Possible Topics of Uchino's Lecture Tour

- **Overview on Ferroelectric/Piezoelectric Devices**
  - Glory of Ferroelectric Perovskite Materials – Historical overview on ferroelectric and piezoelectric perovskite materials development, including discoveries of barium titanate (BT), lead zirconate-titanate (PZT), PMN relaxor/electrostrictor, PZN/PMN-PT single crystals etc.
  - Piezoelectric Actuator Renaissance – Recent development trends of piezoelectric actuator materials and devices are overviewed. Uchino discusses five key trends in this paper for providing the future perspectives of research trends; "*Performance to Reliability*", "*Hard to Soft*", "*Macro to Nano*", "*Homo to Hetero*" and "*Single to Multi-functional*".
  - Crisis Technologies with Piezoelectric Devices – Piezoelectric device applications to crisis technologies (warfare, terrorist attack, natural disaster, epidemic disease, enormous accident etc.) are introduced.
  - How to Develop "Best-Selling" Devices - Piezoelectric actuators have been commercialized in various areas such as information technology, robotics, bio-, medical engineering, ecological and energy engineering. This presentation discusses how to improve the "creative" ideas, followed by SWOT (strength, weakness, opportunity and threat) analysis on piezoelectric new devices, based on Michael Porter's Five Force model.
  - Entrepreneurship for Engineers – How to start-up your own entrepreneurial company, how to protect your patent, how to operate the company are practically introduced based on the case studies of Uchino's 21-year experiences as corporate president/vice president in terms of piezoelectric device developments.
  - Researchers' Misconceptions Top 10 in Piezoelectric Devices – Researchers' common misconceptions top 10 will be introduced and the correct concepts are provided for experienced professors and engineers.
- **Materials Topics**
  - Fractal Analysis in Piezoelectrics – The relationship between the domain dynamics and critical exponent and acoustic emission will be discussed based on the fractal analysis for incorporating macro- and microscopic viewpoints.
  - Size Effect on Ferroelectricity – Particle size dependence of ferroelectricity was first demonstrated by Uchino on barium titanate and lead titanate based ceramics. Thin film ferroelectrics are known to degrade their performance with reducing the film thickness. Based on these experimental results, Uchino will propose a nano-size modeling for discussing size effect on ferroelectricity.
  - Antiferroelectric Shape Memory Ceramics – Based on the antiferroelectric phenomenology, we propose enormous strain generation and shape memory functions, and their practical actuator applications are introduced.
  - Photostrictive Actuators – We invented the "photostrictive" effect by coupling anomalous photovoltaic and piezoelectric effects. Detailed experimental data are described in order to provide the device designing direction in the 21st century.
  - Magneto-electric Materials for Sensor Applications – After reviewing previous multiferroic researches, we introduce a laminate composite structure by combining a piezoelectric disk with magnetostrictive metal plates. The principle and measured performances are explained in details. Then, possible applications are introduced, including magnetic field under power cables, earthquake prediction, submarine detection etc.
  - High Power Piezoelectric Materials – The performance of high power piezoelectric materials is discussed in terms of dopants and their contribution to "domain wall pinning" and "internal

bias" effects. The data of PZT, Pb-free piezo-ceramics and PMN-PT single crystals are compared and discussed.

- Piezoelectric Composites – Design principle of two-phase composite materials/devices is introduced with particular case studies on "cymbal", "monomorph", "flexoelectric", "mageneto-electric" and "photostriction" effects.

- **Piezoelectric Characterization**
  - High Power Piezoelectric Characterization Systems (HiPoCS) – Problems and solutions of various generations of HiPoCS are introduced: Gen I = Constant voltage, Gen II = Constant current, Gen III = Constant vibration velocity, Gen IV = Precise input energy measurement, and Gen V = Burst mode method.
  - Piezoelectric Loss Characterization Method – Though IEEE Standard provides rather detailed procedure on determining the "real" parameters (permittivity, elastic compliance and piezoelectric constant), the characterization method on the losses has not been described in details yet. In particular, the piezoelectric loss is neglected, though the contribution of which to the heat generation is significant in PZT-based ceramics in practice. We will propose highly accurate methodology to determine three dielectric, elastic and piezoelectric losses separately in piezoelectric materials.
  - Piezoelectric Equivalent Circuits with Three Losses – In addition to the normal elastic loss, we proposed to include dielectric and piezoelectric losses in the IEEE Standard equivalent circuit for piezoelectric transducers. Fundamental changes in admittance spectra are discussed, and the theoretical mechanical quality factor calculation is demonstrated, suggesting the maximum Q_m frequency which is the best efficient operation frequency of the transducer.
- **Device Designing**
  - Multilayer Piezoelectric Actuators – After our invention of multilayer actuators, various internal electrode configurations and their manufacturing processes were developed. We will discuss pros/cons of these electrode configurations in terms of cost, performance and reliability, and base metal electrode and structured ceramic usage are also introduced.
  - Photonic Devices with Electrooptic and Piezoelectric Effect – Some of ferroelectric materials such as PLZT, PMN-PT, Lithium Niobate and $K(Ta,Nb)O_3$ single crystals exhibit superior electrooptic effect. Designing principle of photonic devices such as light valves, optical switches, wave-guides, and 2-D displays will be introduced with using electrooptic effect. Some designs for light scan with piezoelectric actuators are also promising in the future.
  - Drive Techniques of Piezo-Actuators – Piezoelectric actuators are driven by either (1) pseudo-DC, (2) pulse, or (3) resonance-AC voltages. Special pulse drive techniques we invented are introduced in particular in this presentation: a) how to suppress vibration overshoot and/or ringing with adjusting the pulse shape, and b) saw-tooth shape displacement generation from an asymmetric pulse voltage at their resonance frequency for inertial piezo-motor applications. Another unique resonating transducer drive includes the "inductive" operation of the piezo-transducer at a frequency between the resonance and antiresonance modes.
  - Catastrophe Phenomena and Non-Linear Vibrations – Unique nonlinear vibrations observed in piezoelectric devices are discussed from the theoretical viewpoint, then their application possibilities will be introduced. Suitable to a long tutorial lecture.
  - Tutorial: How to Use ATILA FEM Software Code – One-day tutorial lecture on how to use ATILA Finite Element Analysis software code, which is one of the highly sophisticated programs including three loss factors and materials data bank. Using a specially licensed digital key (courtesy by Micromechatronics Inc.), Uchino will instruct: (1) background of

piezoelectric devices, (2) how to draw the piezo-device designs, (3) meshing techniques, (3) data analysis of the simulation. Suitable to a long tutorial lecture, in particular for engineers with materials, electrical background, who have not used any FEM software.

- **Application Topics**
  - Piezoelectric Ultrasonic Motors – The principle and various categories of piezoelectric ultrasonic motors are overviewed. Then, various applications are introduced.
  - Piezoelectric Transformers – The principle and various types of piezoelectric transformers and introduced. Designing methods for specific applications are also detailed, including laptop backlight inverters (step-up) and adaptors (step-down).
  - Piezoelectric Energy Harvesting Systems – Development principle will be instructed according to three phases: mechanical-mechanical energy transmission, mechanical-electrical energy transduction, and electrical-electrical energy transmission to rechargeable batteries. The key is the energy flow analysis with high electromechanical coupling factor devices.
  - Piezoelectric Devices for Medical Applications – Various medical applications of piezoelectric devices are introduced, including medical acoustic imaging system, micro blood-clot remover, surgery knives, transdermal drug delivery, prosthetic arms, and MRI drive mechanisms.
  - Piezoelectric Devices for Automobile Applications – Various automobile applications of piezoelectric devices are introduced, including distance sensors, gyro sensors, electronic modulated suspension system, seat/pillow moving mechanisms, diesel injection valves, energy harvesting systems etc.
  - Piezoelectric Compact Camera Modules – The current target of the camera phone manufacturers is an optical zoom mechanism followed by the auto-focusing function. The auto focus requires only 0.2 mm motion of the lens, on the other hand the optical zoom requires a stroke more than 2 mm. These specs can be realized either by a micro ultrasonic motor (USM) or an impulse/inertial piezoelectric motor. This paper reviews present applications of piezoelectric micro-motors for cellular phone camera modules, and foresee future design possibilities.
  - Piezoelectric Printers: Overview – We will review the printer applications of the piezoelectric actuators, started from historical dot-matrix printers, to inkjet printers. Inkjet fine mist generation technique with the double-pulse drive method is introduced. A typical unimorph design is compared with the new multilayer type from the performance viewpoint.

- **Since I have both 1-hour short and 2-hour long versions for most of the above presentation topics, you may ask me to create a presentation by combining multiple number of topics.**