Construction of Inorganic-Organic Nanostructured Sensing Plate

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A visual sensing plate, whose color transferred by the penetration of organic molecules, has been developed by construction of SiO_2-polypeptide bilayer. Poly(n-hexyl-L-glutamate), which is α-helical rod-like polypeptide, repeatedly deposited on SiO_2 substrate by Langmuir-Blodgett method to give polypeptide-SiO_2 bilayer. Since the obtained film was constructed by two layers with different refractive index, a clear color was appeared by the interference of visible light. The color of the film was changed depending on the number of the polypeptide layers. The color also changed when the film was immersed into various organic solvent, where the polypeptide layer gained its thickness by swelling. It was suggested that the change of the thickness of the polypeptide layer was corresponding to the color change. These color changes were successfully detected by reflective UV-vis spectrum. It could be estimated the degree of the color change quantitatively. Thus, a sensing system of organic molecules could be achieved by the constructed film and the reflective UV-vis spectrum. To demonstrate the sensing ability, the color change of the film, when the film immersed into *p*-n-butylphenol as a model for an endocrine disruptor, was investigated. Yellowish color of the film immediately transferred into blue after soaking the film into *p*-n-butylphenol. It was suggested that the film successfully detected the penetration of *p*-n-butylphenol. It was expected that the constructed film could be applied as a sensing plate for various organic molecules, because of diversity of polypeptide layer.

Resistive Oxygen Gas Sensor Using Cerium Oxide Thick Film

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Recently, resistive oxygen sensors are drawing the attention again for new applications because of their simpler structure and smaller size compared to conventional oxygen gas sensors using concentration cells consisting of oxygen-ion-conductor. The oxygen gas sensors for automotive exhaust gas need not only small size but also fast response in order to control the air to fuel ratio of each cylinder in an engine completely. The response time is expected to be shorter when the particle size of cerium oxide thick film decreases, because diffusion distance decreases and the area of reaction increases with decreasing the particle size of thick film.

We fabricated the resistive oxygen gas sensors based on cerium oxide (ceria) thick film with fine particle size and investigated the sensor property including fast response. The sensors were fabricated by screen-printing method. The screen-printed thick films were calcined at 773 K and fired in air at 1373-1573 K.

The SEM observation showed the neck growth and the three-dimensional network-structure of ceria. The resistance of the cerium oxide thick film with the grain size of 120 nm was almost proportional to $P(O_2)^{1/6}$ in wide range (10^{-13} -10^{5} Pa). The response time (t_{90}) decreased with decreasing grain size and/or increasing temperature. The value of t_{90} was 22 and 12 ms at 1073 and 1173 K, respectively. The value of t_{90} of ceria thick film doped with 20 mol% Zr was 9 ms at 1073 K. The ceria porous thick film has the potential to be used for individual-cylinder balancing during combustion.

Preparation and Characterization of buffer for DNA electrophoresis separation by using SiO_2 nano particles

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A micro-capillary electrophoresis (μ-CE) using monodispersed SiO_2 ceramic nano-particles added electrophoresis buffer solution was studied in order to obtain high-mobility and high-separation of double strand deoxyribonucleic acid (dsDNA). SiO_2 monodispersed nano particle was prepared by Stöber process, and was controlled particle diameter by controlling $[NH_3]$/[TEOS] and $[H_2O]$/[TEOS]. In this study, we obtained the various size monodispersed SiO_2 nano-particles in the ranging from 20 to 160 nm. Various particle sizes and amounts of monodispersed SiO_2 nano-particle solutions were mixed with conventional 0.7% hydroxyl propyl methyl cellulose (HPMC) buffer solution for μ-CE. As a result, dsDNA specimen including longer fragments (100 bp ~ 1.5 kbp) is clearly separated by μ-CE using monodispersed SiO_2 nano-particles added HPMC buffer solution. It seems that the mobility and separation strongly depend upon the SiO_2 particle distance. In this study, the best results of separation of the DNA fragments was obtained using the solution with 500 nm of particle distance, which is smaller size compared with the larger radius peak of gyration of DNA specimen. In conclude, appropriate addition of SiO_2 nano-particles could reduce the friction coefficient effectively, and results higher mobility and separation of DNA fragments.

Pattern-deposition of ZnO by soft-lithography technique

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Many recent researches for gas-sensing materials are constructing systems on a single chip, with many kinds of microsensing devices. By such chip technology, highly functional multisensor systems can be realized. For the fabrication the microsystem, site-selective patterning of sensing materials is expected. In the present study, we have focused the pattern deposition of ZnO, which is the one of the typical semiconductor ceramic sensor materials.

We tried to fabricate micropattern by soft-lithography technique at low-temperatures. ZnO line patterns were prepared on patterned self-assembled monolayer (SAM) template, with phenyl and OH-terminated surfaces. Pd/Sn colloid, which is used as catalyst for electroless plating of metals, was adhered to the phenyl-surfaces. ZnO was grown on the catalyzed phenyl-surfaces by the electroless deposition method in an aqueous solution containing dimethylamine-borane. The morphology of the ZnO film and the deposition manner of ZnO on the Pd catalyst was discussed.

Development of Infrared Sensor of Dielectric Bolometer Mode

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Recently, considerable attention has been directed toward uncooled thermal-type infrared (IR) sensor. Especially, among the uncooled ones, dielectric bolometer (DB) mode shows merits in high sensitivity and low-power consumption with chopperless and room-temperature operation. Figure 1 shows an example of temperature dependence of relative permittivity and polarization for a ferroelectric material whose Curie temperature (T_c) is around ambient temperature. As similar to resistive bolometer, temperature change can be detected through the change in the permittivity in the vicinity of T_c, where both the sloping regions are available to use as IR sensing. In order to improve the performance of the IR sensor of DB mode, it is essential that 1) IR sensing material in the detecting capacitor exhibits high temperature coefficient of dielectric constant (TCD) with a low dielectric loss around the room temperature, 2) the detecting capacitor has both excellent thermal insulation and IR absorption. We have made so far a successful DB with IR detecting ferroelectric thin film such as $(Ba_{1-x},Sr_x)TiO_3$, and $Ba(Ti_{1-x},Sn_x)O_3$ where excellent figure-of-merits such as voltage sensitivity (R_v) and specific detectivity (D^*) were obtained, and some 2-D array sensors were fabricated (e.g. Fig. 2) and demonstrated good IR responses.

In this presentation, we will report mainly on the followings; 1) the IR detecting ferroelectric thin films prepared by metal-organic decomposition (MOD) and pulsed laser deposition, 2) thermally insulated structure for the detector by using Si bulk or surface bulk-micromachining processes, 3) a new type of sensing system for the 2-D array sensor using field programmable gate array (FPGA), and 4) various characteristics of the DB such as IR response.

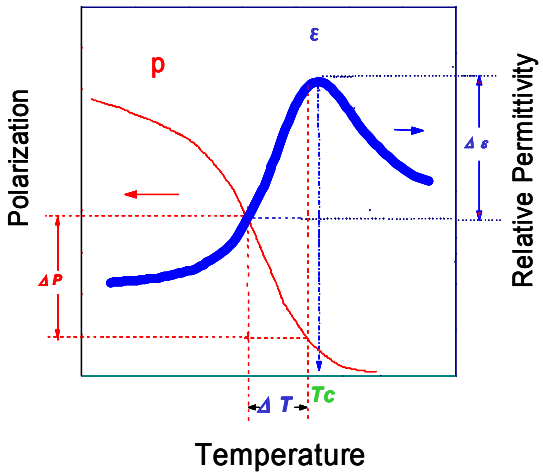

Fig. 1 Bolometric properties of a ferroelectric material.

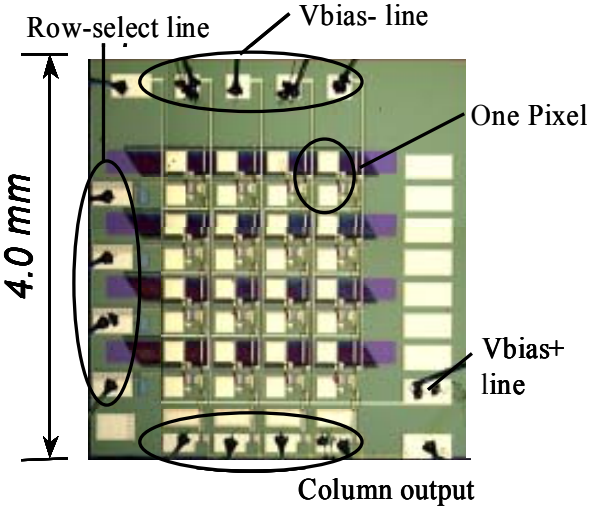

Fig. 2 Photograph of a fabricated image sensor chip(4×4).

Metal-Semiconductor-Metal devices on diamond crystals for the UV detection

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There is a growing need for ultraviolet (UV) detectors being blind to optical visible light. In particular it will encompass the next generation photolithography, flame monitoring, gas monitoring, bio-medical applications, petrochemical applications, atmospheric ozone-level detection and military applications. Current photodetectors based on semiconductor silicon have reached their limits and a new generation is required. Semiconductor diamond material is a very attractive material for the fabrication of UV detectors. Its wide band gap (5.5 eV) ensures good transparency and weak photosensitivity at wavelengths in the visible range (solar blindness) and a high sensitivity in the UV range ($\lambda < 225$ nm). In this study, metal-semiconductor-metal (MSM) planar devices have been fabricated by standard photolithography process on different diamond crystals: IIa, Ib and homoepitaxial boron-doped diamond film grown on Ib substrate. The best performances have been obtained for an as-grown homoepitaxial boron-doped diamond thin film, which is characterized by a high ultraviolet photocurrent at 220 nm, seven orders of magnitude higher than the reverse dark current (<1 pA) for at least an applied voltage of ±0.4 V. The spectral photoresponse displays over six orders of magnitude discrimination between deep ultraviolet (210 nm) and visible light (630 nm), and reveals a shoulder with a threshold at 4.6 eV.

Refractory metal carbide as thermally stable Schottky contact of diamond photosensor for deep-ultraviolet detection

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Development of thermally stable electrode contacts is an essential step toward diamond Schottky photodiodes able to operate at high temperatures as deep-ultraviolet (DUV) sensor. In this work, we have used tungsten carbide (WC) Schottky and Ti/WC ohmic contacts for the fabrication of DUV photodiodes on lightly boron-doped homoepitaxial diamond thin films. The device structure consists of a 420 μm diameter WC Schottky dot separated 10 μm radially from the Ti/WC ohmic contact. The stability of the electrical rectifying properties of the photodiodes upon isothermal annealing at 500 ^{o}C for 5 h with an interval of 1 h is demonstrated. The ideality factor is improved to be unity after annealing for 1 h, and increases to around 1.5 after subsequent annealing for longer time durations. The leakage current at a reverse bias of 30 V is as small as below 10^{-14} A before and after annealing for 4 h, and increases to only 10^{-12} A after 5 h. The influence of the annealing on the optical properties is also investigated. The photoresponsivity at 220 nm is enhanced dramatically by a factor of 10^{3} after the annealing, resulting in a DUV/visible blind ratio of approximately 10^{6} at 2 V reverse bias.

Direct detection of Single Nucleotide Polymorphism Using genetic Field Effect Transistor

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The novel concept of a genetic field effect transistor (FET) is proposed in the present study for improving precision, standardization and miniaturization of a DNA chip system. The genetic FET is composed of Si with Si_3N_4/SiO_2 as the gate insulator on which DNA probes are immobilized and subsequently hybridized with target DNA in sample solutions. The potentiometric detection method is based on the direct transduction of surface density change of charged biomolecules into electrical signal by the field effect and is effective for charged species such as DNA molecules. we report the concept of genetic FET and the ability of SNP genotyping by controlling hybridization temperatures, and by the utilization of intercalator or primer extension reaction using the genetic FET.

The genetic FET is immersed in a measurement solution together with a Ag/AgCl reference electrode with saturated KCl solution. The potential of a measurement solution is controlled by the reference electrode. Oligonucleotide probes are immobilized on the gate surface. When target DNA are contained in a sample solution, hybridization occurs at the surface of the gate area. Since DNA molecules are negatively charged in an aqueous solution, they electrostatically interact with electrons in Si crystal through the thin gate insulator. As a result of the interaction, hybridization reaction can be detected in principle by measuring the change in the electrical characteristics of the FET, such as the threshold voltage (V_T) shift at constant I_D.

Using the genetic FET, single nucleotide polymorphism (SNP) genotyping could be realized by controlling hybridization temperatures, and by utilizing intercalator and primer extension reaction.

Nano-Design of Electrode Structure for High Sensitivity NO_2 Sensor Using WO_3 Thick Film

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The effects of nano-gap size on dilute NO_2 sensing properties have been investigated for WO_3 thin film nanosensors. Nano-gap electrodes with various gap sizes (110-1500 nm) were fabricated by means of MEMS techniques (photolithography and FIB techniques). The WO_3 thin film was deposited on the nano-gap electrode by using suspension dropping method to be nano-gas-sensor. The sensing properties to dilute NO_2 of WO_3 thin film nanosensors were measured in the range of 0.01-3 ppm at 200 °C. The sensitivities to dilute NO_2 are shown in Fig. 1 as a function of gap-size. The sensitivity to dilute NO_2 was almost unchanged irrespective of gap-size larger than 800 nm. On the other hand, the sensitivity tended to increase with decreasing gap size less than 800 nm. The highest sensitivity (S=57 to 0.5 ppm NO_2) was obtained for the nanosensor with gap size of 110 nm. The sensitivity was expected to increase further when the small gap-size less than 100 nm was realized. The effect of micro-gap was explained with related to the number of WO_3 grains included in the gap and the resistance changes at electrode-oxide interface and at grain boundary.

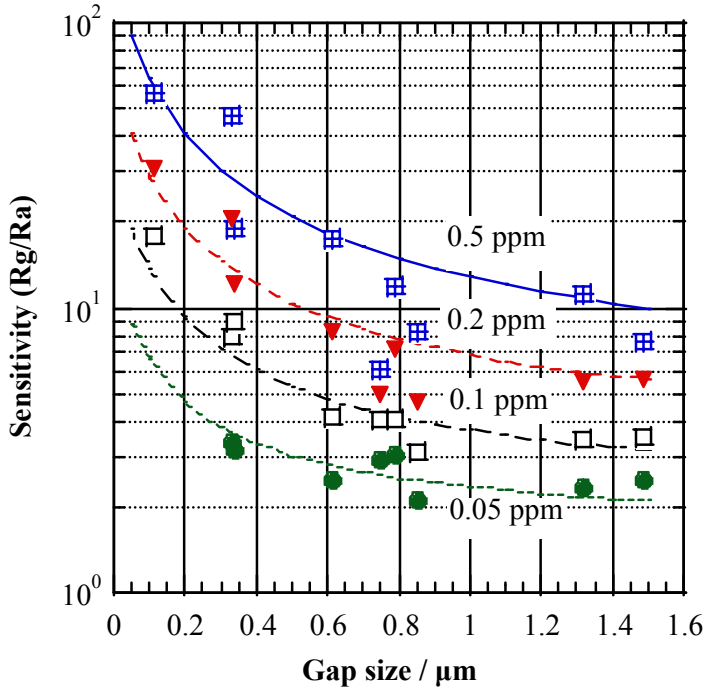

Fig. 1 Sensitivities to dilute NO_2 of WO_3 nanosensors as a function of gap-size (operating temperature : 200 ℃).

Development of High Heat Resistant AE Sensor

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Aluminum nitride (AlN) is a promising AE sensor element for high temperature environments like gas turbines and other plants because AlN maintains its piezoelectricity up to 1200˚C. Highly *c*-axis-oriented AlN thin film sensor elements were prepared on silicon single crystal by rf magnetron sputtering. High temperature AE sensors were developed using these elements. (Figure 1) The sensor characteristics were evaluated at elevated temperatures from 200 to 600˚C using oscillation of continuous waves generated by a commercial AE sensor at the frequencies between 10 kHz and 1 MHz. The signals of the generated wave and the high temperature AE sensor at 500˚C were shown in Figure 2. It was confirmed that the AE sensor worked at 600˚C and was not deteriorated after elevation to 600˚C. But its sensitivity was still low and the structure of the AE sensor case should be improved.

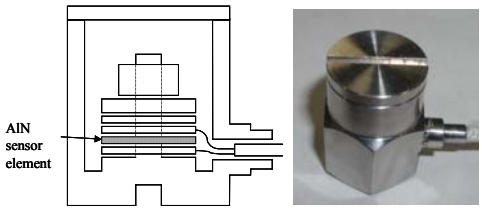

Figure.1 Diagram and photo of high temperature AE sensor.

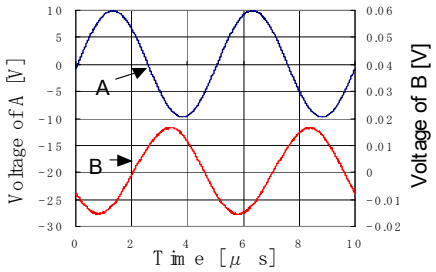

Figure.2 Signals of a generated wave (A: sinusoid 0.2[MHz]) and the high temperature AE sensor (B) at 500℃.

A novel metal oxide thin film process for infrared and gas sensors

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Abstract

Metal-oxide thin films are largely investigated as suitable materials for various sensor technologies. Recently, we have developed the excimer laser assisted metal organic deposition (ELAMOD) for the preparation of the metal oxide thin films. These processes have become very promising methods to prepare the metal oxide thin films for various sensors, because it is possible to fabricate the patterned epitaxial and polycrystalline oxide films at low temperature, and to control the surface morphology. Using this technique, the epitaxial $La_{1-x}Sr_xMnO_3$ (LSMO) films on $SrTiO_3$ (STO) substrate for the infrared sensor have successfully obtained by a ArF laser irradiation at 500℃. The effects of the laser fluence, the irradiation time and the film thickness on the temperature coefficient of resistance (TCR) were investigated. The epitaxial LSMO/STO film obtained by the ELAMOD at 500℃ with ArF laser irradiation at 100mJ/cm^2 for 60min (film thickness = 80nm) showed a metallic temperature dependence of the resistance, and had a maximum TCR of 4.0% at 275K. Likewise, the preparation of the SnO_2 films for gas sensor has been investigated by an ELAMOD. The product films were characterized by the XRD and AFM measurements. The epitaxial and polycrystalline films were obtained by an excimer laser irradiation at room temperature. It was found that the nanostructures and morphology of the SnO_2 films depend on the starting material and irradiation condition.

This study was supported by the Industrial Technology Research Grant Program in 2004 from the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

Improvement of the temporal response and output uniformity of polycrystalline CdZnTe films for high sensitivity X-ray imaging

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Abstract

X-ray detectors that we developed utilizing polycrystalline CdZnTe films exhibited superior sensitivity, but not adequate temporal response and output uniformity for medical imaging purposes. In order to improve those deficiencies, we tested new procedure for deposition and post-deposition chemical-heat treatment of polycrystalline CdZnTe films, in addition to investigating new device structure. We doped the polycrystalline CdZnTe films with Cl in a manner so as to achieve grain boundary passivation. We fabricated and evaluated devices with a replaced barrier layer against charge injection under negative bias. All these measures helped reduce from 40% to 15% the temporal lag (after 1 s) of a 300 μm thick polycrystalline CdZnTe film exposed to continual X-ray irradiation at 80 kV, 1.2 mR/s for 60 s. The output uniformity (defined as the ratio of standard deviation to average signal output) of a detector containing this polycrystalline CdZnTe film decreased from 90% to 23%. Moreover, polycrystalline CdZnTe films that were Cl-doped by our new procedure were found to have a finer and more uniform grain structure. Though some problems remain, we have succeeded in improving the X-ray temporal response and output uniformity of a 300 μm thick CdZnTe film.

Clinical Utility of Pulse Wave Measurement for Prevention of lifestyle disease

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Hypertension, hyperlipidemia, diabetes mellitus and obesity, all of these lifestyle diseases advance arteriosclerosis and cause a cardiovascular event. It is said that the event can be greatly reduced by improvement of lifestyle or medication.

Recently, pulse wave measurement and pulse wave analysis advanced by improvement of bio-sensing technology. The Augmentation Index (AI) is defined in the ratio of the amplitude of the reflected wave to ejection wave. It is known that this index was relating not only an arterial stiffness but also a cardiac load.

In the past, the pulse waveform was measured by using catheter with invasive technique. Recently, we developed the device which enables measuring of the pulse wave of a radial artery by the non-invasive technique with the tonometry method. To confirm fidelity, we measured aorta and radial pulse waveform simultaneously and compared each pulse waveform. As a result of comparing each pulse waveform within each subject, correlation coefficient was more than $r = 0.90$.

The newly developed device enables us AI measurement easily and contributes to get the useful clinical evidences. It is expected that further study with pulse wave measurement will be useful to medical and health care.

Sensor Systems for Structural Health Monitoring

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Fiber optic sensing based on Brillouin Scattering is the state of the art for measuring distributed strain in structures, and recognized as suitable sensor system for the "Structural Health Monitoring System". In this report, the authors applied two types of Brillouin optical sensors, BOTDR and BOCDA, for crack detection in concrete structures. BOTDR (Brillouin Optical Time Domain Reflectometer) is conventional pulse-based sensor having spatial resolution of about 1m and measurable length of about 10km, and is suitable for measuring strain distribution in total length of structure. BOCDA (Brillouin Optical Correlation Domain Analysis) is newly developed correlation-based sensor having spatial resolution of about 1cm and measurable length of about 1m, and is suitable for detecting crack in the narrowed zone by BOTDR.

Bending test on reinforced concrete slab has been conducted to verify sensing performance of BOTDR. Optical fiber with FRP coating was installed along longitudinal reinforcement. The measured strain distribution was in good agreement with that by strain gauge attached on reinforcement.

Then, tensile test on concrete specimen has been conducted to verify sensing performance of BOCDA. This sensor turned out to be effective for measuring crack induced strain in concrete (Figure 1). The crack width estimated using this sensor was in good agreement with that by displacement gauge (Figure 2).

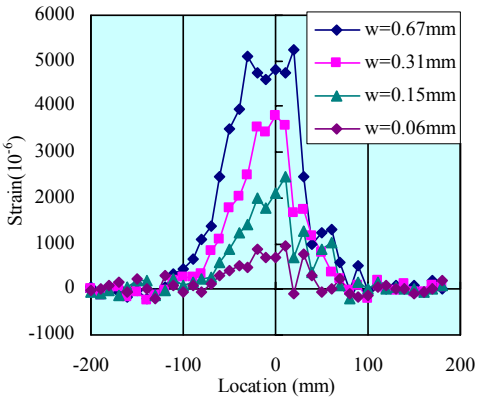

Figure 1 Crack induced strain on tensile test

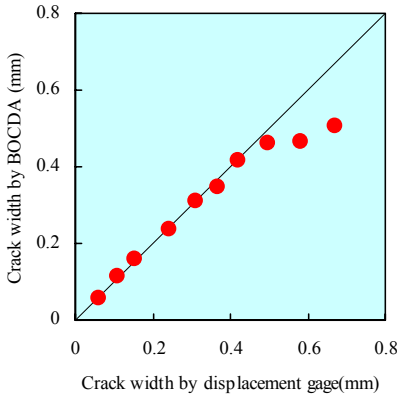

Figure 2 Crack width on tensile test

Magnetic Foreign Substance Detection System using High Tc SQUID

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"Safety on food" is a critical issue these days. Besides pathogens, inclusions such as metals, bugs, human hair are strictly checked and eliminated in the factory lines. Metal detectors are commonly used every food line. However, high sensitivity and the same for thick products are strongly desired because of the limitation of conventional technology. Furthermore, inclusions in metal sealed products can not be detected by the metal detector using an eddy current method. Recently X-ray systems penetrate the market for their high sensitiveness. However, the X-ray system has high running cost and is unsuitable for thick products. Since most of the metals in food industries are stainless steel which has magnetism originally or will have magnetism after the fatigue, we focus attention on using SQUID as a detector. SQUID has highest sensitivity in existing magnetic sensors. When using the SQUID, we can be inconsequential for the package materials and product conditions. We developed two sizes of the detection systems for small products and large products and evaluated their detection abilities. It is demonstrated that the large system can detect 0.7mm diameter and 2mm long stainless needle with the lift off distance of 225mm, and the small system can detect 0.3mm diameter stainless steel ball with the lift off distance of 80mm. Conventional metal detectors can detect few centimeters of stainless needle and more than 1mm diameter stainless steel ball for the same lift off distances. We have installed the SQUID systems in the factories and verified to work in the factory environments.

A Sensing Network using Multiple Robots: Objectives and Protocols

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Tokyo Denki University

In this poster, we will present the details about the WISER project at Tokyo Denki University. The goal of this project is establishing a scheduling algorithm of multiple robots and network protocols especially tailored to collaborative sensing. The scheduling algorithm deals with energy efficiency in addition to wide coverage of gathered data. The network protocols accommodate intentional mobility, delay and disconnection tolerance, which were not observed in conventional wireless ad hoc networks.

Dynamic Power Saving Routing for Multihop RFID Systems

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Abstract

Active Radio Frequency IDentification (RFID) nodes with sensors/actuators can be connected to become wireless networks. For wide-spread wireless sensor networks, multihop is necessary. Generally in wireless sensor networks, energy budget of node is limited and data is concentrated at certain nodes (for example, the gateway that is connected with the fixed networks). If the route is static, nodes that relay more data from nodes on the downstream route, in other words, nodes that are near by the gateway consume more power, and then will die early. As the result, many nodes lose the route to transmit data to the gateway. Therefore, the routing algorithm that considers power consumption is necessary.

We propose dynamic power saving routing algorithms to optimize various network requirements; for example, I) to minimize total power consumption to reduce total power consumption; II) to make lifetime of nodes fairly to make nodes died at almost same time, and so on. We implement several routing algorithms, and in our implementation, we can check remained energy of each node and selected route in real time. Our algorithms might be better about maintenance cost because we can change many batteries at same time.