Report of the work done by Prof.K.Baskarfor the period 20 september 2011 – 21st October 2011 at Institute for Materials Research (IMR), Tohoku University, Sendai, Japan

Laboratory tour at Prof.Matsuoka laboratory has been arranged and had detailed discussions about the facilities available for the growth of InGaN materials on sapphire substrates. Two MOVPE systems are being used to grow InN and InGaN materials. The epitaxial layers are analysed by High resolution X-ray diffraction (HXRD), Photoluminescence (PL), Infrared reflectance spectroscopy, Scanning Electron Microscopy (SEM), Atomic force microscopy (AFM), and Hall measurement system. The special growth conditions, such as temperature, high V/III ratio and high reactor pressure required for the growth of good quality indium based nitrides have been discussed. The in-situ monitoring system, such as Laytech tool, required for the understanding of growth mechanism of indium nitride in MOVPE particularly the shape of the initial stage nucleation and their coalescence at higher temperature to obtain two dimensional growth have been discussed. The possible solar cell structure of InGaN for high efficiency solar cells, particularly the issues related to p-type doping and advantage to have concentrated solar cell applications due to strong bond strength between nitrogen and indium and small changes in the bandgap with temperature have been discussed.

AlGaN samples with aluminium content from twenty to seventy percent prepared by MOVPE on a two inch sapphire substrate have been cut into one square centimetre and one by two centimetre square size samples using a diamond scriber.

The samples were cleaned in acetone and isopropyl alcohol. Indium contacts were used to measure the carrier concentration and mobility using four probe method. Though the samples are undoped they exhibited n-type conduction with a carrier concentration of the order of 10^{17} cm^{-3} up to the aluminium content of thirty five percent. The higher aluminium content samples above forty percent have shown highly resistive and also difficult to measure the conduction type. The AlGaN/GaN samples with aluminium content of twenty two percent and thickness of around 80 nm have shown two dimensional electron gas (2-DEG) with a mobility of 980 cm^2 V/sec. The growth of high aluminium content samples on GaN surface is a challenge to grow without cracks and good crystalline quality due to three percent lattice mismatch between AlN and GaN. The

samples have been analysed by scanning probe microscopy. The smooth atomic surface steps, pinholes and micro-cracks have been observed depending on the aluminium content. A typical microstructure of a $Al_yGa_{1-y}N/Al_xGa_{1-x}N/$ $Al_yGa_{1-y}N$ double heterostructures (DH) on GaN/Al_2O_3 observed in AFM is shown in figure.

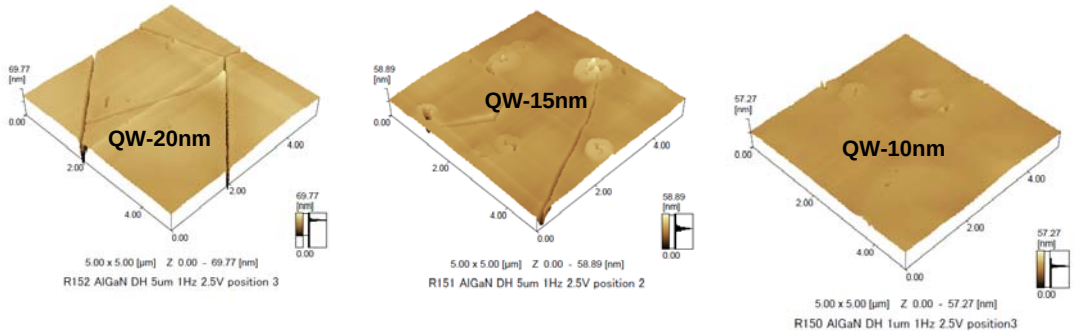

Figure..The surface morphology of AlGaN-DH with various thickness of active layer

Though the thickness of GaN buffer layer and $Al_yGa_{1-y}N$ barrier is the same, a small variation of 5 nm thickness resulted in micro-cracks and the cracks terminate at the pinholes. The micro-cracks are formed due to relaxation of strain once the critical thickness of active layer of $Al_xGa_{1-x}N$ exceeds the limit. Attempts have to be made to grow high aluminium content (Al>40 percent) contained AlGaN with crystalline quality and smooth morphology using AlN buffer with a better lattice match. Once the conditions are optimized for the AlGaN layers, the doping issues particularly p-type doping will be undertaken for the development of high efficiency ultraviolet light emitting diodes.

To promote academic exchange and cooperative research, visits were made to the following universities in Japan, Nagoya Institute of Technology, Hiroshima University, Kyushu University and Hokkaido University during 14-20 October 2011. In general all universities are eager to establish and strengthen the bilateral academic and research cooperation with Anna University, Chennai, India. As there are large number of Japanese companies in Chennai and also discussions are going on between government of Japan and Government of Tamilnadu in Chennai, India, to establish a Japanese industrial park in Chennai many institutions are looking for a trilateral cooperation between industry in Japan or India and academia of Japan and Anna University. In this connection the future

visits are expected from Hiroshima University and Kyushu University through the MEXT programme of Japanese government. Extensive discussions were made to strengthen the semiconductor research at Crystal Growth Centre of Anna University. In this connection it is proposed to have a Indo-Japan joint workshop on nitride semiconductors for electronics, photonics and photovoltaic applications in the year 2012 so that the researchers in Japan and India can join the workshop in Anna University to bring out joint deliberations on future strategy to establish strong collaborations between Indian universities/institutions and Japanese universities. The deliberations will also useful to strengthen the research on nitride semiconductors for the development of novel devices.

The organisers of the Ceremony of the declaration of international material science week 2011 on 11th October 2011 at IMR, Sendai, have invited me to participate and give brief talk.The director of IMR, professors and researchers from IMR and abroad have participated in the programme.

It was a wonderful opportunity to share some of my thoughts about the recent disaster in Fukushima, the collaborative research between IMR and Anna University, the new initiatives in the development of materials at Anna University and other things for a better future and sustained mankind.

I am thankful to IMR particularly Prof.T.Matsuoka and Anna University, India, for their support to establish active collaboration, characterisation of AlGaN and also to develop InGaN for solar cell applications.