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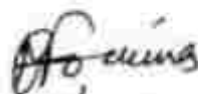
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Editorial Message

The e-magazine of the Physics Department of BUET is a great initiative to promote interaction and communication among the departmental faculty, staff and students. We thank for the responses to the first issue of *BUET Physics Bulletin*, which was published one year ago in 2022 from our department, and we are excited to present the second issue in this publication. Over 10 scientific articles were published in the previous issue and all of them were warmly admired by our readers. We have been honoured to platform the articles of the talented writers, and their submissions to the bulletin have added exceptional tribute to our department. The second issue is a great effort in this direction. It is packed with interesting articles on various aspects of physics research and teaching. We apologize for any inadvertent mistake added in any article of the preceding issue.

In this issue, we again present to you some articles submitted by several authors who nurtured scientific views that can be tacit and overtly accepted. We extend our sincere compliments to those who have submitted their contributions to this second issue. I would like to congratulate and thank to the editorial team to help edit the second issue.

We wish for your endeavors and untiring efforts.



(Prof. Dr. Md. Forhad Mina)
Executive Editor

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Atmospheric Vortices: Tropical Cyclone vs Tornado

Dr. Nasreen Akter, Professor and Head, Department of Physics, BUET

Generally, vorticity is a measure of the rotation of a fluid and is mathematically defined as the curl of the velocity field. As our atmosphere is dynamic along with the rotation of the earth, the formation of vortices and their effects have a vital significance on the weather. Tropical cyclones (TCs) and tornadoes are both extreme weather events consisting of atmospheric vortices but on different scales (Fig. 1).



Source: National Ocean Service

wind speeds of nearly 480 km/hr and the damage paths associated with tornadoes can be more than 1.6 km wide and 80 km long.

Genesis environment: For the genesis of a tornado, a balance between extensive vertical wind shear and instability is essential, whereas, cyclogenesis and its advancement are favourable for very low values (<10-12 m/s) of tropospheric vertical wind shear.



Source: National Weather Service

Fig. 1: Atmospheric vortices (Tropical Cyclone and Tornado).

Both vortices rotate counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. They are threats to life or property due to violent winds and torrential rain with lightning. The differences between a TC and a tornado are explained below.

Structure: TC is a vertically rotating cylinder with 100s of kilometers in diameter and comprises several numbers of convective storms in the rainbands connecting through the eyewall. The outer rainbands of a TC typically develop at a distance of 80–150 km or more from the center. On the other hand, tornadoes spin faster than a TC with diameters of 100s of meters and are developed from a well-organized, most dangerous rotating thunderstorm called a supercell.

Intensity: The intensity of a TC is measured by the highest wind speed found within it. According to the Saffir-Simpson scale, TC is categorized on a scale from 1 (115-153 km/hr wind speed) to 5 (>252 km/hr wind speed). The most powerful tornadoes are capable of massive destruction with

Is it possible to occur both TC and tornado together?

The answer is YES. Within the rainband of TC, the formation of supercell (or giant) thunderstorms is favorable for developing tornadoes. Most of the TCs when made landfall in the United States and Japan offered a large value of vertical wind shear and environmental instability, which spawned several tornadoes (Fig. 2a). Very recently, a tornado outbreak in West Bengal, India (Fig. 2b) was noticed along with Cyclone Yaas formed over the Bay of Bengal (BoB) in 2021. The tornadoes combined with TCs are well-reported and predicted for the Pacific Ocean and Atlantic basins. In contrast, tornadoes related to the TCs over the BoB are still unknown to ordinary people due to a lack of understanding and limited investigation. The TCs integrated with tornadoes can have more devastation than a regular TC due to extra hazardous features of tornadoes like strong downburst winds, hail, lightning, etc.



Source: <https://www.clickorlando.com/weather>



Source: The Hindustan Times, 26 May, 2021

Fig. 2: (a) Tornadoes associated with TC, (b) West Bengal tornado associated with cyclone Yaas.

Therefore, vast knowledge, careful monitoring and tracing of the path of tornadic thunderstorms are essential to reduce the loss of life and damage

to properties in densely populated countries like Bangladesh and India.

Multifunctional Smart Materials from Metal Oxides for Future Technology

Dr. A. K. M. Akther Hossain, Professor, Department of Physics, BUET

A family of specialized materials known as multifunctional materials performs more than one desired function. Some metal oxides show fascinating multifunctional properties. This article will cover the synthesis of multifunctional metal oxides. Discussion may also include experimental results from current researchers in different fields of materials science such as superconductors, colossal magnetoresistive materials, nanocrystalline ferrites, and composite multiferroic materials.

Introduction: An oxide is a molecule comprising at least one oxygen atom and one other element in its chemical composition. Oxygen anion and one or more metal cations are frequently present in metal oxides. Because the elements are oxidized by oxygen in air or water. Most of the Earth's outer shell is made up of solid oxides of different metals. In many fields of physics, chemistry, and materials science, metal oxides are essential. Metal atoms can create oxide compounds in countless different ways. Along with the electronic structure, these may have a variety of structural configurations that exhibit superconducting, metallic, semiconducting,

insulating, ferromagnetic, antiferromagnetic, paramagnetic, and multiferroic, properties.

Oxides are used in many practical high-tech products, including magnetic sensors, memory, read/write heads, fuel cells, piezoelectric devices, microelectronic circuits, and coatings for surfaces to prevent corrosion. Researchers have a great deal of interest in working with metal oxide materials in the domains of magnetism, materials chemistry, biomedical engineering, agriculture, medicine, information technology, electronics, etc, due to the wide range of potential technological applications in the near future.

A wide variety of crystal structures, such as perovskite and spinel-type lattices, as shown in Fig. 1, are formed by metal oxides.

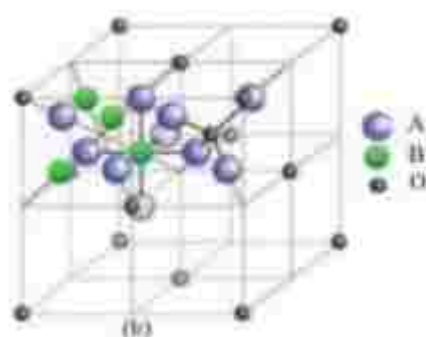
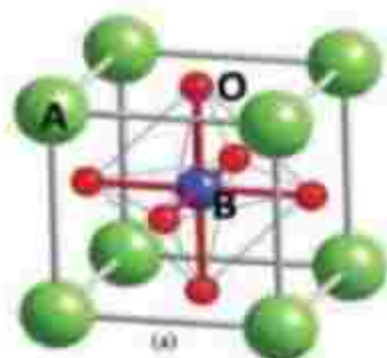


Fig. 1: (a) Perovskite type ABO_3 unit cell, and (b) Spinel type AB_2O_4 unit cell.

In a perovskite or spinel structure, the unit cells can hold a variety of cations. Different kinds of engineering materials can be fabricated for various usages depending on the cation types (magnetic or nonmagnetic), sizes, and positions in the lattices. In addition to this, oxygen anion is also crucial. Cation types and oxygen contents may change a material into an insulator, semiconductor, conductor, superconductor, magnetic material, etc. As a result, these structures can be considered treasure boxes for material scientists. An overview of the author's research on the perovskite and spinel types of materials is provided in this article.

Perovskite-type copper oxides: In 1986, Bednorz and Muller discovered the superconductivity in the layered perovskite-type $La_{2-x}Ba_xCuO_4$ system. It was observed that the critical temperature, T_c , depends on the dopant and the dopant concentration. For the Ba^{2+} dopant with $x=0.15$, the T_c is around 30 K. If Sr^{2+} replaces Ba^{2+} , an augmented T_c around 40 K is observed. When a smaller Y^{3+} replaces the larger La^{3+} , results in a giant jump of T_c around 93 K in the $YBa_2Cu_3O_7$ compound. In this compound, oxygen content plays an important role. The $YBa_2Cu_3O_6$ compound is a Mott insulator, while $YBa_2Cu_3O_{6.5}$ is a superconductor with T_c around 60 K, and T_c increases with increasing oxygen content up to around 110 K, and $Tl-Ba-Ca-Cu-O$ compounds with T_c up to a maximum of 125 K. Besides, the cation dopant and oxygen content, applied pressure also influence the T_c .

93 K for the $YBa_2Cu_3O_7$. The rare earth-free layered perovskite compounds $Bi-Sr-Cu-O$ showed T_c around 110 K, and $Tl-Ba-Ca-Cu-O$

Perovskite-type manganese oxides: Perovskite-type (Fig. 1a) metal oxides, $La_{1-x}A_xMnO_3$ with $A = Ca, Sr, Ba$, etc, have interesting properties, depending on the dopant types and concentration. $LaMnO_3/CaMnO_3/SrMnO_3/BaMnO_3$ compounds are antiferromagnetic insulators. When Ca^{2+} , Sr^{2+} , or Ba^{2+} replaces La^{3+} , there are dramatic changes in the properties of the materials. For small concentrations of dopants $x < 0.10$, the room-temperature phase is a paramagnetic insulator, and the low-temperature phase is a ferromagnetic/canted spin insulator. Most striking features are observed for $0.2 < x < 0.5$, the room-temperature phase is a paramagnetic insulator/semiconductor, and the low-temperature phase is ferromagnetic metal. Interestingly metal-insulator transition, the ferromagnetic to paramagnetic transition, and in some cases, structural changes occur simultaneously at the same temperature. This group of materials shows negative colossal magnetoresistive behavior around the transition temperature. For the higher dopant concentration $x > 0.5$, the room-temperature phase is a paramagnetic insulator, and the low-temperature phase is an antiferromagnetic insulator. The divalent dopant causes changes in the valance state of Mn^{3+} to Mn^{4+} . The population of Mn^{3+}/Mn^{4+} , and their interaction via oxygen anion, and the lattice distortion play a crucial role in showing various properties in these perovskite compounds.

Spinel-type iron oxides: Spinel-type iron oxides exhibit various amazing multifunctional properties. According to the crystal structure, spinel-type materials are natural superlattices. The AB_2O_4 crystal structure (Fig. 1b) has tetrahedral A-sites and octahedral B-sites. Depending on its composition and cation distribution, it exhibits different electrical and magnetic properties. Different cations can be placed on the A-sites and B-sites to tune the magnetic properties. Depending on the A-site and B-site cations, they exhibit ferrimagnetic, antiferromagnetic, spin (cluster) glass, and paramagnetic behavior. The remarkable behavior of their magnetic and electrical properties makes them the subject of intense theoretical and experimental research. The suitable compositions of Ni-Zn- and Co-Zn- ferrites exhibit large negative magnetoresistance. This magnetoresistance can be either parabolic or linear, depending on composition and temperature. The maximum magnetoresistance was observed with $Zn_{0.80}Ni_{0.20}Fe_2O_4$. This magnetoresistance is an intrinsic property of the composition and is independent of microstructures. The origin of magnetoresistance may be due to the suppression of scattering of charge carriers from paramagnetic or canted spins (YK angles) or magnetic polarons. Observed magnetoresistance is nearly linear with an applied magnetic field and is suitable for manufacturing magnetic sensors.

Composites of perovskite-spinel oxides: Some exciting features of perovskite- and spinel-type oxides are discussed in the previous sections. These materials are suitable for fabricating multifunctional devices. Composites of piezoelectric perovskite oxides and magnetostrictive spinel oxides exhibit magnetoelectric coupling. magnetoelectric coupling.

This new effect is absent in the individual oxides. Thus, appropriate combinations of these oxide phases can be used to design suitable multiferroic materials which show ferroelectric and ferromagnetic/ antiferromagnetic properties simultaneously. Proper ferrite and ferroelectric combinations can produce good magnetoelectric coupling effects. Extensive research on these composites revealed that a high magnetostrictive coefficient of the ferrite phases and a large piezoelectric coefficient of the ferroelectric phases are the basic requirements for high magnetoelectric coefficients of multiferroic composites. Therefore, combining two different suitable oxides, including the magnetostrictive and piezoelectric phases, yields a broadly applicable magnetoelectric voltage coefficient.

Concluding remarks: It was demonstrated that perovskite-type metal oxides might exhibit superconductivity, metallic, semiconducting, and insulating behaviour depending on chemical compositions. In addition, some of the oxides also exhibit ferromagnetic to paramagnetic transition along with metallic to semiconducting/insulating transition. For these materials, a colossal magnetoresistance is also observed in the transition region. On the other hand, spinel type of materials shows various magnetic properties depending on the cation substitutions. The substitution of nonmagnetic cations weakens the magnetic interaction in the spinel type of materials. If the nonmagnetic dopant is higher than some optimum value, then the B-sites cations of the spinel structure are no longer collinear, and they become canted. Some of the canted spinel-type materials also exhibit linear magnetoresistance in the presence of a high magnetic field. A suitable perovskite-spinel composite show multiferroic behaviour that is both ferroelectric and ferromagnetic behaviour in the same phase.

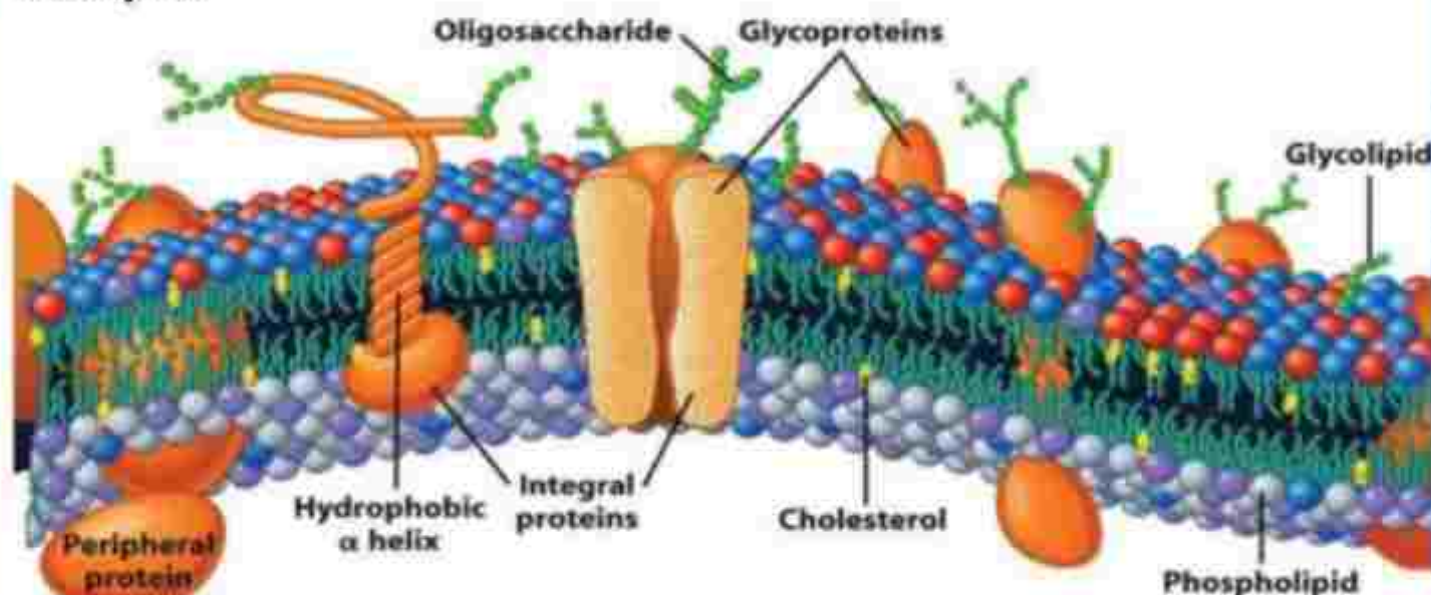
Membrane Biophysics Research in BUET

Dr. Mohammad Abu Sayem Karal, Professor, Department of Physics, BUET

Biophysics Research Laboratory, Department of Physics, Bangladesh University of Engineering and Technology (BUET) is one of the modern laboratories in Bangladesh for conducting cutting-edge research in the field of membrane biophysics. The writer is the founder and principal investigator of this laboratory, which was established in 2015. Several modern equipment have been bought and installed in the laboratory with the funding of TWAS (Italy), BUET, UGC, Ministry of Science & Technology, Ministry of Education, ICT Division etc.

The biomembrane, or cell membrane, is the most important structure of the cell and the cell organelles. It is an enclosing structure that acts as a selectively permeable barrier to living cells. It consists of a phospholipid bilayer with embedded, integral, and peripheral proteins used in communication and transportation of chemicals and ions. They play not only a structural role in the barrier but also contain various functional molecules like receptors, ion channels, proteins and enzymes.

spanning it. The relative abundance of proteins in a membrane varies from species to species, and it correlates with metabolic activity. For example, the mitochondrial wall contains large amounts of protein (52–76%) and smaller amounts of lipids (24–48%), facilitating its high metabolic activity. Conversely, the inactive membrane of the myelin sheath in neurons contains only 18% proteins and 79% lipids.



Source: Singer, S. J, Nicolson, Garth L., 2008

Fig. 1: Illustration of a Biomembrane

The thickness of biomembranes is about 10 nm. The main constituents of biomembranes are lipids. More specifically, they contain a sheet of lipid bilayer. The fluid mosaic model (gel type crystal structure) of Singer and Nicolson views the membrane as a fluid bilayer of amphipathic complex lipids with proteins embedded in it and

cholesterol is an important component of cell membranes, which play an important role in the functioning of real biological systems, varying up to 50 mol% of the total lipid content (bacterial membrane does not contain cholesterol). Cholesterol changes the physical and chemical properties of membranes. More specifically,

it changes the elasticity and bending rigidity of membranes. In any unusual situation (e.g., cancer or any other disease) of the human body, these properties of membranes greatly change. Hence, by measuring these properties, it can be possible to identify whether membranes are in good condition or not. Various static and dynamic natures of membranes can be investigated by optical microscopes (bright field, phase contrast, fluorescent, and confocal microscopes). An illustration of biomembrane is shown in Fig. 1.

Lipid membranes and Vesicles: Currently, artificially synthesized lipid membranes are used as an alternative to biomembranes as the synthesis of biomembranes with exact composition is quite difficult compared to the synthesis of lipid membranes. The thickness of lipid membranes is about 4 nm. Research uses lipid membranes for various experiments. Lipid molecules dispersed in solution exhibit a self-assembled system that transforms into aggregates of various sizes and shapes. Vesicles are closed, spherical structures formed by a double lipid layer ranging from nano- to micrometers in diameter. The vesicles are at the center of a huge amount of research because such vesicles are the models of real biological cells. There are several methods of forming the unilamellar vesicles which produce different sizes of vesicles. Among the different unilamellar vesicles, giant unilamellar vesicles (GUVs) of diameters of 10 μm or more have attracted special interest due to the visualization of their size and shape using optical microscopes. Such vesicles can be obtained through the natural swelling method. The size of GUVs gives the opportunity to study the phenomena happening in a single individual vesicle. The GUVs have been used to investigate the elasticity of lipid membranes, rupture/pore formation of vesicles using mechanical/electrical tension, pore formation due to peptides and nanoparticles, etc. Such vesicles have been substantially investigated in medical research as a potential system for delivering drugs to specific body organs and for electroporation. An illustration of a GUV and a lipid molecule is shown in Fig. 2.

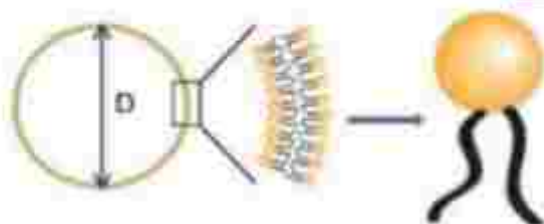


Fig. 2: Vesicle (left) and a lipid molecule (right).

Electroporation: Electroporation is a non-thermal and minimally invasive ablation technique for the destruction of cells in a targeted region, using brief electric pulses. Electroporation is the phenomenon associated with an increase in cell membrane permeability when microseconds to milliseconds of electrical fields are applied across the cell. Irreversible electroporation (IRE) is the permanent permeabilization of the cell membrane. It is considered that this will be the most promising technique for the ablation/destruction of cancer/tumor cells in a targeted region. The IRE technique has been developed in the biophysics research laboratory for conducting research on lipid membrane fusion, membrane poration, vesicle deformation, vesicle rupture etc. In addition, the effect of osmotic pressure on the constant electric tension-induced rupture of GUVs is also being studied.

The electroporation device mainly consists of an ultra-short pulse generator and a high voltage power supply. These parts are connected with a switching circuit for getting the final IRE signal with the microcontroller system. The DC square pulses are created by a multivibrator. A MOSFET-based switching circuit is designed for generating square pulses. To develop a high voltage power supply, initially, a single-phase transformer is driven by 220 V AC that serves 0-800 V AC with 5 A. Then the secondary voltage is converted through a full wave rectifier to get the required DC voltage with proper regulation. The square pulses are generated at low voltage from the pulse generator, which are used to switch high-voltage power MOSFET to get the desired output. A microcontroller is used to control the frequency, pulse width, and number of pulses of the IRE signal accurately.

The developed IRE device provides electric field pulses with pulse width of 200 μ s and frequency 1.1 kHz. The microcontroller-based IRE signal is applied to the GUVs through a gold-coated electrode.

The promising applications of electroporation in biotechnology are genetic transformation, microorganism inactivation, extraction of intracellular compounds from microorganisms and tissues, and biomass drying. Electroporation technology successfully used for tissue decellularization, producing tissue- and organ-derived scaffolds by removing the cellular content while preserving important structural and biochemical features to support cell growth. Several surgical applications using this

Micropipette Aspiration: The mechanical tension in the membranes of GUVs is applied by the micropipette aspiration technique, which helps to understand the process of pore formation, rupture of vesicles, and estimate the elasticity of membranes. In this technique, first a 'single GUV' is held at the tip of a micropipette by applying a small suction pressure and aspirating the GUV to a targeted tension quickly, and then keeping the tension constant for a particular time, say 10 min. GUV is observed until its complete aspiration into the micropipette. The GUV ruptured due to the formation of pore in the membrane. The time of rupture corresponds to the time when GUV is aspirated into the micropipette.

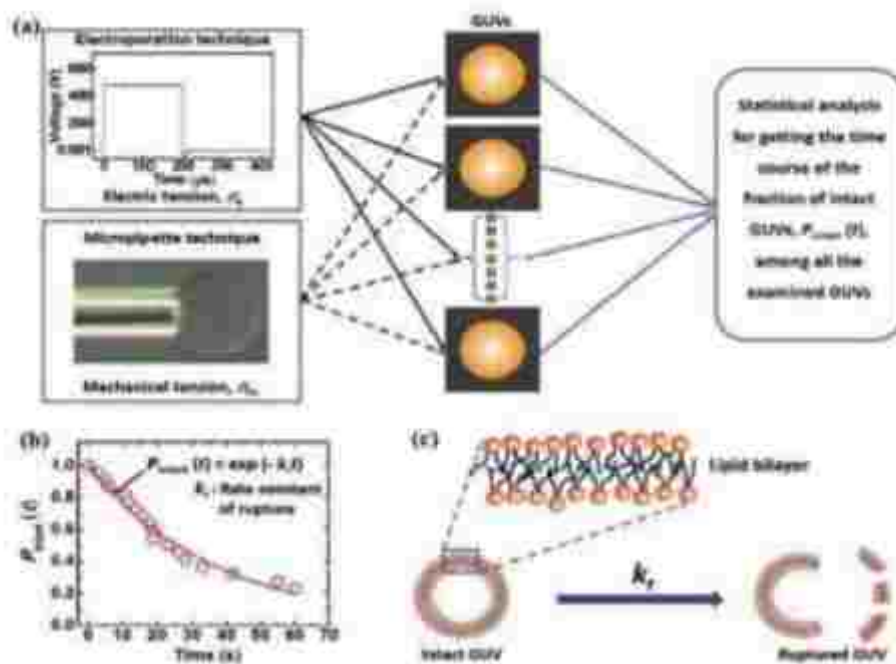


Fig. 3: Vesicle (left) and a lipid molecule (right).

technology are now under study or even under clinical trial, e.g., ablation of hepatocarcinomas, ablation of prostate tumors, treatment of atrial fibrillation, and treatment of vascular occurrences such as restenosis and atherosclerotic processes. The technology is also implemented in food preservation systems, food processing, and biorefinery. Localized prostate, kidney, lymph, and lung cancer treatments along with liver tumor ablation are well studied by the electroporation technique. Stretching of membranes, using the micropipette aspiration technique, activated the antimicrobial peptide-induced pore formation in GUVs.

Additionally, the entry of cell-penetrating peptide into single GUVs without pore formation is modulated by constant tension. The transbilayer movement of lipids was observed in the presence of constant external tension. The penetration of nanoparticles into a 'single GUV' was greatly influenced by lateral membrane tension, in which tension was generated by osmotic gradient. Such types of penetration of particles and peptides into the vesicles through the lipid bilayer are potentially useful for controlling living cells, such as for gene delivery, local heating, and the visualization of proteins. Hence, constant membrane tension plays an important role

various biophysical, biochemical, and biological processes. An illustration for calculating the rate constant of rupture of GUV is presented in Fig. 3.

Vesicle Nanoparticles Interactions: The emission of nanoparticles (NPs) into the environment from various sources is one of the key reasons for the substantial death and illness in cardiorespiratory diseases. Biomedical implants, contrast agents in MRI, insecticides, and food product processing are some of the common sources of NPs entering the human body. Magnetite NPs can be derived from burning fuel in the iron industry, printer toners, stoves, etc. The abundance of magnetite NPs was identified in the human brain, which are prolific in urban areas. Such magnetite NPs can be entered the brain via the olfactory nerve and build-up of reactive oxygen species in cells. Enhanced reactive oxygen species production links to neurodegenerative diseases (e.g., Alzheimer's).

(Gramicidin A) works as an ion channel in lipid membranes. As cells have a resting membrane potential, we apply membrane potential (using the Nernst equation) across membranes by changing the ions in the outer buffer of GUVs. It has been reported that magnetite NPs form pores in the membranes and deform GUVs. The deformation and compactness (C_m) of a GUV induced by $3.33 \mu\text{g/mL}$ NPs are presented in Fig. 4. The biological implications of lipid vesicles as well as their extensive application in biophysical and biochemical research determine the interest in the NPs-induced deformation and poration in GUVs. Due to the rapid increase of nano-bio-technology-based research and industry, it is crucial to save ourselves from the exposure of NPs. Adsorption of NPs deforms the cells and also forms pores in cell membranes. Exposure to NPs affects cardiovascular and pulmonary activities, resulting in substantial mortality and morbidity.

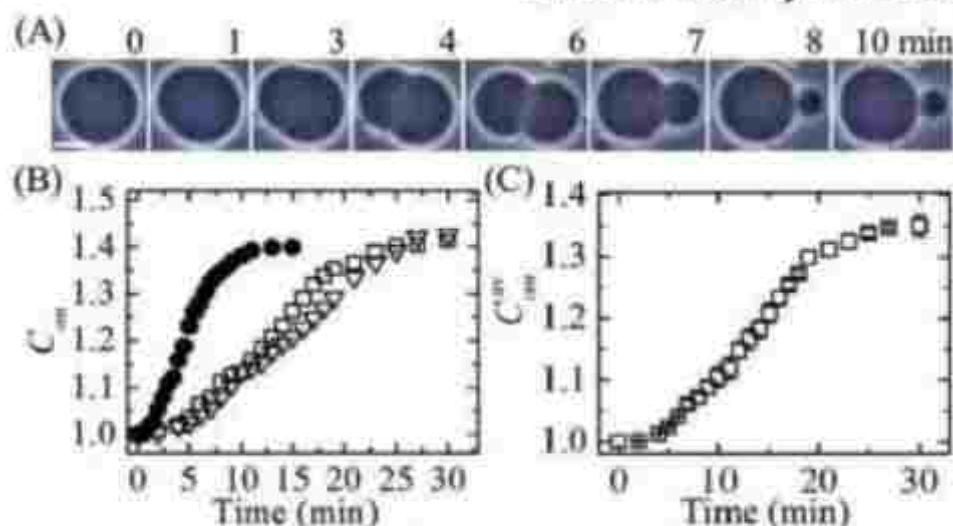


Fig. 4: (A) Phase contrast images show the deformation of a 'single GUV'. The numbers above each image show the time in minutes after starting the addition of NPs. Scale bar is $10 \mu\text{m}$. (B) The time course of the change of compactness of GUVs, filled circles (●) correspond to images shown in (A). (B) Under the same condition as in (A) the time course of the change in compactness of two other 'single GUVs' in one independent experiment. (C) Time dependent average compactness of GUVs.

It was also found that magnetite NPs in amyloid plaques (aggregates of misfolded proteins). Such proteins are responsible for causing Alzheimer's disease. Hence, the exploration of the impact of magnetite NPs in cells or vesicles is important for understanding the possible changes in membranes due to NPs. GUVs are synthesized using a combination of lipids and proteins. The protein

This write-up describes the information on vesicle dynamics using various techniques and agents. Different theories have been used (sometimes new theories are developed) to understand the detailed mechanism of the lipid bilayer induced by electroporation, micropipette aspiration, and nanoparticles.

Metal Oxide as Gas Sensing Materials: Sensing Mechanism and Performance

Dr. Mehnaz Sharmin, Associate Professor, Department of Physics, BUET

Modernization of science and technology has caused revolutionary changes in the industrial global industrial sector. The 4th industrial revolution demands more productivity to cope up with the rapidly emerging needs of modern society. Because we, the inhabitants of this global village are now very much dependent on the modernized devices in our workplaces, homes, amusement areas, etc. In this flow of life, a very precious thing is being overlooked by us, and that is our environment. Significantly, the air quality is a huge concern under the consequences of industrial modernization and large-scale productions. The pollutants released from the factories, vehicles, etc. have a toxic effect on the ecosystem. Moreover, flammable gases often cause firing disasters in factories, public places, and houses. So, monitoring air quality is essential to ensure environmental safety worldwide. The device used to examine the air quality is known as a gas sensor. A gas sensor is a useful device that helps to prevent health hazards to humans, ensure safety and control environmental pollution.

Gas sensor can receive information originating from a chemical reaction or a physical process of the system under investigation and transform it into an analytically useful signal [Hulnicki *et al.* Pure & Appl. Chem., 1991]. A typical chemical sensor consists of two parts named receptor and transducer. Chemical information is converted into any form of energy by the receptor. The transducer measures the converted energy. Finally, the transducer transforms this energy into an analytical signal. Depending on the operational principle of receptors, chemical sensors can be divided into three types- physical sensors, chemical sensors, and biochemical sensors. Usually, in a physical gas sensor, the signal is generated at the receptor by any physical process like the change of mass, absorbance, refractive index, temperature, or resistivity [Umar and Hahn, Am. Sci. Pub., 2010].

Metal-oxides (MO) semiconductors drew the scientific community's attention as gas sensing materials in the middle of the 20th century. MO semiconductor-based gas sensors were designed because the electrical resistance of a semiconductor shows high sensitivity the existence of impurities at the surface or in the volume. Generally, a MO gas sensor has four major components- substrate, sensitive layer, electrodes, and heater. Usually, thin ceramic substrates are chosen for manufacturing a gas sensor. MO film is coated on a small sized substrate. Electrodes are coated on the deposited film and the whole system is placed on a small heating system (Fig. 1).

The electrical resistance of a MO changes because of the absorption of gas molecules preliminarily related to the oxygen chemisorption. The working principle of MO gas sensor is known as the chemi-resistance principle. The gas molecule behaves as either an acceptor or donor during interaction with MO surface and hence causes change in the electrical resistivity of the MO film. The resistivity of MO film depends on several things, like the type of conductivity (p-type or n-type) of the deposited film, the nature of the gas molecule, etc. [Shankar *et al.* Sci. Lett. J., 2015]. Adsorption sites at the surface of the film confirm the interactions between the MO and gas molecules. In an n-type MO material, when oxygen ion species (O^- , O^{2-} , etc.) appears, the surface of the materials is depleted with electron. These ion species interact with gas molecules upon exposure of sensing gas and restore the electrons on the surface. In this process, the electrical conductivity of the MO increases. The generation of oxygen species on the surface of a film depends strongly on the type of material and temperature. Usually, the oxygen species are found to be predominant at temperatures in the range 150 - 400 °C. This causes the creation of an electronic core-shell configuration [Kim *et al.*

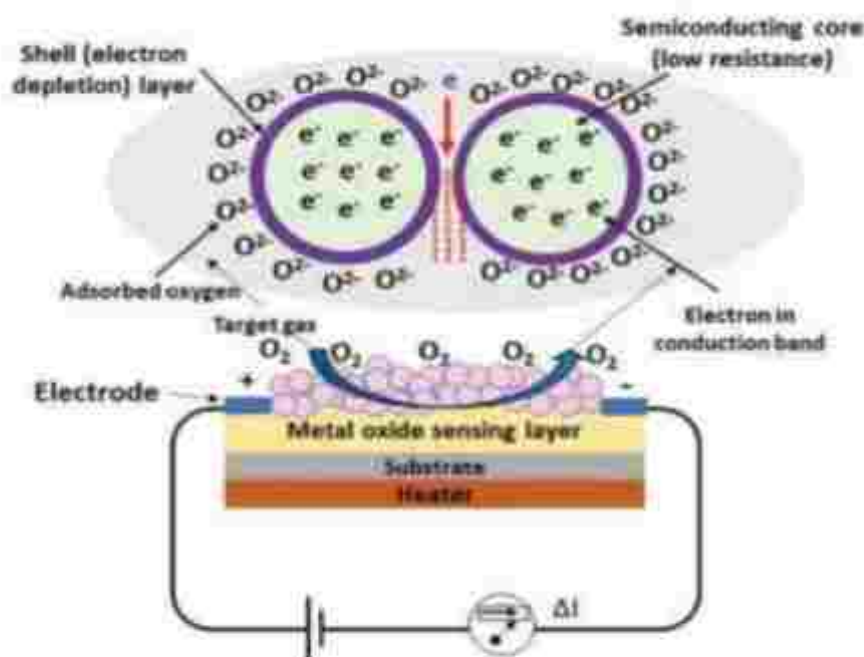


Fig. 1: Schematic diagram of a metal oxide gas sensor and gas sensing mechanism.

Sens. Actuators B: Chem., 2014]. In p-type MO materials, interactions between gas molecules and oxygen species on the film surface reduce the concentration of holes in the shell layer and hence decrease the electrical conductivity of the MO film [Kim *et al.* Sens. Actuators B: Chem., 2014]. Gas sensing mechanism of a MO gas sensor is shown in Fig. 1.

Earlier developed MO gas sensors were less efficient in terms of performance level. They had major drawbacks such as slow response, humidity sensitivity, the requirement of high operating temperature, etc. So, the search of high-performance MO materials had been continued since the initial invention of MO gas sensor. The performance of a sensor depends very strongly on the surface morphology and crystalline structure of the MO film, type of dopant, deposition technique, etc. Operating temperature also affects the performance of the sensor. Recently, with the developments of nanotechnology, researchers are attracted to the research on the gas sensing performance of nanostructured MO materials. Materials scientists are synthesizing several MO using different techniques and investigating their particle size-dependent electronic properties [Bochenkov and Sergeev, Adv. Coll. Int. Sci., 2005]. Following these research outcomes, nanotechnologists are fabricating modernized MO-based gas sensing devices [Fu *et al.* Adv. Coll. Int. Sci., 2004,

Bochenkov and Sergeev, Russ. Chem. Rev., 2007]. Lessening of particle size affects the electrical conduction in a MO material by modifying the grain boundaries or necks. Hence the sensor performance is improved significantly by reducing the particle size to the nano level [Umar and Hahn, Am. Sci. Pub., 2010, Tan *et al.* Sens. Actuators B: Chem., 2000, Michel *et al.* Talanta, 2007.]. Modification microstructural arrangements like the distribution of pores and morphological features influence the gas sensing performance of MO. An increase of porosity enhances gas sensing performance of MO [Shinde *et al.* Sens. Actuators B: Chem., 2007, Xu *et al.* Sens. Actuators B: Chem., 2006]. MO gas sensors show better sensitivity and selectivity when transition metal (example: Pt, Ag, Au, Cu, Co, etc.) or halogen (example: F, Cl, etc.) doped MO nanostructures are used as sensing materials [Umar and Hahn, Am. Sci. Pub., 2010]. Several binary and ternary MOs are synthesized, and their gas-sensing performances are being studied recently [Rzaij and Abass, J. Chem. Rev., 2020, Saruhan *et al.* Frontiers in Sensors, 2021, Singh *et al.* J. Electron. Mater., 2022]. The efficiency MO gas sensors are showing improvement in their performance day by day. There is a vast scope of research based on MO-based gas sensors.

Magnetic Refrigeration: A Supreme Application of Magnetocaloric Effect

Probal Roy, Lecturer, Department of Physics, BUET

Introduction: Magnetic refrigeration is an appealing, environment-friendly technology which is based on a magnetic solid specimen that behaves like a refrigerant by magnetocaloric effect (MCE). This technique is acquainted with the ability of any magnetic material to change its temperature and entropy under the influence of an external magnetic field. By using this technique, extremely low temperatures as well as the ranges used in common refrigerators can be obtained. The refrigeration technology does not use ozone-depleting chemical (such as chlorofluorocarbons), hazardous chemicals (such as ammonia), or greenhouse gases (Hydrochlorofluorocarbons and Hydrofluorocarbons). Most modern refrigeration system and air conditions still use ozone depleting or global-warming volatile liquid refrigerants. In magnetic refrigerators, solid refrigerant and common heat transfer fluids are used that are free from ozone-depleting and global warming effects on the atmosphere.

History: Relative long ago, in 1881 German physicist Emil Warburg discovered the magnetocaloric effect. According to his observation, under the influence of external magnetic field, the iron specimen heated up, or cooled successively. He proposed that the change in temperature of the specimen is nothing but the consequence of the change in the internal energy of that specimen, having a magnetic structure, under the impact of the external magnetic field.

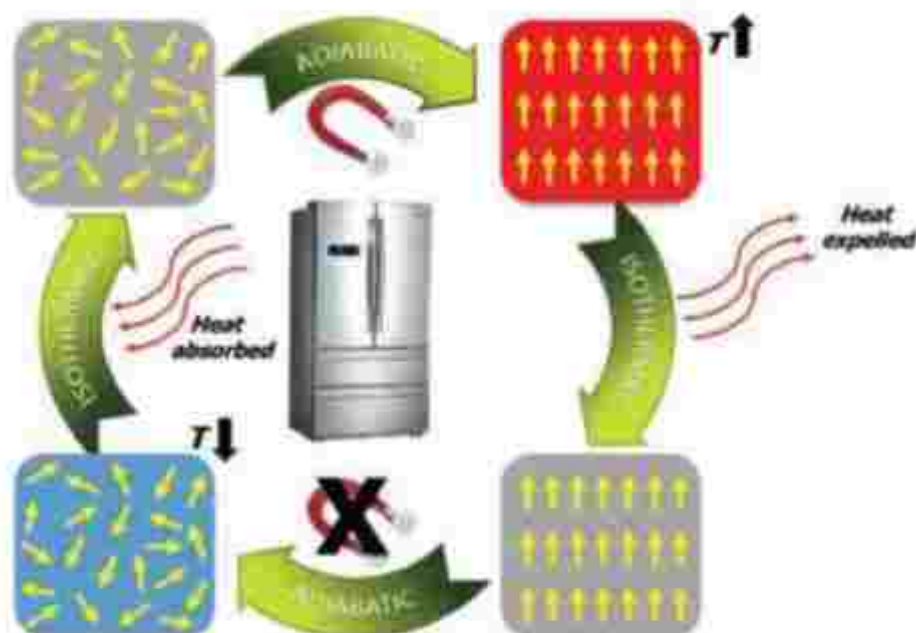
However, it was still far away before the empirical use of this phenomenon. French physicist Paul Langevin (in 1905) was the first who demonstrates that the change of magnetization of a paramagnetic material is responsible for a reversible change in the temperature of a sample. Almost 50 years after the discovery of MCE, the concept of magnetic cooling was proposed independently by two American scientists named Peter Debye (in 1926) and William Giauque (in 1927), as a mode

of reaching temperatures below the boiling point of liquid helium. Then in 1933, Jik and McDougall demonstrated the simplest and convenient experiment to explain the magnetic refrigeration.

Mechanism: The magnetocaloric effect is observed in magnetic materials when it is kept under influence of an external magnetic field. The mechanism for the change in temperature as well as change in entropy arises as a consequence of the manipulation of the magnetic moments in the material. When a magnetic field is applied to a material containing magnetic moments, the moments couple with the field and align with the field direction. This aligning of the moments reduces the randomness or magnetic entropy of the system. When the field is removed, the moments relax and the magnetic entropy increases. If the system is kept under isothermal conditions and constant pressure, the total entropy of the system will decrease when a field is applied and increase when the field is removed. If the system is kept under adiabatic conditions and constant pressure, the total entropy of the system remains constant. Under this condition, temperature of the system increases when the magnetic field is applied and decreases when the magnetic field is omitted.

Advantages and Disadvantages: The magnetic refrigeration system has some remarkable advantages over traditional combined cycle refrigeration system.

- Well compatibility with the environment and eco system.
- Relatively high efficiency.
- The flexibility of technology.
- Keeps continuous cooling cycle and eradicate bacterial development efficiently.
- Low running and operating cost.



Source: <https://www.google.com>

Fig. 1: Schematic diagram of magnetocaloric effect cycle.

As every coin has two sides, this technique also possesses some drawbacks to be worked on.

- The rudimental investment is more as compared with conventional refrigeration.
- As magnetocaloric materials, the rare earth materials have outstanding performance. In this regard their availability as well as high price also becomes a disadvantage.

Conclusion: Worldwide a lot of research and publications have been done extensively on the amelioration of magnetic refrigeration technology. In Bangladesh, many renowned universities as well as research institutes are also doing research works to develop efficient and comparatively less expansive magnetocaloric materials. Such type of advancement is very promising and auspicious in the current backdrop of Bangladesh. Finally, the adaption of this environmentally friendly refrigeration technology will adequately contribute a lot to ensure a healthy, pollution free and liveable civilization.

My Journey in BUET: A New Era of Life

Dr. Farhad Alam, Former Ph.D. student, Department of Physics, BUET

Associate Professor, Department of Physical Sciences, Independent University, Bangladesh.

Earning a Master's degree was not a goal that crossed my mind twenty years ago, let alone attending university in general. As an undergraduate student in a university, I did not view the importance of research as I do today. Graduating with a very good result, I felt the academic route was not the path meant for me to travel. Primarily the goal of life was to be a public service cadre that the most of us to. Having a bright academic result throughout the level of studies till my graduation directed me to teaching profession and my friends and family convinced me and helped me to change the course of my life. Once joined, I was quickly immersed into my teaching profession. I looked forward to engrossing new information daily, and often found myself understanding unassigned episodes for my own knowledge. After various academic and work experiences in my last few years of teaching I began to question my commitment towards my original goal. As I realized, education is one of the few sectors that continue to sustain its importance regardless of the world condition. In fact, history proves that in any incident that befalls someone's world, education helped him bounce back and be on his foot again. This is the pertinent reason why employment after graduation from studies was not the only ultimate goal for me rather, I desired to pursue postgraduate study. The desire shapes into reality after getting admission in BUET for M.Phil. program leading to Ph.D.

As an aspiring postgraduate student, I tried to clutch the mindset that the journey of knowledge is a perennial process. Therefore, after completing the degree, I did not think that the journey to knowledge has ended. Instead, I realized that the undergraduate study has equipped me a bit with the fundamentals or keys at hands to unlock the doors of knowledge and to be awed by its hidden treasure.

With the keys entrusted, I started transforming my role from a knowledge seeker to a knowledge worker. As an individual pursuing a postgraduate degree, I was trying to be equipped with the updated method of sourcing knowledge, to learn updated theories and principles that explain the nature of the knowledge that I want to be specialized in.

Throughout our lives, we will encounter different people that will leave imprints in our career. The person that I am sharing with you is someone who inspired me a lot in my journey of BUET, Prof. Dr. M. Ali Asgar, an eminent scientist and mentor. Actually, we grew up in our boyhood watching his scientific program in BTV and in different electronic and print media. His science club "Khelaghor" was an initiative to make science popular to everyone particularly to the children. As a science lover, I was also fascinated to Prof. Dr. M. Ali Asgar. In my M.Phil. program, I showed keen interest in magnetism and wanted to work with him as he developed a state of art laboratory with all the facilities to prepare and characterize magnetic alloys, ferrites, magnetic thin films, amorphous magnetic ribbons and nano-structured materials in collaboration with the University of Hanoi, Vietnam, through the support of International Plant Propagator's Society (IPPS). Experimental facilities have been developed jointly with Australian Electoral Commission (AEC) for the study of primary and secondary intrinsic magnetic properties and structure dependent properties for the basic understanding of co-operative magnetism and the technical magnetization process in different magnetic media and to develop hard, semi-hard and soft magnetic materials for technological applications. Once in a morning, with a brave heart I stood in front of him and expressed my disposition. In reply, he just told me with a smiling face "magnetism is little bit tough. Can you cope up with it? You need to work hard".

I assured him, I'll try my level best and my journey began. I was amazed with his personality, his very cool and smart talk, his way of dictation. I never found him to underestimate his pupils and that boosted up us to be more responsible, more regular with our task. He gave me always that space to discuss many things despite of being a junior faculty in a newly born private university. He taught me how to do research with perfection, to write a good quality proposal and to stick on the work. He always advised us to be loyal to the family and friends, never to lose hope. I successfully completed my M.Phil. degree with so many glorious memories with him. In this period, I came across few of my faculties namely: Prof. Dr. Gias Uddin Ahmad, Prof. Dr. Mominul Huq, Prof. Dr. Md. Abu Hashan Bhuiyan, Prof. Dr. Nazma Zaman, Prof. Dr. Jiban Podder, Prof. Dr. Md. Feroz Alam Khan. They were very generous to deal with the students whomever they were attached to. It pleased me a lot that they never treated the students with the political or religious colors. One thing I must mention, in the year 2001 I sat in front of a board for a faculty position in a leading private university and was selected for demonstration. I saw Prof. Dr. Mominul Huq sir at his office and requested him to check once the handout I have prepared for demonstration. He went through the topic rigorously and asked me to demonstrate that in front of him. I demonstrated four times in front of him at his office and I could secure the highest point in demonstration. Though I was a student of Prof. Dr. Ali Asgar but Prof. Dr. Huq sir never opposes me to assist. It reflects their generosity and respect to each other. I have also many glorious memories with the other faculties. My second phase of research, Ph.D. program started with a slightly different topic under the supervision of another

frontier in materials science in Bangladesh, Prof. Dr. A. K. M. Akther Hossain. In my M.Phil. program, I worked with amorphous ribbon but in Ph.D. program with crystalline material. This time my journey was not that smooth as I had the responsibility of my own family then along the official responsibility. I could complete the theory part on time but to fix up the topic and prepare the proposal was very crucial for me in the new era. In BUET before submitting the proposal we had the opportunity to choose a topic and prepare the samples for characterization that actually helped us to finalize the proposal with a very good title. This work pressure led me to stay there in the Solid State Physics (SSP) lab day and night. Somehow, I could manage one or two months in a year to spend the whole period in the lab to excel my work. It gave us an opportunity to form a group of researchers and a huge output in our work. Despite of having the sufficient logistics in the lab, this culture of staying in the lab with the approval of the authority is still ongoing in the lab. After lots of scraps, finally I could accomplish the mission of my Ph.D. degree. Many new opportunities like, Nanoscience and Nano technology, Meteorology, Biophysics, Crystal growth, Medical Physics have been introduced in the Physics Department along with Solid State Physics with more technological supports. Lots of memories with my fellow researchers those who worked with me in the lab. I can't help but mention few names: Hamid, Belal, Mahbub, Bablu, Lutfur, Mainuddin, Momin, Ruksana, Mamun, Azizar, Ruhul and so many. Most of them are doing great in their own places and glorifying each and everyone's affiliation. Where ever we are, BUET will always remain in our core of the heart.

Development of Nanomechanical Piezoresistive Sensors Using MEMS Technology

Dr. Md. Abdul Momin, Former M.Sc. Student, Department of Physics, BUET

Department of Bioengineering, Swanson School of Engineering, University of Pittsburgh, USA

Nanomechanical piezoresistive sensors are Microelectromechanical System (MEMS) devices that use the piezoresistive effect to convert mechanical stress into an electrical signal at the micro-meter scale (Toda et al. Sens. Act. B, 2021). These sensors are fabricated using microfabrication techniques, such as photolithography and etching, deposition, to create structures with dimensions on the micro-meter scale (Amato et al., *Faraday Trans. I*, 68, 1998). This gives them high sensitivity, high resolution, and low power consumption. Nanomechanical piezoresistive sensors can be made using various materials, including silicon, SOI wafer, silicon nitride, and silicon carbide, depending on the application and the required properties. Depending on the application and desired mechanical response, they can have different forms, such as beams, cantilevers, membranes, etc.

Fabrication Process of MEMS Piezoresistive Sensors:

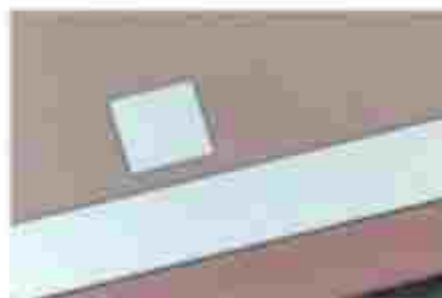
- *Designing the device and developing the sensing principle:* The designing process includes sensor design, mask design, etc.
- *Mask fabrication:* As the MEMS process includes different types of photolithography, etching, deposition, and other processes, we need to fabricate masks to cover unwanted areas during photolithography. Mask can be fabricated using a different method. Cr masks can be fabricated using laser lithography; photo masks can be fabricated using conventional photo mask maker instruments where fluorescence light is used.



Mask



Si etching



After SiO₂ etch



After Au Sputter

Fig. 1: Some of the photos of the microfabrication process.

- *Photolithography processes:* After cleaning the wafer using different cleaning processes, these are heated at 145 °C for drying. OAP is deposited on the sample as an adhesion layer using spin coating. Then different types of photoresists are deposited on the wafer using spin coating. The rotations per minute (rpm) of spin coating and the density of the photoresist can be different depending on the minimum area of the design of the devices. These wafers are post-baked at 110 °C. Then the wafers are exposed to UV light using a SUSS mask aligner and finally developed using different developing chemicals.
- *Different types of etching process:* For fabricating the devices, different types of etching processes are needed, including dry etching and wet etching. (Reactive-ion etching) ICP-RIE is the most used dry technique for etching Si using plasma. CCP-RIE is another dry etching technique that can etch SiO₂, PVDF, and other insulating materials. Different metals, like Au, Cr, Ag, etc., can be etched using wet chemical etching. SiO₂ can be etched using a wet etch, like the BHF process.
- *Deposition process:* During the fabrication process, SiO₂ can sometimes be deposited on the Si wafer as an isolation layer. SiO₂ can be deposited using Plasma-enhanced TEOS CVD, LP-CVD, Plasma-enhanced SiN CVD, Plasma/ozone TEOS CVD, etc. The most used metal deposition processes are RF magnetron sputter, ECR ion beam sputter, etc.
- *Doping process:* Doping of the Si wafer is one of the most important processes in fabricating a piezoresistive device. Boron or Phosphorus can be injected into the Si wafer using an ion implantation instrument. After ion implantation, the wafer is annealed at over 1000 °C to defuse the ion on the surface of the wafer.
- *Packaging:* After successfully fabricated, the sensors are prepared for evaluation. The sensors are bonded on Au-coated ceramic cases, and the electrodes are connected to the pins of Au-coated ceramic cases. The electrodes are connected using a flip-flop wire bonder.
- *Evaluation of the sensors:* After preparing the sensors, these are connected to custom-designed circuits and get the signal using an oscilloscope or a computer. The gas sensors are evaluated using a gas flow meter system, cantilever-type sensors are evaluated using a laser Doppler system, and pressure sensors are evaluated using a pressure gauge system. These sensors can be used in chemical and gas sensing to detect small changes in chemical concentration or gas pressure (Morin et al. proceeding at MEMS conf., Tokyo, 2022).

In nanorobotics and nanomanipulation to control the position and motion of small objects at the nanometer scale. These can also be used in quantum computing to detect small changes in the position or motion of qubits, the basic units of quantum information.

Thin Film Solar Cells

*Meherun Nesa, Former M.Sc. Student, Department of Physics, BUET,
Lecturer in Physics, Dept. of EEE, Green University of Bangladesh, Dhaka*

Second-generation solar cells are known as thin-film solar cells (TFSCs). TFSCs have multiple thin-film layers of photovoltaic (PV) materials. Because of this, TFSCs are also addressed as Thin-film photovoltaic cell. In the decade of 1970s, some researchers of the Institute of Energy Conversion at the University of Delaware, United States, were introduced initially to TFSCs. Early in the 21st century, the thin-film photovoltaic market was developing at an incredible rate, and it continued increasing because of frequent technological advancements.

TFSCs are made up of micron-thick photon-absorbing material layers that are placed on flexible substrates such as glass, plastic, or metal. These are intended to convert light energy into electrical energy (through the photovoltaic effect). The thickness of TFSCs varies from a few nanometers (nm) to tens of micrometers (μm). Consequently, TFSCs are significantly thinner than the other modern technology, the traditional,

first-generation crystalline silicon solar cell (c-Si). Wafers of c-Si solar cells can be as thick as 200 μm . Strong light-absorbing materials are chosen for deposition, most frequently amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium (gallium) di-selenide (CIS or CIGS). Due to their suitability for deposition over broad substrate regions (up to 1 meter), these materials enable high-volume fabrication. Amorphous silicon TFSCs are less expensive to produce than traditional cells because they utilize less Si, while CdTe or CIS cells also have reduced material costs. These flexible and non-assembling cells can be used in a variety of applications.

In the 1980s, watches and calculators used small strips that were the first TFSCs applications. Due to their flexibility, which makes it easier to place them on curved surfaces and utilize them in building-integrated photovoltaic, thin-film applications have significantly expanded in the early 21st century.

Thin Films: Deposition Mechanism and Methods

Selina Akter Lucky, M.Sc. Student, Department of Physics, BUET

In this twenty-first century, it is pretty impossible to think of a moment without modern technology. Technology has played an important role in modern civilization, which is greatly connected with matter and materials. Though we are spending for a comfortable life, researchers do not stop discovering new findings. To make life easier, the research on materials rises day by day. In modern days, thin film has gained a great interest in the world of scientific research. Technology and understanding of films have advanced tremendously in the most recent decade, predominantly due to the demand of reliable thin film in microelectronic device-based industries. This development has brought enormous scientific trust in using thin films for fundamental and applied research. Moreover, research on thin film progressed in many new areas of Solid State Physics and Chemistry, which is related to the geometry, thickness, and structure of films. Depending on the different properties of films, applications may vary. Solar cells, antireflective coatings, memory discs, interference filters, piezoelectric devices, diffusion or alloying barriers, oxidation or corrosion resistant, sensors, electrochromic devices, photocatalytic, photodetectors, batteries, etc. are the most common applications [Donald L. Smith, McGraw Hill Professional, 1995].

The solid material is referred to as a thin film when it is deposited as a layer of thickness in the range of micrometer to nanometer onto solid support known as substrate. They are deposited onto bulk materials to achieve properties that are not easily available in the substrates alone. The basic technology of the integrated-circuit industry depends on multiple layering that is combined with lithographic patterning. Generally, films are uniformly deposited on the substrate where there is a strong adhesion between deposited atoms and substrate atoms. They exhibit linear temperature coefficient, strong protective coating with good edge covering having selective crystalline and non-crystalline phases. Thin films are low-cost,

stable in high temperatures, and miniature, comprehensively beneficial in semiconducting applications.

Deposition mechanism: The structure and properties of thin films rely on the formation mechanism. Film formation has two parts- nucleation and growth mechanism. Thin films are grown via condensation of atoms from either the liquid/melt or vapor phase of a starting material called precursor. Since the substrate is a different material than the precursor, imposing precursor atoms are initially adsorbed on the substrate surface. Condensation is originated by creating small-scale clusters of the atoms adsorbed. These small-scale clusters then act as the primary centers of condensation. When an atom's kinetic energy is lower compared to the energy required for desorption, thermal accommodation occurs by donating its additional energy via lattice vibration of the substrate, causing adsorption of the atom. Because of the forces like surface tension and capillarity, the adsorbed atoms combine to form small clusters which are unstable. These unstable small clusters are expected to be desorbed if they do not attain a specific critical size related to a particular substrate temperature. After gaining the critical size, they keep producing stable condensates. Critical size or radius means the minimum radius for which nucleation starts to grow. Finally, the growth mechanism takes place. The structure of a film and hence its properties can largely be attributed to the growth procedure, which has fundamental significance in the science and technology of thin films. Typical growth features of thin film are shown in Fig.1. Various experimental studies revealed three fundamental modes of nucleation: Island growth, Layer growth, and Island-layer growth. Island or Volmer-Weber growth appears when the growth species are more closely bounded to each other than to the substrate. Consequent growth generates islands that coalesce to develop a continuous film. In layer or Frank-van der Merwe

growth, the growth species are more likely to be attached to the substrate than to each other, resulting in the formation of the first monolayer prior to the deposition of a second layer. An intermediate situation happens in the island-layer or Stranski-Krastonov growth. In this growth process, strain is adapted in a layer-by-layer growth region up to a certain critical thickness. This region is called the wetting layer [Oura *et al.*, in Surface Science, Adv. Texts Phys., Springer, 2003]. For thicknesses higher than the critical thickness, it becomes energetically advantageous to release strain energy at the cost of surface energy by nucleation of islands on the top of the wetting layer. Such a type of growth usually engages the stress created during the development of the nuclei.

porous, and highly pure thin films, solution-based deposition methods are being popular day by day. Because both PVD and CVD methods are generally complex, sophisticated, expensive, need high substrate temperature, and produce toxic by-products during the deposition process. On the other hand, solution-based deposition techniques consist of a simple and low-cost experimental setup. In a solution-based deposition technique, it is possible to deposit thin films at relatively low substrate temperatures without any requirement of vacuum; deposited films are reproducible and have ample surface area coverage.

Chemical bath deposition: Chemical bath deposition (CBD) is the method that generates films of non-metallic, solid inorganic compounds



Fig. 1: Thin film growth features.

Deposition methods: Thin films can be deposited on to varieties of substrates using different methods. Classification of thin film deposition methods are represented in Fig.2.

Solution-based thin film deposition: Though physical vapor deposition (PVD) and chemical vapor deposition (CVD) produces uniform, less

on substrates by submerging the substrate (once or several times) in a precursor solution. The film's growth rates, structures, and properties depend on various parameters such as pH and concentration of the solution, temperature (below 100 °C), etc. Metal salts and chalcogenide (Sulfides, Selenides, Tellurides, and Polonides) precursors are dissolved in water to form an

aqueous solution. The solution contains metal and chalcogenide ions. A substrate is dipped into the solution, which plays the role of a catalyst to the nucleation, then the precursor ions adhere to the substrate forming a thin crystalline film. The method is convenient and less expensive for large-area deposition and can tune thin film properties by adjusting and controlling the parameters.

Dip coating: Dip Coating is a technique that refers to the immersing of the substrate into a chemical solution, withdrawing from the solution, allowing draining, and finally, drying or baking. Uniform and high-quality films are deposited where self-assembly provides monolayer thin films. This is a low-cost coating technique in which layer thickness can be easily adjusted. The neatness of the substrate, submersion

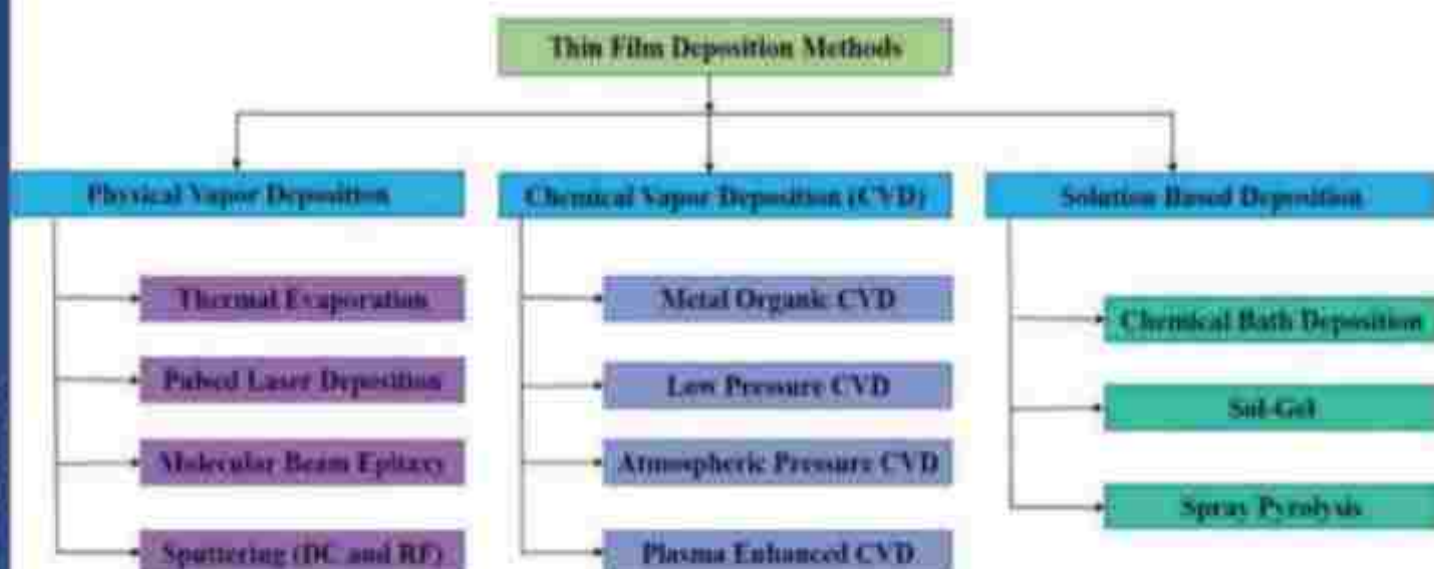


Fig. 2: Thin film deposition methods.

Sol-gel method: In the sol-gel process, a sol is prepared using different colloidal solutions mixed with an organic solvent. This sol is combined with slow-rate water to make alcogel, then the slow removal of solvent gives the required film after sintering. The films produced by this method are uniform and highly pure. Organic-inorganic hybrids thin films can be easily fabricated at low processing temperatures using this method.

There are two sol-gel methods used for film preparations; they are (i) spin coating and (ii) dip coating.

Spin coating: Spin coating is a process of forming a film onto a substrate in which a liquid solution is positioned at the centre of the circular surface and is speedily rotated to grow a uniform film. Film properties depend on the viscosity of the liquid, surface tension, spin process parameters (rotation speed, acceleration), drying rate, fume exhaust, etc.

time, substrate-withdrawal speed, number of dipping cycles, composition and concentration of the solution, temperature, environmental humidity, etc., are the parameters that affect film formation in this technique.

Spray Pyrolysis: Spray pyrolysis (SP) is a low-cost, simple method requiring only a liquid source, atomizer, and heated substrate. In the SP method, two reactions are involved. One is hydrolysis which occurs during the preparation of the solution, and another is pyrolysis which occurs at the surface of the heated substrate. During the SP process, the spray droplets are carried toward the heated substrate via the atomization process. The droplets splatter on the substrate surface, and a reaction takes place, leaving behind the film as a precipitate. The deposition parameters which influence the properties of the films are substrate temperature, the flow rate of the carrier gas, the substrate to

nozzle spacing, droplet size, the concentration of the solution, flow rate, etc. Unlike the other solution-based techniques, it has a major benefit that the deposited films adhere to the substrate very nicely without any post-deposition heat treatment like annealing. Another major advantage of this technique is that relatively less time is required for the deposition of the films. This is an efficient technique to produce dense and porous films with good control over composition, crystallinity, and surface morphology.

However, solution-based deposition techniques have some disadvantages, too. One of the major disadvantages is the possibility of unwanted contaminations and defects. These mostly occur because of the film growth in an open atmosphere (without vacuum) and lack of proper optimization in deposition conditions.

Nowadays, improvisation of solution-based deposition setups is being done considering various aspects of the methods to overcome the disadvantages.

Thin film-based research is one of the most attractive fields to scientists nowadays. Applications of thin films are spreading out in various fields of modern technology. The properties of thin films are important for deciding the application, and the property of a film is very much dependent on the deposition method. Thus, it is necessary to choose the deposition method according to the requirement of the application purpose. Low-cost film deposition methods like solution-based techniques can reduce the device fabrication costs and make research easier for the scientist of the whole world, especially for those who work in a low or mid-low income country.

A Brief Discussion of Nobel Prize in Physics in the Year 2022

Monira Sohel Eva, M.Sc. Student, Department of physics, BUET

Summary of Nobel Prize: The five awards collectively referred to as the Nobel Prizes are presented to those who, in the words of Alfred Nobel's 1895 bequest, had conferred the greatest value to humanity during the course of the preceding year. Swedish chemist, engineer, and industrialist Alfred Nobel is well known for creating dynamite. In 1896, he perished. In his will, he specified that the creation of five prizes that would come to be known as Nobel Prizes should be done with all of his remaining realizable assets. The first Nobel Prize was awarded in 1901 [<https://www.nobelprize.org/>]. Nobel Prizes are awarded in the disciplines of physics, chemistry, physiology or medicine,

The Nobel Prize for Peace is awarded to the individual who has done the most or best to develop fellowship among nations, the elimination or reduction of standing armies, and the formation and support of peace congresses, according to Nobel [<https://www.nobelprize.org/>]. The Alfred Nobel Prize in Economic Sciences, which Sveriges Riksbank funded in 1968, will likewise be established under the direction of the Nobel Foundation [<https://www.nobelprize.org/>]. Most people agree that Nobel prizes are the most distinguished honors offered in their disciplines. However, according to the recent view, the brief of the Nobel prize in Physics in the year 2022 is discussed in this article.

The Significance of the 2022 Nobel Prize in Physics: The long-awaited public acknowledgment of experiments that support the theoretical elements of a key quantum physics phenomenon. Three experimental physicists have been given the 2022 Nobel Prize in Physics for their foundational research, dispelling considerable public misunderstanding regarding the structure and application of quantum theory. Alain Aspect (Université Paris-Saclay and École Polytechnique, Palaiseau, France), John F. Clauser (Walnut Creek, CA, USA), and Anton Zeilinger (University of Vienna, Austria) were nominated by the Royal Swedish Academy of Sciences for the 2022 Physics Nobel Prize. They deserve our sincere congratulations! The short biography of the Nobel prize winner in Physics 2022 is shown in Fig. 1.

The intangible consequences of quantum mechanics are starting to find applications. Research into quantum networks, computers, and secure quantum encrypted communication is now being conducted in a variety of fields. A key component of this development is the ability of quantum physics to allow for the coexistence of two or more particles in an entangled state. When two particles are entangled, their actions have an impact on one another even when the particles are far apart. It has been hotly contested for a very long time whether the correlation was brought on by hidden variables, instructions that inform the particles in an entangled pair whose result they should produce in an experiment. The mathematical inequality that bears John Stewart Bell's name was developed in the 1960s.

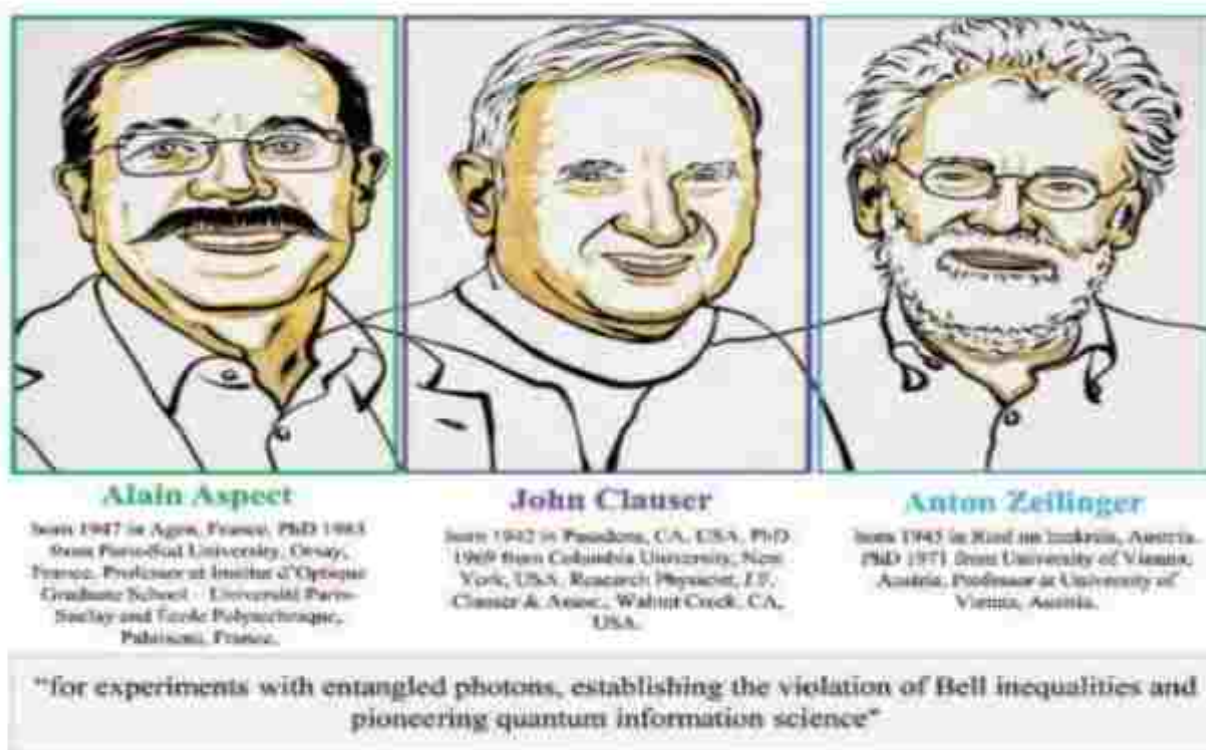


Fig. 1: Nobel prize winner in Physics 2022 with their short biography [Source: Internet].

The Contribution of Quantum Information by the Winners: Alain Aspect, John Clauser, and Anton Zeilinger have carried out ground-breaking research utilizing entangled quantum states, in which two particles behave as a single unit even if they are separated. They opened the way for revolutionary quantum information-based technology with their discoveries.

This suggests that if there are hidden causes, the correlation between the results of several measurements will never be higher than a particular number. However, Bell's inequality will be defied by a certain type of experiment in quantum physics, resulting in a stronger relationship than is normally imaginable.

Artemis: A New Chapter in Human Lunar Exploration

Md. Khokon Miah, M.Sc. Student, Department of Physics, BUET

After a record-breaking mission, traveling more than approximately 2.25 million kilometers on the path around the moon, NASA's Orion spacecraft returned safely to earth and splashed down in the Pacific Ocean, completing the Artemis I flight test. Which was the final milestone of the Artemis-1 mission that began with a successful lift off of NASA's Space Launch System (SLS) rocket on 16 November 2022. Fig.1 is a photograph of space mission sent to the moon.

for three hours. They did experiments. They picked up bits of moon dirt and rocks. They put a U.S. flag on the moon. They also left a sign on the moon. Then they returned to orbit and joined with Collins. On July 24, 1969, all three astronauts returned safely to Earth.

After the Apollo mission, the Artemis mission will be the first crewed moon landing mission. This mission is a series of ongoing space missions



Fig. 1: Mission – Sending Humans to the moon and beyond [Source: Internet].

It was 1961, when John F. Kennedy wanted to land humans on the moon. Apollo 11 blasted off on July 16, 1969. Neil Armstrong, Edwin Aldrin, and Michael Collins were the astronauts on Apollo 11. Four days later, Neil Armstrong and Edwin Aldrin landed on the moon. They landed on the moon in the Lunar Module. Michael Collins stayed in orbit around the moon. He did experiments and took pictures. On July 20, 1969, Neil Armstrong became the first human to step on the moon. Armstrong and Aldrin walked around

run by the National Aeronautics and Space Administration (NASA) and collaborated with commercial companies like SpaceX and Boeing. Three Artemis missions are currently in progress namely Artemis-1, Artemis-2, and Artemis-3.

Artemis-1: Artemis-1 is a test flight uncrewed mission. Which has already been completed on 11 December 2022. This uncrewed mission was a comprehensive test of the Space Launch System (SLS) and the Orion module. SLS is the most powerful spacecraft ever built-in history. Which

was 15% more powerful than Saturn V (used in the Apollo mission) that first took astronauts to the moon. This mission was designed to broaden our lunar knowledge, which will help to make further technologies more exquisitely. Also on this mission, there were three spacesuits (moonikins). These spacesuits were worn by three mannequins which will be used in Artemis-2 and Artemis-3 by real astronauts. Different types of sensors were placed all over the spacesuits to provide information on what human crews may face during the next flight.

Artemis-2: Artemis-2 is a crewed flight beyond the moon, which will take humans the furthest they have ever been in space. But it will not land on the moon. Most probably this mission will carry four astronauts. For the first time, it will carry female and astronauts of color to the moon. They will fly by SLS rocket beyond the far side of the moon. After completing the lunar flight they will come back to earth. On average this they will come back to earth. On average this mission will take eight to ten days and will collect valuable data for the final mission.

Artemis-3: artemis-3 will be the first mission since the Apollo mission to land humans on moon. Four astronauts of Artemis-2 will dock with the lunar gateway (a small space station orbiting the moon) with the Orion module and remain in space for 30 days. Among the astronauts, two of them will land on the south pole of the moon. They choose the south pole of the moon because this region has never been visited by humans. The astronauts are expected to spend one week on the surface of the moon. During this time they will perform a variety of scientific studies, including sampling water ice which was detected in 1971 during the Apollo mission. The objective of this mission is to pave the way for the future deep space mission. Also, equality will stand as it will send the first woman and first person of color on the lunar surface. Artemis aims to set up a base for the next mission and extract more knowledge about the moon. This series of missions will be able to retrieve samples more extensively than the Apollo era. This mission will help to discover water and other minerals for both scientific and economic purposes. This will be the first step to sending humans to Mars.

RESEARCH AND FACILITIES

Solid State Physics



Spin Coating Unit



Impedance Analyzer



Plasma Polymerized Thin Films



FTIR with ATR



Optical Micro. Lab



Extrusion Molding Machine



Vibrating sample magnetometer (VSM)



Nanotechnology Lab

Biophysics, Medical Physics and Health Physics



Inverted Phase Contrast Microscope



Refrigerated Centrifuge



Incubator

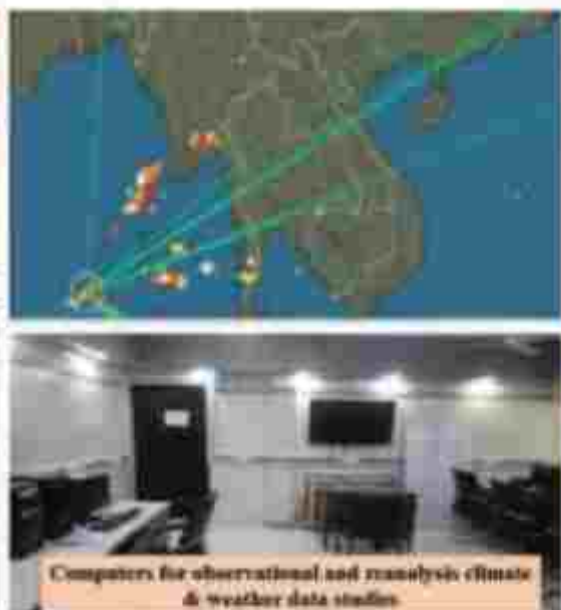
Atmospheric Physics



Weather Server



Lightning Detector



Computers for observational and reanalysis climate & weather data studies

ADMISSION NEWS

Department of Physics, BUET is a well-recognized seminary for studying postgraduate level Physics in Bangladesh. This Department offers three postgraduate degree programs- M.Sc., M.Phil., and Ph.D. Generally, students are admitted to these programs in either April or October postgraduate

semester in every academic year. The admission notices are served on the website of BUET (<http://pgadmission.buet.ac.bd/>). The admission details are also available on the website of Department of Physics (<https://phy.buet.ac.bd/>).

DEPARTMENTAL NEWS

Faculty of Science: A New Faculty at BUET

Faculty of Science started its journey in BUET from 12 May 2022 with the approval of University Grant Commission (UGC) of Bangladesh. This faculty consists of the three royal departments of BUET, namely Department of Physics, Department of Chemistry and Department of Mathematics. Earlier, these three departments were functioning under the Faculty of Engineering, which was split into Faculty of Chemical and Materials Engineering and Faculty of Science. Professor Dr. Md. Abdur Rashid, Department of Chemistry, BUET was appointed as the first Dean of the Faculty of Science on 17 July 2022. Professor Dr. Jiban Podder, Department of Physics, BUET is currently working as the Dean of this faculty.

Achievement of Faculty Members

Prof. Dr. Jiban Podder served as a visiting professor in the Department of Chemical and Biological Engineering, University of Saskatchewan, Canada from October 2021 to September 2022. Prof. Dr. Mohammed Abdul Basith has been elected as a Fellow of the Institute of Physics in October 2022.

Faculty of Science, BUET Organized Its First Conference

1st International Conference on Frontiers in Science (ICFS-2022) was organized successfully by the Faculty of Science, BUET dated on 11 - 12 November 2022. This conference was conducted in hybrid mode. More than 200 papers from home and abroad were presented among which 43 oral and 23 poster papers were presented from Physics discipline. The conference was enlightened by the presence of distinguished academicians and cordially appreciated by reputed scholars in the field of science and technology. The conference ended up with a very lively cultural program participated by the students of this Faculty.

Conference on Crystallography

Department of Physics, BUET and Bangladesh Crystallographic Association jointly organized the 7th Conference of Bangladesh Crystallographic Association at BUET dated on 8 - 9 December 2022. The conference was conducted in a hybrid mode. About 70 lectures including keynotes, plenary and invited talks and contributory papers were presented in the conference.



Inaugural ceremony of 1st International Conference on Frontiers in Science, ICFS-2022

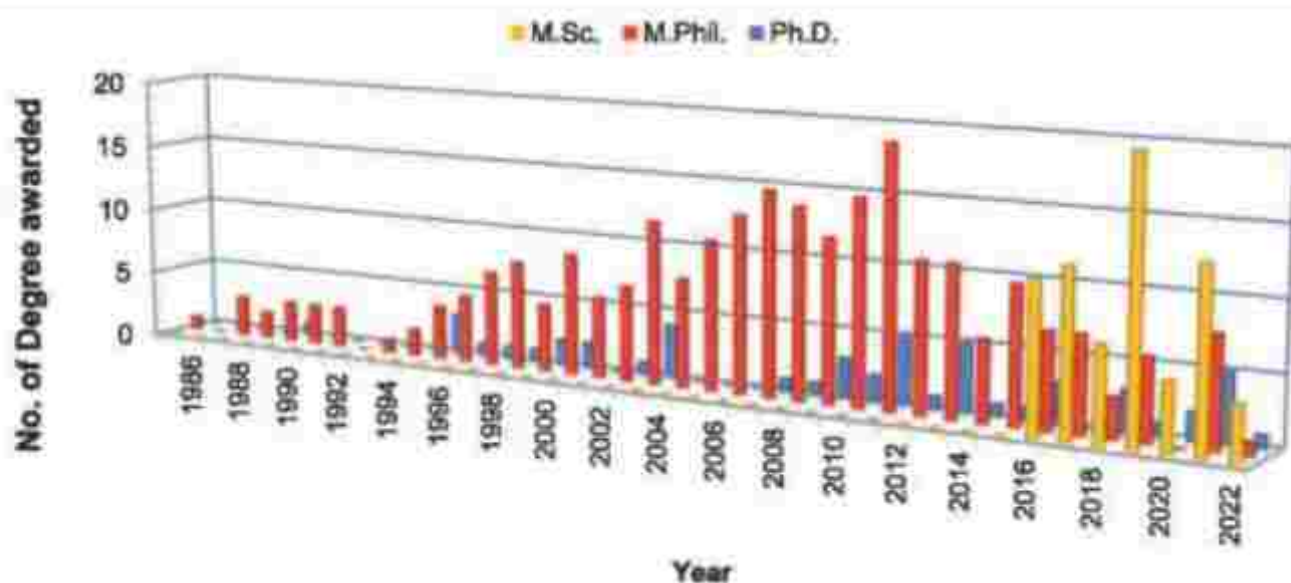
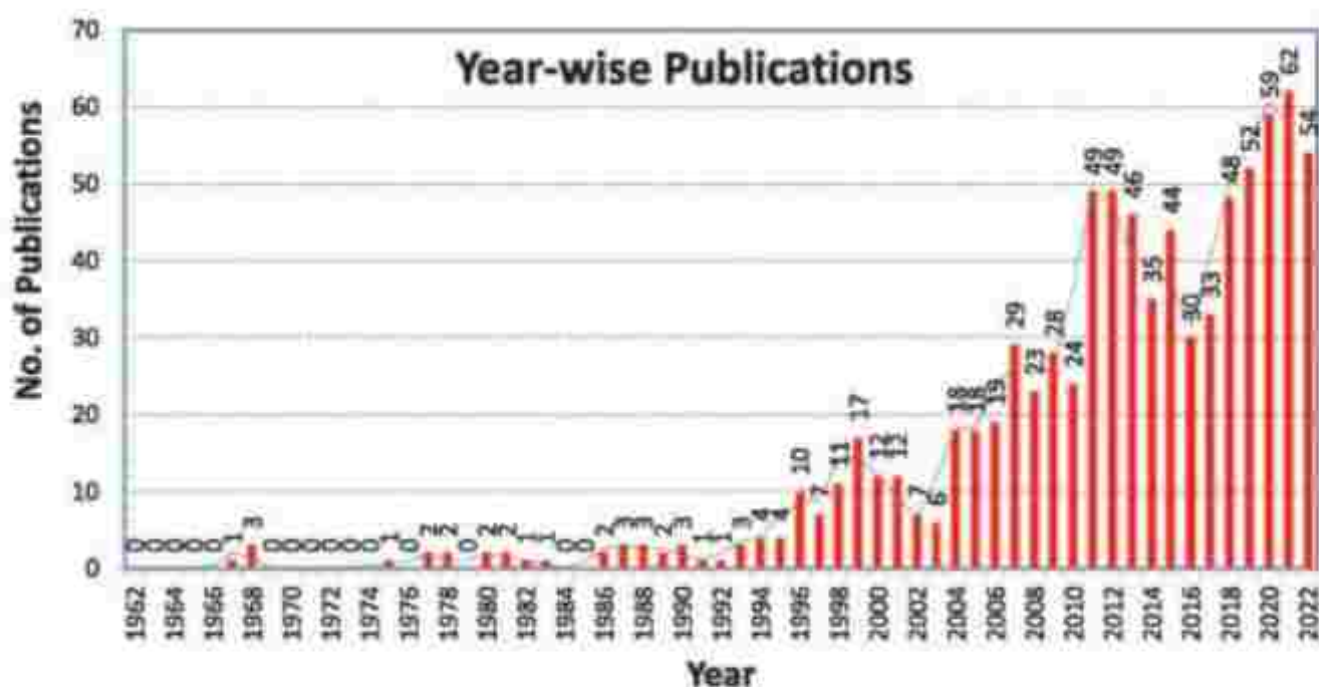


Inaugural ceremony of 7th Conference of Bangladesh Crystallographic Association

Degree Awards and Publications

M.Phil. and Ph.D. programs were started in 1982 and M.Sc. program was started in 2014 in the Department of Physics, BUET. So far, 52 Ph.D., 250 M.Phil. and 72 M.Sc. degree were awarded from this department during the last 40 years. Among these, one Ph.D., one M.Phil. and five

M.Sc. degrees were awarded in 2022. The department publishes a fair number of scientific papers in well-reputed peer reviewed journals every year. Till 2022 the number of papers published is about 830, among which 54 are published in 2022 only.



Teaching Assistantship and Postgraduate Fellowship Awardees in 2022

In April 2022 semester 12 post-graduate students received Teaching Assistantship (TA-ship) while 4 students received PG Fellowship from the Department of Physics. In October 2022 semester, 13

students got the TA-ship and 3 students obtained PG Fellowship. The remuneration is 22,000 BDT per month for TA-ship. Each of the PG fellows are awarded 30,000 BDT per month for M.Sc. program and 45,000 BDT per month for Ph.D. program.

Fellowship Awardees

Semester: April 2022		Semester: October 2022	
Name	Program	Name	Program
1. Md Shehab Chowdhury	M.Sc.	1. Md. Abdul Wadud	M.Sc.
2. S M Naimul Mamun	M.Sc.	2. Mizanur Rahman	M.Sc.
3. Salvin Mustakim	M.Sc.	3. Tawfika Nasrin	Ph.D.

Teaching Assistantship Awardees

Semester: April 2022		Semester: October 2022	
Name	Program	Name	Program
1. Md. Abdul Wadud	M.Sc.	1. Ferdous Yasmeen	M.Sc.
2. Mohasin Tarek	M.Sc.	2. Palash Dhali	M.Sc.
3. Selina Akter Lucky	M.Sc.	3. Md. Khokon Miah	M.Sc.
4. Sourav Bhowmik	M.Sc.	4. Tamanna Mostafa Sinigdha	M.Sc.
5. Israth Jahan Jeni	M.Phil.	5. Mahidul Islam Suman	M.Sc.
6. Md. Moniruzzaman	M.Sc.	6. Manisha Ahmad	M.Sc.
7. Dholon Kumar Paul	M.Sc.	7. Khalid Hossain	M.Phil.
8. Md. Asif Adib	M.Sc.	8. MD. Mahtabur Rahman	M.Sc.
9. Tania Tabassum Hredy	M.Sc.	9. Selina Akter Lucky	M.Sc.
10. K.M. Yamin Arafath	M.Sc.	10. Md. Rasel Shikder	M.Sc.
11. Mizanur Rahman	M.Sc.	11. Sourav Bhowmik	M.Sc.
12. Jannatul Ferdous Flora	M.Sc.	12. Md. Abdul Owahab	M.Sc.
		13. Dholon Kumar Paul	M.Sc.

Spotlight



Dr. Md. Abdul Momin has recently been appointed as a *Postdoctoral Scholar* at the Department of Bioengineering, University of Pittsburgh, Pennsylvania, USA. He worked as a postdoctoral researcher in the Department of Mechanical System Engineering, Tohoku University, Japan. He achieved his Ph.D. degree from the Department of Optoelectronics and Nanostructure Science, Shizuoka university, Japan in September 2020. He completed his M.Sc. degree from the Department of Physics, BUET in June 2016 under the supervision of Prof. Dr. Md. Abu Hashan Bhuiyan.



Md. Rana Hossain has completed his M.Sc. from Department of Physics, BUET, in September 2018 under the supervision of Prof. Dr. Mohammed Abdul Basith. He got the Japanese Government (MEXT) scholarship for study doctoral program in Bioengineering, Osaka University, Japan. He successfully defended his Ph.D. thesis in October 2022. Currently, he is working as a Specially Appointed Researcher at Osaka University. His research focuses on developing interatomic potential for multielement ceramics and alloys to study their plastic deformation, mainly by dislocation, twinning, and kinking mechanisms.

Achievements



A. H. M. Areef Billah has received Japanese MEXT scholarship from Japanese Government for pursuing his Ph.D. degree at Yamagata University (YU), Japan. He is working as a research assistant at the Department of Informatics and Electronics Engineering, YU. His research topic is "clean energy generation". He got his M.Sc. degree from Department of Physics, BUET in May 2016 under the supervision of Prof. Dr. Mohammed Abdul Basith.



Md. Shafiqul Islam Mollik is currently working as a Research Assistant at the Department of Physics, The University of Alabama, Birmingham, USA. His Ph.D. research is funded by the US department of Energy. He is conducting research on ultra-materials for next-generation smart electrical grids. Specifically, with phosphorous-doped diamond films to determine their spectral reaction to microwave power. He achieved his M.Sc. degree from the Department of Physics, BUET in July 2019 under the supervision of Prof. Dr. Muhammad Rakibul Islam.



Rabeya Binta Alam has started her Ph.D. program at Colorado State University, Colorado, USA from Fall 2022 semester. She is working as a Graduate Teaching Assistant in the Department of Physics, Colorado State University. She completed her

M.Sc. degree from the Department of Physics, BUET in May 2021 under the supervision of Prof. Dr. Muhammad Rakibul Islam.



Urbi Shyamolima Orchi has enrolled in a fully funded Ph.D. program with stipend at the Department of Physics and Astronomy, Ohio University, Ohio, USA. She completed her M.Sc. degree from the Department of Physics, BUET

in June 2021 under the supervision of Prof. Dr. Mohammad Abu Sayem Karal.



Md. Hasive Ahmad has got Graduate Teaching Assistantship at the Department of Physics, Colorado State University, Colorado, USA and started his Ph.D. degree program from Fall 2022 semester. He completed his M.Sc. degree in July 2021 from

the Department of Physics, BUET under the supervision of Prof. Dr. Muhammad Rakibul Islam.

“Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning.” -Albert Einstein

DEPARTMENTAL EVENTS



Teachers attended a get-together program



Open seminar of an M.Sc. student before her defense



Foreign scientist visiting our department



Teaching Assistants of April 2022 semester



Cultural program of ICFS-2022 conference



Students working in different research laboratories



Contact Address:

Head, Department of Physics
 Old Academic Building
 Bangladesh University of Engineering and Technology (BUET)
 Dhaka-1000, Bangladesh
 Telephone: +880-2-9665613; Fax: +880-2-58613046
 E-mail: headphy@phy.buet.ac.bd
 Website: www.phy.buet.ac.bd