yielding process (heterogeneous to homogenous) using inclusions and its microscopic understanding will surely have ramification in developing theory of yielding transition in future. Finally the approach to understand bio-preservation using statistical mechanics tools is new and novel as it tries to understand the basic phenomena from a simplified minimalistic model system.