Involved in Projects at JU (2000 to 2005)

- My Ph.D. research was devoted to the synthesis and characterizations of p-type transparent conducting $CuAlO_2$ thin films and some device fabrication (e.g. transparent diodes) from them for potential application in 'Transparent Electronics'. Most of the transparent conducting oxides (e.g. ZnO, SnO_2 etc.) are n-type. $CuAlO_2$ is the first reported p-type transparent conducting oxide thin films, which has opened up a new field in opto-electronics device technology, the so-called "Transparent Electronics", where a combination of the two types of transparent conducting oxides in the form of a p-n junction could lead to a 'functional' window, which transmits visible portion of solar radiation yet generates electricity by the absorption of UV part of it. We have synthesized this $CuAlO_2$ thin film by cost-effective direct-current (D. C.) sputtering and reactive D. C. sputtering techniques from prefabricated targets. A large part of the research was devoted to the optimization of oxygen content within the film, by controlling oxygen partial pressure during sputter deposition, to get highest p-type conductivity. The film properties were studied by XRD, EDX, SEM and TEM studies, UV-Vis-NIR and FT-IR measurements, electrical conductivity and Hall studies etc. In characterizing the films emphasis was given on the detection and physical origin of defects, impurities and measurement of the electrical effects, which they produce.[1-6]

- Successful fabrication of all-oxide transparent heterojunction thin film diode of the form p-$CuAlO_{2+x}$/n-ZnO: Al was also performed, which is the major step towards the realization of "Transparent or Invisible Electronics".[7-9]

- Also thermoelectric and field-emission properties of $CuAlO_2$ thin films were studied, which have potential applications in thermoelectric converters and field-emission displays. Being a superlattice material, $CuAlO_2$ provides the two-dimensional confinement of the electrons and phonons within the crystal lattice which enhances the thermoelectric properties of this material. Also, as a wide bandgap material, $CuAlO_2$ shows low-electron affinity which enhances the low-macroscopic field-emission properties of the material and provides the potential alternative to the conventional metallic and carbon-based field emitters.[4, 10, 11]

- Also I have worked on the fabrication of p-$CuAlO_2$ nanoparticles and first time observed the photoluminescence properties of these nanocrystalline films. These nanostructured p-TCO materials can be combined with existing and well-known n-TCO nanomaterials to form nano-

active devices, which may open up new avenues in the field of "Transparent Nanoelectronics".[12]

- Besides my Ph.D. related work, I have also devoted myself on the Sol-Gel processing of some nano-crystalline thin films, such as, doped SnO_2 (SnO_2: F/Sb), doped zinc oxide (ZnO: Al) thin films etc. Also I have worked on the wet-chemical synthesis of nano-fiber-structured ZnO thin films as well as CdS nano-particles and studied their field emission properties.[13-15]

- Another important work I have performed during my doctoral research is the deposition of transparent conducting oxide (TCO) thin films (such as ZnO) on plastic (PET) substrates for flexible display technology.[16-20]

- I have also worked on the successful fabrication of p-type semiconducting, layered-structured sodium cobalt oxide (γ-$Na_{0.71}Co_{0.96}O_2$) thin film by chemical route for potential applications in thermoelectric converters.[21]

- I have also partially worked on the preparation of some carbon and boron based thin films e.g. diamond like carbon (DLC), cubic boron nitride (cBN), carbon nitride (CN_x), diamond and nano-diamond (nD) etc. and their characterizations.[22-26]

References

1. Preparation of P-Type Transparent Conducting $CuAlO_2$ Thin Films by Reactive D.C. Sputtering; **A. N. Banerjee**, R. Maity, K. K. Chattopadhyay, Materials Letters 58 (2003) 10 - 13.
2. Synthesis and Characterization of P-Type Transparent Conducting $CuAlO_2$ Thin Film by D.C. Sputtering; **A.N. Banerjee**, S. Kundoo, K.K. Chattopadhyay, Thin Solid Films 440 (2003) 5 – 10.
3. Effect of Excess Oxygen on the Electrical Properties of Transparent P-Type Conducting $CuAlO_{2+x}$ thin films; **A. N. Banerjee**, C. K. Ghosh, K. K. Chattopadhyay, Sol. Energy Mater. Solar Cells 89 (2005) 75-83.
4. Electro-Optical Characteristics and Field-Emission Properties of Reactive D. C. Sputtered p-$CuAlO_{2+x}$ Thin Films, **A. N. Banerjee**, C. K. Ghosh, S. Das, K. K. Chattopadhyay, Physica B 370 (2005) 264-276.
5. Synthesis and Characterization of Transparent P-$CuAlO_2$ Thin Film by Reactive D. C. Sputtering for Opto-Electronic Devices. **A. N. Banerjee**, K. K. Chattopadhyay, Proceedings of the Twelfth International Workshop on the Physics of Semiconductor devices **(**IWPSD-2003**),** IIT Chennai, India, Eds. K. N. Bhat, A. DasGupta (Narosa; New Delhi) pp. 235.
6. P-Type Transparent Conducting $CuAlO_2$ Thin Films Synthesized by D.C.-Sputtering. **A.N. Banerjee**, R. Maity, S. Kundoo, K.K. Chattopadhyay, Proceedings of International Symposium on Recent Advances in Inorganic Materials **(**RAIM-2002**),** IIT Mumbai, India, Eds. D. Bahdur, S. Vitta, Om Praksh (Narosa; New Delhi), pp. 191.
7. Fabrication and Characterization of All-Oxide Heterojunction p-$CuAlO_{2+x}$/ n-$Zn_{1-x}Al_xO$ Transparent Diode for Potential Application in "Invisible Electronics"; **A. N. Banerjee,** S. Nandy, C. K. Ghosh and K. K. Chattopadhyay Thin Solid Films 515 (18) (2007) 7324-7330.
8. Electro-optical Properties of All-Oxide p-$CuAlO_2$/n-ZnO: Al Transparent Heterojunction Thin Film Diode Fabricated on Glass Substrate; **Arghya Banerjee**, K. K. Chattopadhyay, Central European J. Phys 6(1) (2008) 57-63.
9. Fabrication of p-$CuAlO_2$ / n-ZnO: Al Heterojunction Diodes for Transparent Electronics; **A. N. Banerjee**, D. Panda, K. K. Chattopadhyay, Proc. of Seventh International Conference on Optoelectronics, Fiber Optics and Photonics**,** Kochi, India (Photonics-2004).
10. Thermoelectric Properties and Electrical Characteristics of Sputter-Deposited P-$CuAlO_2$ Thin Films; **A. N. Banerjee**, R. Maity, P. K. Ghosh, K. K. Chattopadhyay, Thin Solid Films 474 (2005) 261 – 266.
11. Low-Threshold Field-Emission from Transparent P-Type Conducting $CuAlO_2$ Thin Film Prepared by D. C. Sputtering; **A. N. Banerjee**, K. K. Chattopadhyay, Applied Surface Science 225 (2004) 243 – 249.
12. Size-Dependent Optical Properties of Sputter-Deposited Nanocrystalline P-type Transparent $CuAlO_2$ Thin Films; **A. N. Banerjee**, K. K. Chattopadhyay, J. Appl. Phys 97 (2005) 084308.
13. Synthesis and Characterization of Nano-Crystalline Fluorine-Doped Tin Oxide Thin Films by Sol-Gel Method; **A. N. Banerjee**, S. Kundoo, P. Saha, K. K. Chattopadhyay. J. Sol-Gel Science and Technology 28 (2003) 105 -110.
14. Poole - Frenkel Effect in Nanocrystalline SnO_2: F Thin Films Prepared by Sol-Gel-Dip-Coating Technique; **A. N. Banerjee**, R. Maity, S. Kundoo, K.K. Chattopadhyay, Physica Status Solidi (A) 201 (2004) 983 – 989.

15. Low-Macroscopic Field Emission from Fibrous ZnO Thin Film Prepared by Catalyst-Free Solution Route; R. Maity, **A. N. Banerjee**, K. K. Chattopadhyay, Applied Surface Science 236 (2004) 231-235.
16. Low-Temperature Deposition of ZnO Thin Films on PET and Glass Substrates by DC-Sputtering Technique; **A. N. Banerjee**, C. K. Ghosh, K. K. Chattopadhyay, Hideki Minoura, Ajay K. Sarkar, Atsuya Akiba, Atsushi Kamiya, Tamio Endo, Thin Solid Films 496 (2006) 112-116.
17. Depositions of ZnO Thin Films on Glass and Plastic PET Film, Atsuya Akiba, Ajay K. Sarkar, Tamio Endo, **A. N. Banerjee**, C. K. Ghosh, K. K. Chattopadhyay, International Symposium on Surface Science and Nanotechnology, (ISSSN-2005), Omiya, Japan.
18. Ultralow Temperature Deposition of ZnO Thin Films on Plastic PET Films, A. Akiba, A. K. Sarkar, T. Endo, **A. N. Banerjee**, C. K. Ghosh, K. K. Chattopadhyay, Research Meeting on Thin Film Materials and Devices (TMFD-05), Kyoto, Japan.
19. Ultralow Temperature Deposition of ZnO Thin Films on Glass and Plastic PET Films, A. Nishio, A. Ukai, A. Akiba, M. Okada, H. Nakashima, A. K. Sarkar, T. Endo, M. Shoyama, **A. N. Banerjee**, C. K. Ghosh, K. K. Chattopadhyay, 16th Japan MRS Symposium (JMRS-2005), Tokyo, Japan.
20. Low-temperature Deposition of ZnO Thin Films on PET Substrate by DC-sputtering Technique, **A. N. Banerjee**, C. K. Ghosh, K. K. Chattopadhyay, Hideki Minoura, Ajay K. Sarkar, Atsuya Akiba, Atsushi Kamiya, Tamio Endo, Proceedings of International Symposium on Transparent Oxide Thin Films for Electronics and Optics (TOEO-05), Tokyo, Japan.
21. Wet-Chemical Synthesis of p-type γ-$Na_{0.71}Co_{0.96}O_2$ Powder and its Characterization; D. Panda, **A. N. Banerjee**, S. Saha, K. K. Chattopadhyay, Proc. of International Symposium on Advanced Materials and Processing (ISAMAP-2004), IIT Kharagpur, India, pp. 507 - 512.
22. Reduced Bias Synthesis of Cubic Boron Nitride Thin Films by Magnetically Enhanced Inductively Coupled Radio Frequency Plasma Chemical Vapor Deposition; K. K. Chattopadhyay, **A. N. Banerjee**, S. Kundoo, Materials Letters 57 (2003) 1459- 1463.
23. Synthesis and Optical Characterization of Amorphous Carbon Nitride Thin Films by Hot-Filament Assisted R.F. Plasma CVD; S. Kundoo, K. K. Chattopadhyay, **A. N. Banerjee**, S. K. Nandy, Vacuum 69 (2003) 495-500.
24. Synthesis of Crystalline Carbon Nitride Thin Films by Electrolysis of Methanol-Urea Solution; S. Kundoo, **A. N. Banerjee**, P. Saha, K. K. Chattopadhyay, Materials Letters 57 (2003) 2193-2197.
25. Synthesis of Boron Doped Diamond Films by DC Plasma CVD Using CH_4 + CO_2 + H_2 Gas Mixture at Lower Substrate Temperature and Formation of n-Si / p-Diamond Heterojunction. P. Saha, S. Kundoo, **A. N. Banerjee**, K. K. Chattopadhyay, Vacuum 72 (2004) 129 –134.
26. Synthesis and Optical Characterization of Diamond Like Carbon and Amorphous Carbon Nitride Thin Films Produced by Electrolysis of Organic Liquids. K.K. Chattopadhyay, S Kundoo, P. Saha, **A. N. Banerjee**, Proceedings of Seventh International Symposium on Advances in Electrochemical Science and Technology (ISAEST-VII-2002), Chennai, India, Ed. R. Pattabiraman (SAEST; Karaikudi) pp. D-188.