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Prof. Song-Yuan Ko received NSC Excellent Project Award with Technology of Storing ECG Data on the Cloud System

*The technology allows instant upload of ECG data via Bluetooth and smartphones, and the automatic reading technology is under development.*

Cloud computing and smartphones have shed new light on the research of medical data transmission. Mr. Song-Yuan Ko, the associate professor of the Dept. of Information Engineering at I-Shou University, has developed the technology of transmitting ECG (Electrocardiogram) data through cloud computing and smartphones, so doctors can receive the ECG data of the patients immediately. With the application of this technology, the automatic reading technology that reminds patients with ECG abnormality to conduct medical checks can be further developed. The research project receives the NSC (National Science Council) Excellent Project Award for Projects on Free Software & Embedded System of 2010, and the award ceremony is held on August 31, 2012 at the Technology Building in Taipei (NSC).

In the past, patients with cardiac problems have to receive the ECG test at professional medical institutions, and people with potential heart attack may not be able to detect cardiac problems earlier due to the lack of time or other reasons. Besides, many of the cardiac symptoms may occur intermittently or suddenly. In other words, patients may feel chest tightness or irregular heartbeats
when the symptoms occur, but the symptoms may disappear when patients go for a physical examination at the medical institutions.

The method combines cloud computing technology and android phones to develop a portable ECG data control system, allowing users to record their ECG data from time to time. Moreover, users can record the time, activity engaged in, symptoms and GPS latitudes when they feel uncomfortable. Users can record the ECG data on their own when the symptoms occur and transfer the ECG data to the cloud system via their smartphones, so medical employees can understand patients’ symptoms by reading the data through the Internet, which could help reduce the chances of heart diseases. In addition, the equipment can track the results of cardio-vascular-related medicines, which not only help cure cardiac diseases but also reduce the chance of receiving wrong medication as well as lower the medical cost. The research project was also recommended by NSC for participation in the 2011 Taipei Int’l Invention Show & Technomart.

“Heart disease is the top second cause of death among Taiwanese people, and the ECG data are effective in understanding heart conditions. Now, we are having discussions on industry-university collaboration with hospitals and manufacturers for cloud media set-top box, and we aim to further develop technologies for automatic reading of ECG data so as to achieve effective home healthcare,” said Prof. Song-Yuan Ko.

“By combining the android phones and the cloud computing technique (Hadoop), the physical conditions of the patients/users can be stored in the same storage device for further research and analysis. The technology not only allows the access among users, but improves the pathological research with actual patient conditions,” said Mr. Gang-Min Wang, an alumnus from the Dept. of Information Engineering at I-Shou University, who participated in the research project and received the “Award of Complete Design” in the 2011 Embedded System Design Contest held by the Ministry of Education.

Mr. Wei-Cheng Lian, another alumnus who also participated in the project and the contest, said, “It is my very first experience of developing a new system with software engineering techniques. I really have learned a lot in the project control from this experience, as I have to draft up the project items, arrange schedules, analyze system requirements, establish testing environments and conduct final testing.”
Shi-Hao Lian of ISU International Tourism & Hospitality Won the First Prize in TPO Tourism Universiade in Korea

*Turning the passion for culinary arts with Taiwanese delicacies into a glory for ISU*

A group of students from colleges in Kaohsiung joined the 2012 Tourism Universiade, which took place in Korea in late July to participate in the cooking and tourism product planning contests. Shi-Hao Lian, a student from the Dept. of International Tourism & Hospitality of I-Shou University, won the championship for the cooking contest with four Taiwanese delicacies.

The exchange event is jointly organized by Tourism Promotion Organization for Asia Pacific Cities (TPO), Busan City Government and Youngsan University in Korea to invite undergraduate and graduate students from colleges in Asia Pacific cities to conduct exchange on cooking and tourism product planning. With the invitation of Kaohsiung City Tourism Bureau, a group of students majoring in tourism & hospitality represented Kaohsiung City to participate in the great event. Moreover, Shi-Hao Lian from the Dept. of International Tourism & Hospitality at I-Shou University and Xing-Lin Wu from National Kaohsiung University of Hospitality & Tourism won the first prize among the 20 teams participated in the cooking contest.

“To underline the food culture of Kaohsiung, we have decided to prepare Karasumi slices with 

![Award receiving photo](image-url)
Apple slices, fried shrimp balls with mango Mayonnaise and Roselle Jam, Pork chops with Plum Sauce, and Anka (red yeast) fried rice with Karusumi slices and Sergestid Shrimp,” said Lian, as participants for the cooking contest are required to prepare competition menus in advance. In addition, the participants have to overcome the difference in ingredients and cooking materials between Taiwan and Korea since the cooking contest is organized in Korea. Lian said, “There is a clear difference in ingredients between Taiwan and Korea. For instance, the size of scallion and garlic sprouts in Korea is extremely different from those used in Taiwan, and the size of shrimps is quite similar to that of prawns. Moreover, we don’t have a multifunction oven or an electric rice cooker, so we even used a bamboo steamer instead to cook rice. We want to thank the staff for double-checking the ingredients and materials before the contest and helping find things we can use.”

As for his passion for cooking, Lian said, “I enjoy watching cooking shows on TV, and I often visit recipe websites, buy recipes and discuss cooking techniques with family members from time to time. Also, I often cook for my family to improve my skills.” Lian also talked about his studying at ISU as well as about the future development, “The courses at the Dept. of International Tourism & Hospitality at ISU are all taught in English, and most of the teachers are international teachers who often share their experiences in the class. Further, I can also broaden my horizons by participating in contests, as I have to exchange ideas with other participants from different countries in English. I’m currently working at the Crowne Plaza Kaohsiung E-DA World Hotel as a part-time waiter, and I hope I can get a professional job after graduating and taking an examination for a professional certificate. With the experience of participating in this contest, I also find there are more professional knowledge and skills I need to acquire in the future.”

According to Chair Hong-Hui Pan of the Dept. of International Tourism & Hospitality at I-Shou University, “Our department offers courses taught entirely in English to improve students’ competitiveness in the international arena, and we also encourage students to participate in contests organized at home and abroad to enhance their professionalism, so Lian’s performance and achievements in the contest is considered a good example for the students of the Department.”
Notable Success in Promoting Japanese Haiku: Double Achievements by Department of Applied Japanese, I-Shou University

Students of the Department of Applied Japanese, I-Shou University, scored a triumph at a Japanese haiku competition in Japan. Zong-Ying Yang and another nine students of the Department of Applied Japanese won Honorable Mention and other awards in the 23rd Ito En Oi Ocha New Haiku Competition held by Ito En, Ltd., a Japanese multinational beverage company from Japan. The award-winning works of haiku will be printed on PET containers of Ito En tea products to be released this winter.

Haiku is a very short form of Japanese poetry which lays great emphasis on artistic ambience and atmosphere. For example, the haiku, “Drinking alone in the winter, feeling his desolation and loneliness, even the bright moon shining in the winter night cannot dispel the loneliness; the Sake warmed him up, but he might feel the chill of winter more easily,” penned by Zong-Ying Yang on the theme of drinking in the winter, appropriately conveys the loneliness one feels in the bleak wintertime. Printed on PET bottles of Ito En tea products to be released this winter, this poetic work will surely warm people deeply.

In addition, this year also saw the 3rd Inter-University Japanese Haiku Competition hosted by I-Shou University. What makes the 3rd competition special for this year is that the main theme involves Yoichi Hatta, a Japanese engineer known for his major contributions to agricultural development in southern Taiwan. This year marks the 70th anniversary of his death. The Department also made headlines for publishing the third edition of the magazine TAIWAN HAIKU: Eucalyptus on the international pages of Yomiuri Shimbun, a Japanese newspaper which has the largest circulation in Japan. “All faculty members and students were extraordinarily excited and proud when knowing that I-Shou University made headlines on an international newspaper,” said Dr. Shou-Ai Lee, Chair of the Department of Applied Japanese.

Now published for the third consecutive year by Teacher Yoshihiro Hanashiro, Associate Chair
of the Department of Applied Japanese, the *TAIWAN HAIKU: Eucalyptus* is a collection of significant haiku works taken from the Inter-University Japanese Haiku Competition held each year. The haiku works on the theme of “Warm Regards and Prayers for Japanese Earthquake and Tsunami Victims” last year provoked encouraging responses from both Taiwan and Japan. The 70th anniversary of the death of Yoichi Hatta is the main theme of this year’s Inter-University Japanese Haiku Competition, and the compliments and photos printed on the magazine were completed solely by Teacher Hanashiro.

Teacher Hanashiro not only offers courses on haiku writing jointly with other teachers, but he also encourages students to take part in overseas haiku competitions. In addition to the Ito En Oi Ocha New Haiku Competition, students also took part in the International Kusamakura Haiku Competition held in Kumamoto, Japan, and the International Kinki Haiku Competition held in Osaka, Japan. “I didn’t compose haiku works until I began to teach in Taiwan. I’m, of course, not an expert in haiku writing,” said Teacher Hanashiro, with a smile. These achievements and awards are fostered by the unceasing efforts of all the faculty and students of the Department, and these students surely live up to the praise as junior poets!
Headquarters of International Symposium on Biocatalysis and Agricultural Biotechnology (ISBAB) established in Taiwan

Dr. Jei-Fu Shaw, President of I-Shou University, was elected as the first chairperson of the International Symposium on Biocatalysis and Agricultural Biotechnology (ISBAB).

The inauguration of the headquarters of the International Symposium on Biocatalysis and Agricultural Biotechnology (ISBAB) took place at I-Shou University on September 21, making it one of a few international organizations with headquarters located in Taiwan. Some one hundred experts and industrial professionals in biotechnology were present at the inauguration ceremony, showing Taiwan’s research excellence in the field of biotechnology. Moreover, Dr. Jei-Fu Shaw, President of I-Shou University, was elected to be the first ISBAB chairperson.

According to Dr. Shaw, Chairperson of the Preparatory Committee, biocatalysis technologies, which use enzymes, microorganisms and cells as catalysts, are novel green (i.e. non-polluting) high technologies that can adequately address thorny issues in the fields of agriculture, biotechnology, medicine, industry, energy, and environmental protection, and further stimulate sustainable economic development. The establishment of the ISBAB headquarters in Taiwan will enhance Taiwan’s visibility and status within the international community, thereby giving the island a bigger advantage when seeking international cooperation and talent cultivation.

To further Taiwan’s research on biocatalysis and biotechnology as well as to seek international cooperation, Dr. Shaw established ISBAB jointly with Dr. Ching-Tsang Hou, Director of the National Center for Agricultural Utilization Research of the Agricultural Research Service for the United States Department of Agriculture, in 2005. The first to the fifth conferences all took place in Taiwan, the sixth and the seventh conferences were held in South Korea and Japan, respectively, and the eighth and the ninth conferences are eventually scheduled to take place in the United States and the Slovak Republic. This year the eighth ISBAB conference will be held in the U.S., in the Napa-Sonoma Wine Country of northern California, from October 28th ~ 31st, 2012.
ISBAB annual conferences attract experts, scholars and agriculture officials from around the world, including Taiwan, the United States, South Korea, Japan, the United Kingdom, France, Australia, India, Hong Kong, Canada, and the Slovak Republic. The conference papers presented at the first five conferences were published by ELSEVIER in the form of monographs, while the conference papers presented at the sixth and the seventh conferences were published in the SCI-indexed journal New Biotechnology by ELSEVIER in the form of special issues. In light of growing importance of agricultural issues, ISBAB further set up its own international editorial board and had ELSEVIER publish the international journal Biocatalysis and Agricultural Biotechnology, with the inaugural issue published in 2011.

In order to express its gratitude to Dr. Shaw for his considerable efforts in establishing ISBAB, attendees of the sixth conference held in South Korea awarded him the very first ISBB Merit Award. In addition, Dr. Shaw and Andrew H. J. Wang from Taiwan, Ching-Tsang Hou from the United States, Kiyoshi Hayashi from Japan, Randy Weselake from Canada, and Suk Hoo Yoon from South Korea were elected as the first-term ISBAB fellows.

To facilitate the sustainable operation of ISBAB, a registration application for the ISBAB headquarters at I-Shou University was submitted to the Ministry of the Interior, and this action will undoubtedly heighten Taiwan’s international profile in the ever growing field of biotechnology.
ISU Professors’ brilliant inventions stand out at 2012 Taipei Int’l Invention Show & Technomart

WORRY-FREE, GERM-FREE

Don’t want to touch the mouse or keyboard while seeing an exhibition because they might have been used by so many other people? Dr. Chi-Fa Chen, Associate Professor of the Department of Electrical Engineering at I-Shou University and his research group have developed a novel interactive guidance system to solve this dilemma. With only one click of the finger on the printed brochure, you can see whatever you want to on the screen. Such a visitor-friendly design is not only of great convenience, but it has also won Dr. Chen and his research group a silver medal at this year’s Taipei Int’l Invention Show & Technomart.

NO MORE WORRIES WHILE ENJOYING THE EXHIBITION GERM-FREE

According to Dr. Chen, the idea was drawn mainly from the public’s recent worry about exposure to communicable diseases in public areas. Differing from traditional guidance systems which generally show the 2D image of exhibits on a screen, Dr. Chen’s system can show a 3D image of the exhibit so that visitors can see it from all dimensions. The Kaohsiung Museum of
History has evinced great interest in this system, and it plans to set up this system for visitors making inquiries.

A SMALL MAGNET MATTERS

Dr. Li-Ming Chu, Professor of the Department of Mechanical and Automation Engineering, I-Shou University, has also won a silver medal for the design of a permanent magnetic torque measurement system. Instead of using a fan driven by an eddy current, Dr. Chu’s system uses only two magnets to measure the torque, thereby lowering the costs and improving testing safety. Dr. Chu stated that his idea comes from his previous experience. A traditional testing apparatus might cost millions of New Taiwan dollars, and laboratories usually adopt intrusive measurement methods. In case of any accident, repairs will cost millions of New Taiwan dollars to affect, not to mention any damage or loss arising from those resulting accidents. As a result, Dr. Chu integrated magnets to make non-intrusive measurement possible, in the hope of fabricating non-intrusive testing apparatuses and lowering their costs.

There were a total of 964 entries in the Invention Contest of this year’s Taipei Int’l Invention Show & Technomart, and I-Shou University had nine entries and won two silver and three bronze medals.
Effect of Al nano-particles on the microstructure, electrical and optical properties of AZO/Al/AZO tri-layer thin films

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Abstract

In this paper, the designed growth of the multilayer electrode with aluminum and aluminum doped zinc oxide (AZO) as Al/AZO, AZO/Al/AZO and AZO/Al were studied. These were deposited on glass substrates by radio frequency (RF) magnetron sputtering. The microstructures, optical properties and electrical characteristics of the multilayer electrode thin films were analyzed. The structural denseness and thickness of the multilayer electrode thin films were observed by field emission scanning electron microscopy (FE-SEM), and the crystal orientation was identified by X-ray diffraction (XRD). The resistivity and transmittance of the films were measured by a four-point probe and UV-VIS-NIR spectrophotometer, respectively. The resistivity of the AZO/Al/AZO multilayer electrode thin film was $1.77 \times 10^{-4} \, \Omega \cdot \text{cm}$. The average transmittance of the AZO/Al/AZO thin film over the wavelengths 400-800 nm is much...
better than that of other thin films, since Al nano-particles distribute in the AZO thin film during the sputtering process, as observed by high-resolution transmission electron microscopy (HRTEM). In addition, the figure of merit of the AZO/Al/AZO tri-layer film is much larger than that of the other structures.

Keywords: Transparent Conducting Oxide (TCO), multilayer electrode, RF magnetron sputtering, Al nano-particles.

I. Introduction

Transparent conducting oxides (TCOs) have received much attention because of their various technological applications, such as in liquid crystal displays (LCDs), solar cells, organic light emitting diodes (OLEDs) and touch panel displays. Transparent Conducting Oxide (TCO) has 80% transmittance in the visible range (400nm~800nm), and the resistivity is less than $10^{-3} \Omega\text{-cm}$. Indium tin oxide (ITO) film has been used for TCO, but since the indium is a rare metal and also has higher toxicity, ITO thin films will be gradually replaced by zinc oxide (ZnO), which is a wide band gap (3.2eV) semiconductor material with high transmittance in the visible region. It is lower cost, abundant, and non-toxic, and has the qualities of higher penetration and lower resistance. However, ZnO thin film has poor electrical conductivity at room temperature. Therefore, it is necessary to dope some metal material to increase the conductivity as aluminum doped. This is, because the Al ion substitutes the Zn ion or it occupies the interstitial position of the ZnO lattice, which increases the carrier concentration and electronic conduction of the ZnO thin films. However, the higher Al content may cause $\text{Al}_2\text{O}_3$ or $\text{ZnAl}_2\text{O}_4$, which will induce more grain boundary. The optimum Al doped is therefore about 1.6~3.2wt%. To further improve the conductivity of transparent conducting films, it is necessary to try new materials or structures. It is well known the conductivity of metal films is very high, but their transmittance is relatively low. It had been reported when a metal mirror layer was embedded within the dielectric layer, it could suppress the reflection from the metal in the visible range and achieve a selective transparent effect. From then on, there have been more and more studies on multilayer films, especially tri-layer films, such as ITO/Ag/ITO, ZnO/Ag/ZnO and ZnO/Cu/ZnO. All have displayed fine photoelectric performance, and high conductivity in particular. In this paper, the microstructures, optical properties and electrical characteristics of aluminum doped zinc oxide (AZO) thin films with different locations of the Al layer between the AZO layers (AZO/Al/AZO, AZO/Al and Al/AZO) and the single AZO thin films were analyzed. The final figure of merit amounts of the different growth thin films were calculated.

II. Experiments

The designed growth of the AZO/Al/AZO tri-layer, Al/AZO, AZO/Al bi-layer, and AZO single layer films were prepared on glass
substrates by RF magnetron sputtering of AZO using an AZO target (2wt.%). All films are designed to have the total thicknesses about 200 nm, and the thickness of the Al layer was controlled about 10 nm. First, the glass substrate was cleaned with acetone, methyl alcohol, and deionized (DI) water using an ultrasonic cleaner, respectively. A diffusion pump coupled with a rotary pump was used to achieve the base pressure of $5 \times 10^{-6}$ torr. The working pressure was maintained at 70 mtorr under the sputtering process. The AZO and Al target were cleaned by pre-sputtering with Ar plasma for 5 minutes. The distance between the target and the substrate was kept at 5 cm and the RF power was kept at 50W. The thicknesses of the designed growth of the AZO/Al/AZO tri-layer, Al/AZO, AZO/Al bi-layer, and AZO single layer films were about 200 nm. The structural denseness and thickness of the multilayer electrodes thin films were observed by field emission scanning electron microscopy (FE-SEM), and the crystal orientation was identified by X-ray diffraction (XRD). The distribution of Al nano-particles in the AZO thin film was not comprehensively examined with HRTEM. This was mostly due to the difficulties in preparing a thin film transmission electron microscopy (TEM) specimen with large differences in hardness between the hard glass substrate and AZO thin film. Cross-sectioned TEM specimens were prepared by cutting the specimen into slices, which was then mechanically ground and polished to less than 10 µm, and finally ion-thinned to an electron transparent thickness using a Gatan precision ion polishing system. High-resolution micrographs were obtained using a field emission gun- transmission electron microscopy (FEG-TEM) with a point resolution of 0.23 nm operating at 200 kV. Lattice image simulations based on the multi-slice method were performed with the MACTEMPAS software package to compare with the experimentally obtained images. Atomic image processing was performed using Gatan DigitalMicrograph software. HRTEM images were compared with diffractions using the processed image to confirm the local orientation of the AZO thin film. The optical transmission was measured by a UV-VIS-NIR spectrophotometer. The electrical resistivity was measured by a four-point probe, and the final figure of merit growths of the different thin films were calculated.

III. Results and discussion

The XRD spectra of the AZO/Al/AZO tri-layer, Al/AZO, AZO/Al bi-layer, and AZO single layer films were shown in figure 1. The crystal property was determined using a 1.540598 Å line of the X-ray diffractometer and the 0.5° low angle scanning. The standard (002) and (103) planes of ZnO were verified as $2\theta=34.419^\circ$ and 62.8° by a joint committee on powder diffraction standards card (JCPDS) card. The intensity of the (002) and (103) peak of the AZO/Al film were similar to the peak of the AZO single layer film. This implied the polycrystalline with the ZnO hexagonal structure and have a preferred orientation of (002) and (103) with the c-axis perpendicular to the substrates, which suggests an improvement of crystallinity. For Al/AZO and AZO/Al/
AZO films, the intensity of the ZnO(002) peak are stronger, indicating both layers have the polycrystalline with the ZnO hexagonal structure and have a preferred orientation of (002) with the c-axis perpendicular to the substrates. The grain size was estimated using the Scherrer equation (equation 1)\(^6\). The ZnO grain size in the AZO single layer films was calculated as 11.1nm, 11nm in the AZO/Al layer, 13.4 nm in the Al/AZO layer, and 12.1nm in the AZO/Al/AZO layer, respectively. This implies the Al spacer layer can partly improve the polycrystalline with the ZnO hexagonal structure and have a preferred orientation of (002) with the c-axis perpendicular to the substrates, especially on the Al/AZO and AZO/Al/AZO structures. In other words, the Al spacer layer plays the role of a buffer layer\(^20\) for better crystallinity.

\[ b = \frac{0.9 \lambda}{A(\theta) \times \cos \theta} \] (equation 1)

\[ \theta \]

The FESEM images of the designed growth of the multilayer electrode of AZO, Al/AZO, AZO/Al/AZO, and AZO/Al are shown in figure 2. All the films have the same thickness about 200 nm, as shown in figure 2. (i)~(l). Figure 2 (a)~(d) show the top-view of the FESEM images. A higher grain size is observed in figure 2(c). Compared with the strabismus view shown in figure 2 (e)~(h) and the end view shown in figure 2 (i)~(l), less columnar structures were observed in the AZO/Al/AZO structures. This means the Al layer plays the role of a buffer layer to reduce the density of columnar structures during the sputtering process.

![Figure 1](image1.png)

**Figure 1.** The XRD spectra of the AZO/Al/AZO tri-layer, Al/AZO bi-layer and AZO single layer films.
The Al nano-particles were observed in the AZO/Al/AZO structures by HRTEM analysis, as shown in figure 3. The pure crystalline structure was an aluminum layer. The polycrystalline structure was AZO thin film, which was proved by analysis of the selected area diffraction (SAD) pattern. A white diffraction point was observed around the atmosphere rings. This means the
aluminum structures did not segregate to form a micrometer cluster during the sputtering process, instead of the formation of Al nanoparticles, which is good for the electrical and optical properties of the AZO/Al/AZO tri-layer structure, especially on transmittance. Due to the micrometer Al cluster structures will enhance the Mie-scattering effect\(^2\) and reduce the transmittance of thin film. The less columnar structures were observed in the AZO/Al structure and also in the AZO/Al/AZO structures from FESEM views, it means the deposited Al layer can reduce the columnar structures during deposition process, but due to the Al spacer layer crystal structure is discontinuous as shown in figure 4 and the quantity is also lower compare with AZO thin film, the aluminum peak is not observed in the XRD spectra. Depend on the RF sputtering method, it is difficult to deposit the uniform aluminum thin film, but the crystal structure was deposited successful in our thin film structures. The Al spacer layer crystal structure is discontinuous and the size of Al nano-particle is about 10-30 nm, but the size of Al nano-particle generated from the AZO layer-self is about 2 nm.

![Figure 4. The cross-section HRTEM image of Al layer in the AZO/Al/AZO tri-layer.](image)

Figure 5 shows the average transmittance in the wavelength from 400-800 nm of different films (tri-layer, bi-layer, and single layer films). The AZO/Al structure has the lowest average transmittance of 65%, because the Al layer was grown on the surface of the film. We found the
average transmittance increases from 77% to 84% of the comparison of the transmittance in the Al/AZO layer and AZO/Al/AZO tri-layer structure. When an appropriate thickness (10 nm in our case) is deposited, the Al layer seems to become a reflective mirror, but the tri-layer film can suppress the reflection from the Al layer because the dielectric/metal/dielectric (D/M/D) structure has a surface plasma effect, that enhances optical transmittance\(^2\). Depend on the HRTEM observation in figure 4, the micrometer Al cluster structures had not been formed and reduced the Mie-scattering effect\(^2\). Thus, a relatively higher transmittance is achieved, and the AZO/Al/AZO structure has the best average transmittance of 84%.

![Graph](image)

**Figure 5.** The different optical transmittance of the AZO/Al/AZO tri-layer, Al/AZO, AZO/Al bi-layer and AZO single layer films.

The merits of the different constructions (tri-layer, bi-layer, and single layer films) are shown in Table 1. The resistivity(\(r\)) of the tri-layer films is proportional to its sheet resistance (\(R_s\)) (\(\rho = R_st\), where \(t\) is the film thickness). The tri-layer film can be considered a parallel circuit of the three resistors\(^1\). Therefore, the relationship among the sheet resistance of the tri-layer film (\(R_s\)), AZO layer (\(R_{AZO}\)) and Al layer (\(R_{Al}\)) is shown by equation 2:

\[
\frac{1}{R_s} = \frac{2}{R_{AZO}} + \frac{1}{R_{Al}} \quad \text{(equation 2)}
\]

However, the conductivity of the tri-layer film is mainly supplied by the metal layer\(^2\). In the various applications of transparent conductive films, the optical and electrical properties of the films are very important. Ideally, both optical transmittance and electrical conduction should be as large as possible. However, their interrelation
usually excludes the simultaneous achievement of maximum transmittance and conduction. Haacke\cite{24} proposed a figure of merit $\Phi_{TC}$ using equation 3:

$$\Phi_{TC} = \frac{T^{10}}{R_s} \quad (equation \ 3)$$

| Table 1. The figure of merit for the optical and electrical properties of the AZO/Al/AZO tri-layer, Al/AZO bi-layer, and AZO single layer films. |
|--------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Sample                                          | Al/AZO          | AZO/Al/AZO      | AZO/Al          | AZO             |
| Thickness (nm)                                  | 10/180          | 90/10/90        | 180/10          | 190             |
| Sheet resistance (Ω/square)                     | 32              | 9               | 5               | 800             |
| Resistivity (Ω-cm)                              | 6.17×10⁻⁴       | 1.77×10⁻⁴       | 1.02×10⁻⁴       | 1.52×10⁻²       |
| Transmittance (%)                               | 77              | 84              | 65              | 89              |
| the figure of merit (10⁻²Ω⁻¹)                   | 0.229           | 1.94            | 0.269           | 0.0389          |

Where, $\Phi_{TC}$, $T$ and $R_s$ are the figure of merit ($\Omega^{-1}$), the average transmittance (%) and the sheet resistance (Ω/square) of the film, respectively. This equation can be used to compare the performance of transparent conductive films. The AZO/Al has the lowest resistivity of 1.02×10⁻⁴Ω·cm, due to the Al layer being distributed on the surface of the film. The resistivity of the AZO/Al/AZO tri-layer was 1.77×10⁻⁴Ω·cm, the Al/AZO thin film was 6.17×10⁻⁴Ω·cm and the AZO single layer film was 1.52×10⁻²Ω·cm, respectively. The resistivity of the tri-layer film is much lower than that of the AZO single layer film, and the transmittance of the tri-layer film is much higher than that of the bi-layer system. The final figure of merit of the tri-layer film is 1.94×10⁻² (Ω⁻¹), which is much larger than the other similar dielectric/metal/dielectric (D/M/D) structure\cite{25-28}, indicating the designed AZO/Al/AZO tri-layer film has the best photoelectric performance.

**IV. Conclusions**

In this study, highly transparent conducting oxides of AZO/Al/AZO tri-layer films were deposited on glass substrates by RF magnetron sputtering. It was found the AZO/Al/AZO tri-layer film is superior to the bi-layer and the AZO single layer films in photoelectric performance. The Al nano-particles were observed in AZO thin film, which play an important role in the conductivity and transmittance. The best figure of merit of the AZO/Al/AZO tri-layer film is 1.94×10⁻² (Ω⁻¹). This means a lower resistivity of 1.77×10⁻⁴ (Ω·cm) and higher average transmittance of 84% of the transparent conducting oxides were found in our study.
Acknowledgements

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Release of FITC-BSA from poly(L-lactic acid) microspheres analysis using flow cytometry

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Abstract

In this investigation, biodegradable polymer poly(L-lactic acid) (PLA) microspheres were prepared by the W1/O/W2 solvent evaporation method. These microspheres were separated by the glycerol gradient method, and take microspheres at part of 25% glycerol gradient concentration was analyzed by flow cytometry, indicating a more homogeneous particle size distribution than that not separated. The microspheres were degraded using several enzymes, and around 40% was degraded by 72 hour. This result reveals the effectiveness of drug delivery by PLA microspheres, which was evaluated by performing a drug release test and flow cytometric analysis. The FITC-BSA concentration in the supernatant increased with the experimental time. At the phagocytosis experiments, coated with FITC-BSA drug of microspheres can be used by the cell, as particle size approximately 1 μm.

Key words: Poly(L-lactic acid) (PLA), Solvent evaporation, Microsphere, Flow cytometry

Introduction

Microspheres technology has been extensively used in food production, agriculture, environmental protection, medicine and other fields. In recent years, they have been utilized more in the pharmaceutical industry, and to develop drug delivery systems [1-7]. Traditional medicines cannot generally be released in a
targeted or controlled manner. Accordingly, a delivery system that uses microspheres of a biodegradable polymer coated with a drug, to avoid destruction process from a stomach to intestine, and treat the target with stable and slow release. The drug release rate can thus be controlled to maximize efficacy [8-11].

Generally, local injection of muscle tissue vaccines causes the immune system to produce antibodies; the effect of a vaccine is throughout the body. However, some bacteria or viruses through the mucosal system (such as through the oral cavity or gastrointestinal tract), and they can be suppressed by vaccines that are absorbed by the mucosal system. To make of a convenient system for delivering an injectable vaccine orally using microspheres, biodegradable PLA microspheres are coated with the vaccine by W1/O/W2 solvent evaporation [12, 13]. The inner phase of the aqueous solution (W1) which containing bovine serum albumin labeled with fluorescein isothiocyanate (FITC-BSA) and PLA is dissolved in chloroform with emulsifiers span 80 as the dispersed phase (O).

The solution as above-mentioned was homogenized using a mixer. It was dispersed the solution as above-mentioned with heating to 80 °C polyvinyl alcohol (PVA). PVA was the outer phase (W2) of the liquid forming microspheres. The characteristics of coated microspheres are studied under various conditions, by performing in vitro experiments and degradation experiments, to determine the effect of release of the drug on microsphere. A simple testing method, flow cytometry, was used to analyze the effectiveness of drug release from microspheres.

**Materials and methods**

**Preparation of microspheres**

Poly (L-lactide) (PLA) (LECEA, H-100) and PVA were Purchased from Mitsui Chemicals Co. Ltd. (Japan) and Sigma. To form the microspheres, 2% (w / v) dispersion solution PVA was used. Various concentrations of PLA microspheres were dissolved in chloroform, and then the drugs was added to a PLA volume of 10% (v / v), and 2% span80. The mixed solution was sonicated for around 10 seconds. The PVA solution was stirred using a homogenizer at various rates. Then the mixed PLA solution was added to the PVA solution, until a shell was formed after 5 minutes of stirring. The microspheres thus formed were put into a vacuum, heated to 40 °C to evaporate off all of the chloroform. They were then freeze-dried and stored.

**Analyses**

To observe the degradability of PLA microspheres and the effect of drug release in vitro, enzymatic degradation was performed. To simulate the human body, five enzymes were used. They were lipase (20μg/ml), proteinase K (50μg/ml), trypsin (100ng/ml), chemotrypsin (20μg/ml) and lysozyme (20μg/ml). A certain amount of microspheres was placed in a 15 ml centrifuge tube, to which many enzymes were added to various concentrations; 1ml of buffer solution was also added. The tube was placed
shock tank-type water bath at 37 °C and 100 rpm to perform in vitro tests. After the supernatant was removed at various reaction time, and the freeze-dried weight of the PLA microspheres was measured to determine the weight loss associated with biodegradation.

PLA microspheres that were embedded with FITC-labeled bovine serum albumins (BSA) were placed in a centrifuge tube that contained 25% glycerol. The tube was centrifuged for 25 min at 14000 rpm at 4°C (Kubota 5920). After centrifugation, 50 µl of glycerol-separated PLA microspheres was suspended in 2 ml of sterile water and incubated in an incubator shaker at 37°C in the dark for 7 days. In the incubation period, 200 µl of the solution was removed every 24 hr, and FITC-BSA-contained PLA microspheres were further harvested by centrifugation at 3000 rpm. Subsequently, 100 µl of the supernatant was collected in the 96-well microtiter plate for fluorescence analysis using a LAS-3000 image system (Fujifilm), and the fluorescence intensity of the supernatant was quantified using Adobe Photoshop CS4 software. The amount of FITC-BSA that released from PLA microspheres into sterile water was thus determined. The pellets were suspended in 300 µl of sterile water for flow cytometry analysis. The amount of FITC-BSA in the PLA microspheres was analyzed using a FACSCalibur (BD) with excitation at 488 nm, and the measured mean fluorescence intensity (MFI) at 530 nm yielded the amount of FITC-BSA remnant within the microspheres over a period of seven days. In flow cytometry analysis, the PLA microspheres were technical usage by forward and side scattering to eliminate the effects of debris and aggregates from the results.

The macrophage cell line RAW264.7 was cultured in Dulbecco’s modified Eagle’s Medium that was supplemented with 10% fetal calf serum, 100 µg/ml of streptomycin and 100 µg/ml of ampicillin on 8-well chamber slides. Phagocytosis of microspheres that contained trypan blue or FITC-conjugated BSA by RAW264.7 cells was performed to study the intracellular release and distribution of antigen molecules. Fluorescent or dye-containing microspheres were passed through a 2 µm syringe filter, and the microspheres (4 × 10^5) that were smaller than 2 µm were collected and further cultured for 48 hours with 1 × 10^5 RAW 264.7 cells in each chamber. Each chamber was washed twice using sterile PBS to remove extracellular microspheres after 6, 12, 24 or 48 hours of incubation, and the cells were observed and photographed under a fluorescence microscope (Nikon).

**Results and discussion**

Figure 1 presents the PLA microspheres degraded by various enzymes. Survival rate was measured as weight loss after 72 hours. The experimental enzyme equals that in at 37 °C and 100 rpm shock in vitro. The figure presents the following weight losses of PLA microspheres; (△) lysozyme, 30%; (◇) proteinase K, 20%, and (×) lipase 40% enzymes; trypsine (□) and chemotrypsine (○) yielded no weight loss in 72 hours. Therefore, the survival rates of
PLA microspheres after 72 hours of enzymatic degradation were (△) lysozyme, 70%; (◇) proteinase K, 80%, and (×) lipase, 60% respectively. These results indicate that PLA microspheres that are coated FITC-BSA seem can be used in the therapeutic applications in the intestines.

Fig. 1. The PLA microspheres in the role of various enzymes, and measured by the survival rate of weight loss after 72 hours. (△) lysozyme ; (◇) proteinase K ; (□) trypsin ; (○) chemotrypsin ; (X) lipase.

Flow cytometry is a new, rapid and accurate method of estimating both the size and the releasing efficiency of PLA microspheres. The size of microspheres determined by forward scatter of the flow cytometer revealed a distribution of sizes from 3 to 24 µm (Fig. 2A). Following separation by glycerol, a narrow size (around 10 µm) distribution of PLA microspheres was obtained, shown as by the dot-plots obtained from the results of flow cytometry (Fig. 2B). The mean fluorescence intensity of the narrow size distribution of PLA microspheres revealed that around 50% of the FITC-BSA was released from the PLA microspheres within 24 hours. However, the mean fluorescence intensity in the

![Graph showing residual weight loss over time](image)

Fig. 2. The kinetics of FITC-BSA released by PLA microspheres in vitro.

![Flow cytometry histograms](image)
microspheres remained constant for 2-3 days, and then slowly decreased to 35% after 7 days of incubation (Fig. 2C). Additionally, fluorescence analysis using the LAS-3000 image analyzer revealed gradually increasing fluorescence in the supernatants that were collected from the PLA microspheres from day 1 to day 7 (Fig. 2D). These results demonstrate that one-half of the FITC-BSA was rapidly released from the PLA microspheres in 24 h, and then slow release was sustained for seven days.

Figure 3 plots the rate of the intracellular release of antigens from PLA microspheres. Fluorescent or dye-containing microspheres ($4 \times 10^5$) were cultured with $1 \times 10^5$ RAW 264.7 cells on 8-well chamber slides. At 12 hr (A) or 48 hr (B and C), chambers were washed twice with PBS to remove extracellular microspheres, and the cells were photographed under a fluorescence microscope. (A) Diffuse trypan blue in cytosol of RAW264.7 cells revealed the intracellular release of PLA microspheres. The magnification was X200. (B) Residues of microspheres with a small amount of trypan blue were still visible in the cytoplasm of RAW264.7 cells following 48 hr-culture. The magnification was X400. (C) The fluorescence of FITC-BSA was detected in RAW264.7 cells following 48 hr-culture. The magnification was X 400.

Professional antigen-presenting cells, such as macrophages, can engulf exogenous antigens to T cells to initiate adaptive immunity. T cell activation depends on release of the contents of the microspheres after they are taken up by macrophages. The intake of microspheres by RAW264.7 cells was observed at 6 hr and most of the microspheres that contained trypan blue dye were released into the cytosolic space of the RAW264.7 cells after 12 hr of incubation (Fig. 3A). Nonetheless, the residues of the residual microspheres that contained a small amount of trypan blue were still visible in the cytoplasm of RAW264.7 cells at 48 hr (Fig. 3B). Similar results were observed in the group of cultured with FITC-BSA-contained microspheres: low levels of fluorescence in the cytosol of the RAW264.7 cells were detected by fluorescence microscopy at 48 hours after incubation (Fig. 3C). These results demonstrate that the microspheres that were ingested by macrophages released the contents of their capsules’ into the cytosol, promoting the presentation of antigens and inducing the immune response.

![Fig. 3. Intracellular releasing of antigens from PLA microspheres.](image)
Conclusions

In enzymatic degradation of PLA microspheres, lipase was the most effective enzyme. This enzyme is usually present in the digestive tract. Therefore, PLA microspheres can be taken orally in vaccination: they degrade in the digestive tract, releasing the contained medicine.

FITC-BSA or drug-containing microspheres with around 1 µm can be taken easily by macrophages and the contents of microspheres release into the cytosol, promoting the presentation of antigens and inducing the immune response.

References

4. “Preparation of insulin-loaded PLA/PLGA microcapsules by a novel membrane emulsi-

The Measurement and Assessment of Cognitive Functions in Schizophrenia

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Abstract

The treatment for persons in schizophrenia is always an important topic in the practice of the Department of Psychiatry. Deinstitutionalization and the development of medical technology improve the demands of patients on returning to the community. However, a complete and defined assessment tool for cognitive function, which is the most important thing for returning to the community, is still absent locally. Through the related studies overseas, the project Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) activated by the National Institute of Mental Health (NIMH) has developed MATRICS Consensus Cognitive Battery (MCCB), which looks into seven cognitive domains and ten cognitive tests, may be a reference for local research.

1. Introduction

Schizophrenia is the most commonly diagnosed disorder in the Department of Psychiatry; more than half of the patients in the ward suffer from schizophrenia. Therefore, treating schizophrenic patients is an important
topic in psychiatric medicine. Since 1950, due to the improvement of the psychiatric medication, the development of “deinstitutionalization” has been promoted to establish community centered medical model. The goal of deinstitutionalization is to reduce the number of ward beds occupied by psychiatric patients, reduce the medical expenses, and reduce the financial burden of the government; most importantly, the quality of life and the living status of psychiatric patients can be improved in the community (Rong, et al, 2008; Chiang, 2009; Yang & Yang, 1992; Lougher, 2008).

However, the ability of returning to the community has always been difficult in aspects of living technique and community life due to the disease progression in schizophrenic patients; 95% of the patients living in the community still require daily care from their family members (Song, 1996). Cognitive function is the key affecting the activities of daily living in schizophrenic patients. The cognitive function of schizophrenic patients is significantly different from other psychiatric disorders. Although cognitive function impairment appears in several psychiatric disorders, the impairment in schizophrenic patients is more severe. Clinically, a related full assessment tool for schizophrenic patients is missing; only partial cognitive function assessment tool is available. Hence, the aims of this study are to discuss the measurement of schizophrenic patient cognitive function.

## 2. Schizophrenia

The diagnosis of schizophrenia is based on Diagnostic and Statistic Manual of Mental Disorder-IV (DSM-IV). The following criteria must be met to be diagnosed as schizophrenia: 1. The presence of two (or more) of the following characteristics: delusions, hallucinations, disorganized speech, grossly disorganized or catatonic behavior, negative symptoms; 2. The presence of social/occupational dysfunction; 3. Continuous signs of the disturbance persist for at least 6 months (prodromal, onset and residual periods), including at least 1 month of the symptoms listed in criterion 1; 4. Rule out schizoaffective disorder and mood disorder with psychotic features; and 5. Rule out disturbances of the direct physiological effects or a general medical condition (American Psychiatric Association, 1994).

Schizophrenia is an important topic in psychiatric medicine. The continuous advancement on the medical technology may rapidly control the symptoms and increase the opportunity of the patients returning to the community (Kelland & Lewis, 1996; Lewis, 1995). However, there is no adequate tool assessing the cognitive techniques required by the schizophrenic patient for returning to the community; it is an obstacle for professions in the field of psychiatric medicine on establishing an appropriate treatment and rehabilitation program for the patients (Sheridan et al., 2006). It is necessary to find an assessment tool fitting the requirement of the patients and fulfilling the clinical demand based on the related references (Smith, 1995).

Schizophrenia is a significant psychiatric
disorder that caught much attention in the 20th century. Nearly half of the psychiatric medicine research is focused on the schizophrenia and developing the treatment models for hospitalized patients, including emergency clinic, outpatient clinic, acute treatment, chronic treatment, rehabilitation program, daytime ward, rehabilitation house and community rehabilitation center. According to a study of community epidemiology, the lifetime prevalence rate of schizophrenia in urban regions of Taiwan was 0.40%, in the countryside was 0.20%, and in the whole adult population was 0.30% (Hwu, 2002). Schizophrenic patients represent the majority, 60%-80%, of the hospitalized patients in the Department of Psychiatry of general and psychiatric hospitals (Hwu, 1996). Schizophrenia may lead to disability, and thinking, perceptual, emotional, action impairment; the adaptation ability on living may also be significantly regressed, limiting daily living, social and occupational functions of the patients (Midorikawa et al., 2008). Major symptoms observed in patients include thinking, perceptual, and emotional impairment, significantly disconnected from reality; of those, social dysfunction or regression has been observed on 40%-60% of the patients (Henry, Hippel, & Shapiro, 2010).

Deinstitutionalization improves the demand of patients on returning to the community. If the patients want to live in a community successfully, mental rehabilitation and community healthcare will be the essential treatment for psychiatric medicine; the related description can be found in Mental Health Act, announced on December 7, 1990. Due to the lack of community knowledge, technique and resource, and the lack of overall plan and support, a great amount of pressure and burden has been added to the major caretakers of the patients (Hsu & Tseng, 1998), leading to a revolving door effect in schizophrenic patients, who circulate among hospitals, care institution and community; the problem of “institutionalization” still exists in reality (Shiau, Huang, & Lin, 2005). The new Mental Health Act, announced on July 4, 2007, reinforces the notion of community psychiatric healthcare and promotes patients returning to the community. In order to improve the community function of the patients, the Act clearly establishes that the community psychiatric rehabilitation needs to provide patients rehabilitation and care on daily living ability, social skill, mental reestablishment, working ability, and working attitude (Hsueh & Liao, 2007). In practice, an effective cognitive function assessment is required to establish an appropriate rehabilitation program for schizophrenic patients.

The mental state of psychiatric patients always affects their social function, including positive symptoms, negative symptoms and residual symptoms; for example, withdrawal, regression, panic, anxiety, perceptual or cognitive impairment, inability to trust, leading to the loss of ability (Connelly & Dilonardo, 1993). Self-care is a key indicator that determines whether the patients may successfully stay in a community; however, families of most patients do not wish them to be dismissed from the
hospitals due to the high recurrent rate of the chronic psychiatric disorders. As a result, the condition of institutionalization becomes more severe and the impairment of social function becomes more common. Some studies stated that a good cognitive training may effectively improve the daily living function, including self care, to achieve the social interaction skill and independence, promoting the self esteem and the community adaptability of the patients (Lee & Chen, 1991; Tsai, Lee, Chen, & Wu, 2002; Borelli & Deluca, 1993).

3. Cognitive Function Test

The cognitive deficit is thought to be the core feature of schizophrenia (Egeland, 2007; Gur et al., 2007; Luck & Gold, 2008; Mogami, 2007; Shimizu et al., 2007). Deficit in cognition is an intermediate characteristic in schizophrenia and may be a steady vulnerability indicator of schizophrenia (Ageberg, Flenhagen, & Ljung, 2007; Kenny & Meltzer, 1991; Liu, Chen, Chang, & Lin, 2000). Impairment cognition is also a primary characteristic deficit and a major obstacle to daily functioning, so it is a particularly important target for remediation in schizophrenia (Harris, Minassian, & Perry, 2007; Mausbach et al., 2008; Meyer & Blechert, 2005). The severity of cognitive function impairment affects the efficacy of the mental and social rehabilitation, community adaptability and occupational rehabilitation in schizophrenia patients (Chan, Yip, & Lee, 2004; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Nieuwenstein, Aleman, & de Haan, 2001; Prouteau et al., 2004). The exponential growth in new technology and techniques has had profound influences on cognitive rehabilitation (Anastasi & Urbina, 1997; Gomm, 2008; Laenen, Vangeneugden, Geys & Molenberghs, 2006). New applications of already existing technology can support sophisticated tracking, orienting, and signaling devices for people with cognitive deficit (Bjorkly, Hartvig, Heggen, Brauer, & Moger, 2009; Brennan & Silman, 1992; Rankin & Stockes, 1998). Therefore, the National Institute of Mental Health (NIMH) activated Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) project, aiming to stimulate the drug development for the cognitive function of schizophrenia patients. Although no drug has been proved to improve the cognitive function, the METRICS provided a good skeleton of assessment on the cognitive function of schizophrenia patients.

The NIMH-MATRICS developed a complete set of cognitive function assessments called the MATRICS Consensus Cognitive Battery (MCCB). The related studies found that cognitive function of schizophrenia patients can be divided into seven domains, which were 1. Speed of processing, 2. Attention/vigilance, 3. Working memory, 4. Verbal learning, 5. Visual learning, 6. Reasoning and problem solving, and 7. Social cognition. Through strict selection criteria, seven assessment tools established, which were Brief Assessment of Cognition in Schizophrenia: Symbol Coding, Category Fluency: Animal Naming, Trail Making Test: Part A for speed of processing; Continuous
Performance Test-Identical Pairs for attention/vigilance; (nonverbal) Wechsler Memory Scale-Third Edition: Spatial Span,(verbal) Letter-Number Span for working memory; Hopkins Verbal Learning Test-Revised for verbal learning; Brief Visuospatial Memory Test-Revised for visual learning; Neuropsychological Assessment Battery: Mazes for reasoning and problem solving; Mayer-Salovey-Caruso Emotional Intelligence Test: Managing Emotions for social cognition. There are 10 independent cognitive function tests available for a complete assessment on the seven domains of the cognitive function (Nuechterlein & Green, 2006).

4. Conclusion

In clinical practice of the Department of Psychiatry, schizophrenic patients urgently require a full version of the cognitive function test to provide a basis for future studies, cognitive function treatment efficacy, and treatment planning. The NIMH activated MATRICS project and the developed MCCB provide important references for the local professions. Through the verification of the related psychometrics, the possibility of MCCB applications will be increased, which further improves the current status of insufficient assessment tools.

References


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Quantitative Analysis of Changes in Neuromuscular Function with Myofascial Pain Using Surface Electromyography

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Abstract

This study aims to analyze functional neuromuscular changes due to myofascial pain on the upper back using surface electromyography. Due to the limitations in using the conventional parametric measures of surface electromyography to differentiate the signal of myofascial pain from the normal signals, this approach developed an innovative model based on wavelet energy differences to inspect the pattern of electromyography due to dominant-hand effect. Through comparison of the derived patterns from 30 normal and 26 patient subjects, we found that pattern of the dominant-hand effect changed with myofascial pain. We also proposed a solid explanation for the changes in these patterns based on physiology of muscle systems. Therefore, this model could provide a reliable feature for clinical diagnosis of myofascial pain.

Key words: surface electromyography, myofascial pain, wavelet energy
Introduction

Nowadays due to the popularity of computer use and increasing working stress, myofascial pain with upper back (MFPUB) has been a common occupational hazard. The number of people with this syndrome seeking medical treatment is increasing abruptly. Although there are various inferences for its’ etiology, it is commonly attributed to the accumulation of lactic acid, a metabolite from muscles, as a result of the restrained circulation under stress[1-3]. However, the investigation into any sort of induced muscular functional changes is rare. Therefore this study aims to investigate whether myofascial pain can cause changes in muscular function by using surface electromyography (SEMG) analysis. It is believed that this study can explore the etiology of myofascial pain, and therefore to improve its prevention and treatment, and to consolidate further clinical studies.

Even though SEMG is a common non-invasive measure to examine neuromuscular function, use of the conventional parameters derived from SEMG is still limited in terms of clinical observation to identify myofascial pain. The limitations partly arise from the non-stationary nature of the SEMG signal associated with the large subject-dependent variations in its parametric measures; therefore, the thresholds of these measures for MFPUB identification are difficult to define. The major limitations are due to patients with chronic MFPUB lacking any clear-cut pain location on one side of the back. They usually feel the pain on both sides with different degrees of severity, which makes it almost impossible to conduct within-patient comparisons between the affected and normal sides. The ambiguity in the SEMG variation within and between patients hinders practitioners from relating their clinical findings by SEMG to MFPUB.

Considering the aforementioned limitations, an efficient analytical model for MFPUB should normalize the within-subject variation for between-patient comparison; therefore, the changes in neuromuscular function induced by MFPUB can be identified. To achieve this goal, several factors should be taken into account. One is the dominant-hand effect [4]. The other is the significant fluctuation being found in the post-recruitment stage of MFP SEMG signal [5]. Another, given that the different properties of two types of motor units (MU’s)—type I (slow-twitch) and type II (fast-twitch)—are recruited at different stages of sustained contraction[6]. However, the interference pattern of the SEMG signal contains the summation of all motor unit action potential (MUAP) trains from all active motor units within the recording range of the surface electrode [7]; as a result, variations in the shape and size of MUAPs are averaged. Thus, neither general changes induced by myofascial pain in the frequency domain nor the signal amplitude in the time domain are likely to clarify the detailed mechanisms. Therefore, a multi-scale analytical model should be developed.

Past efforts to analyze SEMG signals were mainly based on the feature extractions in time or frequency domain approaches, such as the shift in median frequency [4], and the root
mean squares (RMS) of the signal amplitude [5]. However, these methods do not take both time and frequency variation into account in an optimal sense. The wavelet transform (WT) is an efficient tool for multi-resolution analysis of non-stationary and fast transient signals. These properties make it especially suitable to study the neuro-physiological signals. In addition, the good localization of wavelet decomposition maintained in the time and frequency domain makes it easier to measure the difference between two consecutive signal resolutions [8]. Finally, according to previous studies [7, 9], the MUAPs can be considered as dilated and attenuated versions of a single wave. By choosing a mother wavelet similar to the shape of a MUAP, the resulting WT yields the best possible localization of MUAP in the time-scale domain.

The aim of this study had two phases: first, to develop a multi-scale analytical model considering muscle contraction and relaxation to discover the associated pattern with the dominant-hand effect in the SEMG signals from normal subjects; second, to examine whether such a pattern can be affected by MFPUB.

**Method**

We recruited two groups of participants ranging in age from 30 to 50 years: a normal group of 30 subjects and a patient group of 26 subjects. Before the tests, informed consent was obtained in accordance with the Human Subjects Internal Review Board (IRB No.: EMPR-098-007) at E-Da Hospital; this board approved all experimental procedures and protocols. To maintain consistent conditions, only right-handed subjects were selected. Participants who suffered from MFP were screened and diagnosed by a physician by the criteria of a taut band situated on the upper back across the intersection of the middle trapezius and rhomboid major/minor muscles, and pain lasting for more than six months.

An action cycle was designed over 5 beats at the tempo of 1 beat per second to record the complete time course from muscle contraction to the resting state. During each cycle, subjects lay on their stomach and rested on the 1st–3rd beats, lifted both arms with maximal force toward the ceiling on the 4th beat, and then released the hold on the 5th beat. Each subject was requested to conduct six cycles following this tempo.

Active electrodes MA-411 were attached to the taut-band loci on both sides of the upper back to measure the SEMG signal. The analog signal was amplified up to 3800 times, band-pass (20–3,000 Hz) by MA-411, digitized with a 5-kHz sampling rate by an instruNet 100 data acquisition card, and transferred to a computer for further analysis.

The measured SEMG signals were further processed to precisely identify the occurrence of epochs corresponding to the arm-lift in the 1st cycle. Based on those epochs, the correspondence between the SEMG signals and the action cycle were determined. To achieve this goal, we first derived an estimator for signal-to-noise ratio to select the most appropriate denoising process [10]. The reconstructed signal with the best denoised quality was then used for the
Results and Discussion

The 3D graphs of the wavelet energy difference are shown in Fig. 1, where the x-axis indicates the wavelet decomposition level, the lower level with high frequency and vice versa; the y-axis denotes the beat number, and the z-axis represents the value of $\Delta E_j$. The value of $\Delta E_j$ in the 3rd dimension is now represented by a color, higher positive values being more reddish and lower negative values being more dark blue, as shown in the color bar on the left of the figures. Note that the transition in the change of the color has been smoothed to avoid the chessboard effect in the original color map.

We explored the dominant-hand effect in the normal group as higher wavelet energy of the right-hand side in the high frequency band and lower in the low frequency band as shown in Fig. 1A. In contrast, a reverse change was found in the pattern of the patient group as shown in Fig. 1B. These figures suggest two points. First, the dominant- and non-dominant hands have different neuromuscular responses to this quick arm-lift action. Second, this dominant-hand effect can be modified by MFPUB. The reasons for these inferences are discussed below.

Previous studies have confirmed that the wavelet energy of the SEMG signal reflects the
degree of correspondence of the shape of the MUAP and the wavelet waveform at a certain scale in terms of the frequency band [7, 9, 12-13]. In addition, it is well-known in the physiology of muscle systems [14-17]—the type I MU’s with a slow twitch rate are in charge of sustaining a posture because they have a high oxidative capacity and are able to maintain a contraction for a long period of time without fatigue. In contrast, the type II MU’s with a high twitch rate can reach maximum tension in a much shorter period of time than type I MU’s. According to these approaches, we postulate that the dominant differences in the wavelet energy across various frequency bands may involve a transition between the recruitment of different types of MU’s[18].

The positive tendency towards the acting state within high frequency bands in Fig.1A of the normal group may reflect that more type II MU’s were recruited in the dominant hand. This can be the long-term adaptability that enables the dominant-hand to activate more type II MU’s in a short time to accommodate such a quick action at beat 4. For the non-dominant hand, because it is not used to backward lifting, more type I MU’s are recruited. Because type I MU’s fire slowly and need a longer time to increase in strength for this reaction, recruitment takes place as early as at the resting state to prepare for such a quick action. Therefore, a negative tendency, which reflects the greater energy measured from the non-dominant hand, especially at resting states, appears as the bluish region at the low-frequency range. In contrast, the graph of the patient group in Fig.1B shows the wavelet energy of the right-hand side tends to be lower in the high frequency band and higher in the low frequency band. This phenomenon may be attributed to a compensation effect for the lower recruitment of fast-twitch MU’s to prepare for fast arm-lifting by synchronizing or recruiting more slow-twitch MU’s in the right-hand side of MFPUB patients.

In brief, the major differences featured in the wavelet energy graph between the normal and patient groups reveal that the superiority of the dominant-hand side found in the normal group diminished in the patient group. MFPUB transforms the dominant-hand effect in terms of neuromuscular function by taking over additional slow-twitch MU’s to compensate for the fewer fast-twitch MU’s for a quick arm-lift.

**Conclusion**

To overcome the difficulties in within-subject and between-subject comparison using conventional parametric SEMG measures, we present a multi-scale model based on wavelet energy differences in SEMG to inspect the differences in neuromuscular activation between the dominant and non-dominant hand and the associated changes due to myofascial pain. The results of the multi-scale analysis using this model suggest that the normal subjects tend to recruit more high-frequency components on the dominant-hand side for an arm-lift, while the MFPUB patients tend to weaken the high-frequency components and strengthen the low-frequency components for the same action. In contrast to the conventional SEMG parameters,
which can only reveal gross changes associated with myofascial pain, our proposed model reveals opposite patterns of the two groups, and this may indicate that the neuromuscular responses associated with the dominant-hand effect were modified by myofascial pain. Therefore, the pattern in the 3D graph of the wavelet energy difference provides a valuable tool to analyze the changes in neuromuscular activation due to myofascial pain.

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References


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  2. Deadline for proposal: Wednesday, Jan. 02, 2013

• **2013 EU FP-IDEAS SYNERGY GRANTS**

  2. Deadline for proposal: Thursday, Jan. 10, 2013 at 17:00

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