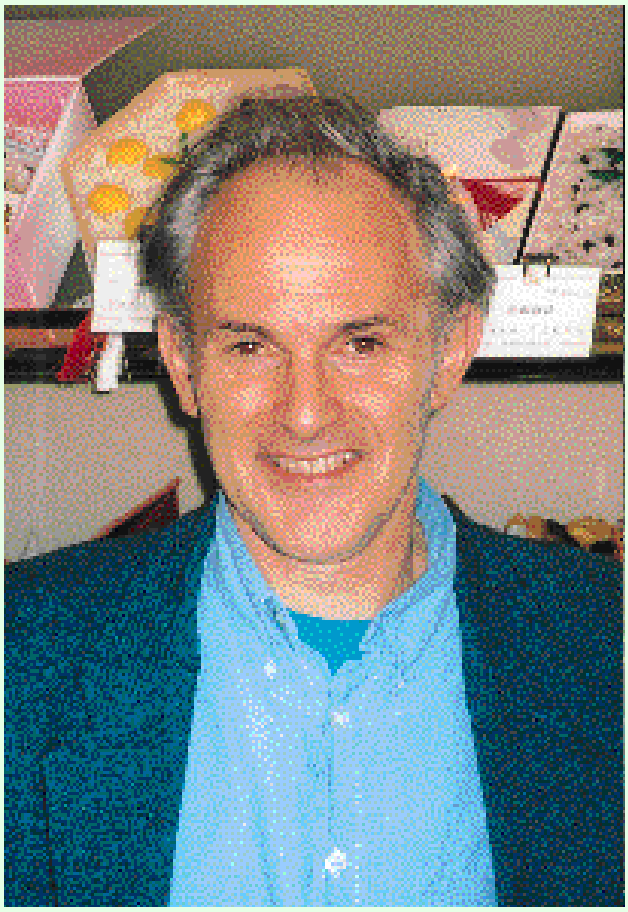
Interview

Talking to Professor Sir Harold Kroto FRS, University of Sussex, United Kingdom, joint winner of the 1996 Nobel Prize in Chemistry for the discovery of Fullerenes and C_{60}.

Professor Kroto was born in Wisbech, Cambridgeshire, (uk) on October 4th, 1939. He received his doctorate on high resolution electronic spectra of free radicals produced by flash photolysis from the University of Sheffield in 1964. He was a postdoctoral researcher at the National Research Centre, Canada, and at Bell Labs, usa, before returning to the uk to join the University of Sussex in 1967 where he became a professor in 1985. His first major prize was a British award for a book jacket design, awarded in 1964. In 1976 he was the first person to discover carbon chain molecules in space, and in 1982, he was the first to create the c=p, c=s double and triple bonds. In 1985, he was a leading member the group that discovered C_{60}. Other recent awards include, 1981-82:Tildon Lecturer (Royal Society of Chemistry); 1990:Elected Fellow of the Royal Society (FRS); 1991: Royal Society Research Fellowship; 1992: International Prize for New Materials (APS), University of Stockholm (PhDHC), Longstaff Medal 1993 (Royal Society of Chemistry), Academia Europea (Member); 1993: University of Limburg (DHC); 1994: Hewlett Packard Europhysics Prize, Moet Hennessy/ Louis Vuitton Science Pour l'Art Prize; 1995: University of Sheffield (Hon. Degree); 1996: Knighted, Nobel Prize for Chemistry. Currently, Professor Kroto holds the prestigious Royal Society Professorship at Sussex University.



OBI: Thank you for your time today and may we start off by asking why you took up science?

Professor Kroto: When I was a kid my main interests were graphic art and playing tennis. I really ended up as a scientist by accident. In those days it wasn't obvious that you could make a living in art. I didn't want to be an artist but I think if I were to go back I would have been involved in illustration or magazine design. But my father made sure I was good at science, and I'm naturally inquisitive, so that's why I am where I am.

OBI: When did you actually decide become a scientist?

Professor Kroto: I did well in science at school, and my A level results (see footnote) in Britain were such that I could go to university. I was pretty good at chemistry, I wasn't brilliant at it, but I got sufficient qualifications to go to university, so I went into science. I had no intention of becoming a scientist, I simply wanted to go university so I could leave home.

OBI: So why did you do continue in science?

Professor Kroto: My main reason for doing a doctrate , apart from liking science and enjoying it, was to stay on at university and play tennis. I would have liked to have been a tennis player, but I wasn't good enough, I kept losing...

OBI: What happened after you got your doctorate?

Professor Kroto: I wanted to live abroad, so I went to Canada and the usa. I came back to England in 1967, to Sussex. It was a new university with a very trendy image and in nice part of the country. Even then I thought "Well I'll try academic life for a few years and if it isn't working I'll go and do some graphics, "I've always had the thought that one day I might pack it all in and go into graphic design.

OBI: You still do designs?

Professor Kroto: Yes, they're usually for scientific organisations. My designs are quite good. I spend all my excess money on buying books on art and design and photography.

OBI: What about your research interests?

Professor Kroto: I'm really a spectroscopist. My first work was in the use of spectroscopy to discover new compounds in chemistry. The first breakthroughs I made were in areas of phosphorous and sulphur chemistry. I'm actually most proud of the fact that our group made the first c=p double bond. That was in 1974. Then, at about the same time, I discovered carbon chains in space with a Japanese scientist named *Takeshi Oka*. So those are two contributions to science of which I'm very proud. I would have died happy with just those.

OBI: And what about the discovery of C_{60}?

Professor Kroto: When C_{60} was discovered, for me it was serendipity. It wasn't serendipity in general, because C_{60} was surely going to be discovered within a year. Rick Smalley's apparatus was going to discover C_{60}, of that, there's no doubt in my mind. Two other groups had already used his apparatus, but they hadn't looked at their data with sufficient care and Rick wasn't interested in looking at carbon. The serendipity was that I, and also Rick, was were both involved in it. Serendipity is a subtle thing and only occurs when the time is right.

OBI: How do rate your achievements?

Professor Kroto: The Noble prize is fantastic, I've got to say that. But I was very proud of winning that first national book jacket prize. I'm very proud of discovering the c=p double and triple bonds and really being a founder of that field. I'm very proud of discovering the carbon chains in space. And I am very proud indeed of discovering C_{60}. But it's a funny thing, it was an accident. It's a question of how much credit one should take for doing the right experiment at the right time.

OBI: You must have travelled to many countries. Do you have a favourite?

Professor Kroto: I don't have favourites, but I always come to Japan whenever I'm invited and I've got lots of friends here. I've been here more than a dozen times. On average at least once a year and sometimes twice. I love the country, partly because there is such a deep sense of culture and history.

OBI: What is your favourite place in Japan?

Professor Kroto: I like *Yasakuni-dori*, which is the main row of book shops between *Jimbocho* and *Ogawa-machi* in Tokyo. This is perhaps my favourite street in the whole world. Every time I come to Japan I spend at least a day in Yasakuni-dori. I just love going to the bookstores and looking at the art books.

OBI: Japan is viewed by many in the West as lacking in basic science, lacking in imagination. What to do you think?

Professor Kroto: I think that's stupid. I think that it's just a matter of emphasis. There is a lot of imagination in believing that certain things can be done, such as the magnetically levitated (maglev) train. It's just that there seems to be a much closer interaction between research and industry here than in Britain. And therefore the interface between imaginative studies and development is somehow more efficient. The highly imaginative paper by *Osawa* on C_{60} is an example. (**OBI:** Osawa predicted in 1970 that C_{60} could exist[1]). And *Iijima*, who instead of looking at the C_{60}, looked at what was happening on the target and discovered nanotubes[2]. These are just two examples of Japanese ingenuity.

OBI: What about the future of science in Japan?

Professor Kroto: I don't have high hopes for grand strategies for science. I think science is much more about an individual's creative capability. One has to have a very flexible system. If the Japanese government says that we have to have a very fertile field, so that all types of plants can flower in it, so that all individuals can succeed, then I think that will work. But if you have a restrictive approach and say, "I want value for money", which is what Britain and the usa are trying to do, then I think it will stifle creativity. Taking my approach to science is now very difficult in Britain.

OBI: As auniversity researcher and academic, do you have any particular ways of inspiring your graduate students?

Professor Kroto: Well I have ideas and we discuss them. I tend to suggest things and not specify particularly well how they should be done and they then usually come up with something much more imaginative then I would have done.

OBI: Are you actively involved in the day to day research activities?

Professor Kroto: Yes, as best I can. For example, all the electron microscope images come to me. I look at them on a plane or a train and then come back and discuss them and think about how to write the papers.

OBI: Are you still fascinated by science?

Professor Kroto: I wouldn't say I'm fascinated by science. It's a drug and it's a drug I don't know I'm taking. Life's just so very interesting! We're looking at these nanotubes and I can't understand how they form. Its just very interesting to try and understand that. Its not so much fascination, its more an interest in the way things work. But my major area now, I spend between a quarter and a third of my time on it, is, making these television films with the *Vega Science Trust*[3]. My aim is to get science on television, maybe a European science channel or certainly a European science night. I want to make an archive of scientists, individual scientists, talking about the aspects of science that they are most interested in.

OBI: How will you organise that project?

Professor Kroto: I'm the executive producer, which means I have to find the people. The most recent series is called *Reflections On Science*. It's something I'm trying to do here in Japan: I'm trying to get the Japanese, American and European science communities focusing on an archive of the best scientists, talking about science and discussing it with students, school students and university students and maybe senior scientist of all kinds across the board. We've made about 22 films up to now. My aim is to make 10 to 30 films a year, getting a record of British, American and Japanese scientists for archives that can be down loaded on the internet from special file servers as well, that is, as the science channel, where the channel is under the "control" of the scientific community. My belief is that all the science on tv today is under the control of media people who don't understand science. That is like having theatre plays put on by people who don't understand plays and can't speak the right language.

OBI: Who will fund this channel?

Professor Kroto: Let's take Japan. Why shouldn't all the physics, chemistry and engineering societies etc., in Japan get together and form a nucleus supported by companies? The payoff in the future for the science base is that scientists and the scientific community would have a cultural home base on tv and an archive of the scientists. It would be tremendous! I think that would have a major impact because at the moment there is no science on tv. I mean let's take an example, the maglev train. The kids are watching the train running at 460 km/h or so, but the science is about how it works and that has got to be put in it somewhere. The Japanese love their art and writers like *Akutagawa*, *Mishima* and *Terebata*, why should you expect to understand their writing without being exposed to their writing?

OBI: The governments writing?

Professor Kroto: The governments, and even scientists, believe that the public can be pulled into an understanding of science without actually understanding any science at all. That's like expecting a blind person to appreciate a painting, or someone who can't speak Japanese to understand Mishima, its impossible. You tell people that nanotubes can do this and that, and that the maglev train is going to get you from Osaka to Tokyo in half the time, but they will never appreciate that science as a cultural activity. Until they do that they won't actually respect you, they'll just say you're the slaves of society. They'll say that you, as a group of scientists, are only as good as your discoveries are useful. And that is our big mistake-to allow them to believe that. They don't think that writers and musicians should be useful other than to elevate the mind. And science elevates the mind just as much, as long as you can read it and understand the language. Until that happens, people will only look on scientists as the slaves of society.

OBI: What do you think is the greatest scientific achievement of the 20th century?

Professor Kroto: Quantum mechanics, no doubt about it, the greatest intellectual achievement was quantum mechanics. It underpins the whole of chemistry and most of physics. I suspect the double helix is going to be the key discovery for the 21st century.

OBI: What do think about the morality of science, the uses of such discoveries and projects as the human genome project?

Professor Kroto: I think that one has to stand back and say this is knowledge and the problem that society faces is the injudicious use of science and technology. As long as science is a closed book to people in government and society, it's going to be used injudiciously.

OBI: How would you try and change that?

Professor Kroto: In general, people don't need more education in the arts because they get it automatically. They listen to music, they go to the theatre, they read books. I believe that education should have a major scientific component. I think that no one should leave school without having say 50% of their time involved in science. The situation now is that science has become so efficient that the need to recognise the scientific achievements on which peoples lives are so precariously balanced has become less and less obvious.

OBI: Would you advise a 15 year old to take up art or science?

Professor Kroto: At that stage you just follow whatever you want, you just need the background.

OBI: What about your own children?

Professor Kroto: They're not scientists. One is in a rock group and ones a film director in London.

OBI: What is your favourite film?

Professor Kroto: My favourite film is *Rashomon*. It's based on a book by *Akutagawa*. I think it's one that every scientist should watch. There is a crime committed and everyone sees a different version of the same events. Each one is different yet each one is equally valid. My view is that there is no objectivity, because each individual is an individual and their perception is dependent on their experience.

OBI: What about music?

Professor Kroto: I'm a 60's child, so my favourite albums are the Rolling Stones - "...Angie", Pink Floyd's "Wish you were here", and the Eagles' "The path of the Sorcerer".

OBI: What's next? Have you got anything left to achieve?

Professor Kroto: Me? Oh, yes. I've got my paintings to do yet. I was going to go into that but C_{60} messed it all up. My main interest at the moment is to understand how nanotubes form. Then, I'd like to see an international science channel, where scientists can talk about their cultural home base. After that, I'd like to get back to graphics and art and design, but I'm getting on a bit now.

Interview By Govind Pindoria

References

1. E. Osawa, *Kagaku*, 25, 854-863, (1970), (published in Japanese).
2. S. Iijima, *Nature*, 345, 56-58, (1991). An interview with Dr. Iijima will be featured in a future issue of OBI
3. Vega Science Trust home page: `http://www.vega.org.uk`
4. Footnote: "A" levels are taken in the uk at the age of 17-18 years and are approximately equivalent to the final examinations at senior high school or the university entrance exams in Japan.

Technology and Society in Japan (1500–1900)

This is the second part of the essay series based on a lecture by Dr Eichi Maruyama. Details about the background to these esays can be found in the April issue of obi.

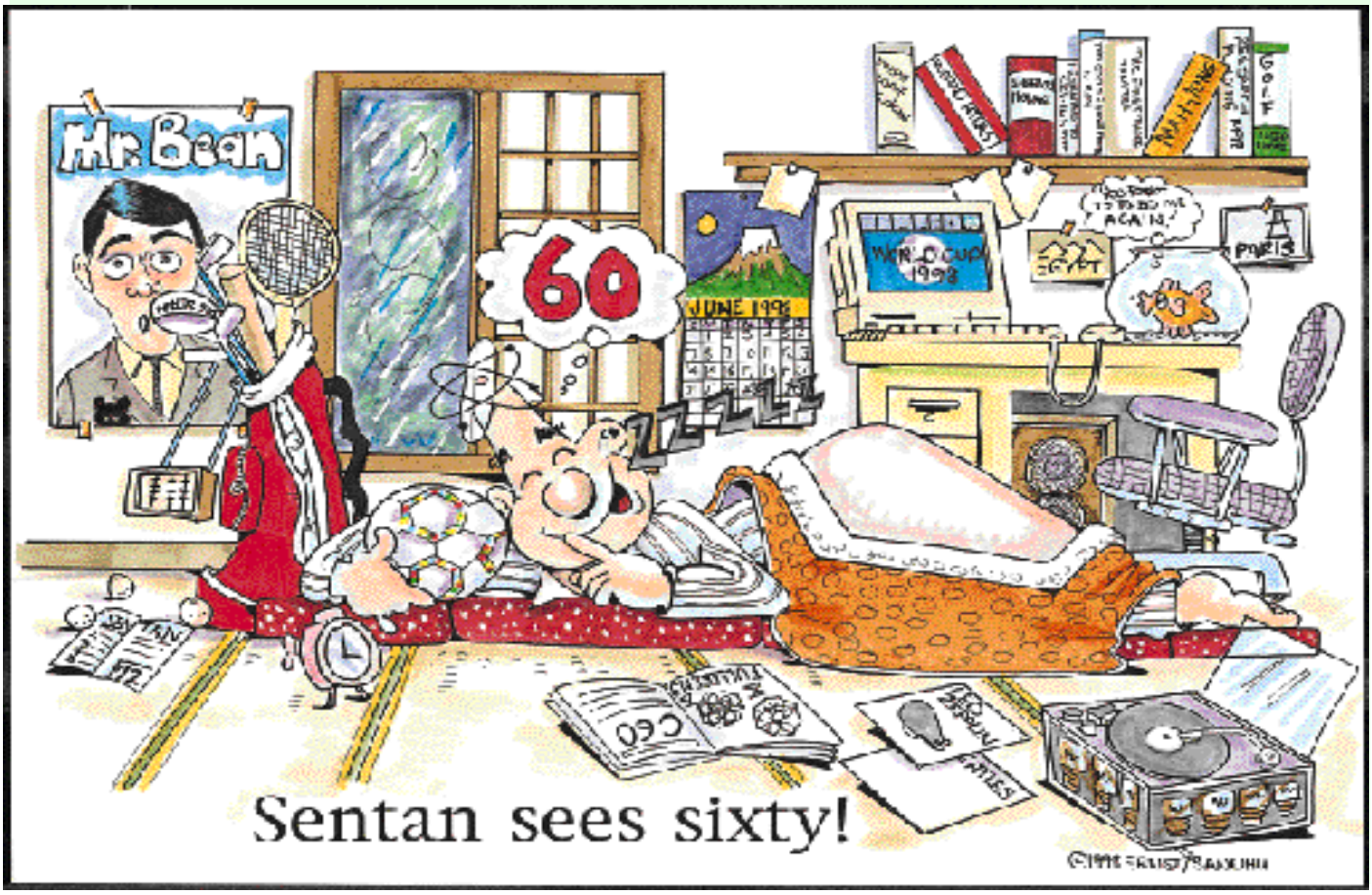
Socio-Technological Infrastructure

During the Edo Period (1603-1867) the practice of *sankin kotai*[1] contributed to the establishment of a very efficient socio-technological infrastructure in Japan. This was because if approximately 260 *daimyos* spread over Japan travel back and forth between Edo and their respective domains once every other year, it is necessary to establish an extensive traffic management system, including chains of relay stations to provide lodgings, horses, labourers, food and other provisions, distributed along major paths. This required a systematic operation based on a precise timetable, flexible adjustment to cope with unexpected accidents such as storms and flooding, and effective information gathering on the part of the relay stations. The money spent by the Daimyo's during this biennial journey was mostly used for maintenance of the traffic infrastructures. The establishment of a traffic infrastructure stimulated tourism among the general public. They enjoyed travelling in groups to *Ise Shrine*. According to statistics, nearly 3 million people, about 10% of the total population of the nation at the time, visited Ise each year. The Japanese fondness of teamed tourism seems to have been inherited from this period.

The long distance travel of a daimyo on sankin kotai required frequent communications between his home and Edo by *hikyaku* or courier system. At that time, a courier ran from Edo to Kyoto in about 10 days, while an express courier on relayed horses covered the distance in 2 days. This speed is comparable to that of the current mailing system.

Centralised Economy

Feudal lords or daimyos during the Edo Period were given autonomous political authority for their domains, but the economy was fully centralised.



Edo with one-million inhabitants was one of the largest cities in the world. Samurais and their employees accounted for about half of the Edo population. They were all consumers. Most of commodities were transported to Edo from other parts of Japan, mainly via sea. A number of *kaisen* , or coastal trading companies, with fleets of merchant vessels, flourished with bases at Osaka, such as *Higaki Kaisen* and *Taru Kaisen.* For example, *sake* (rice wine) produced at *Nada* near Osaka and sent down to Edo was more highly evaluated than that locally brewed. From this, the Japanese adjective *kudaranai* evolved for lower quality, literally meaning "not sent down".

The centralized economy was based on exchange of bill notes, thus requiring merchants to be able to keep accounts by using a fore runner of the digital calculator, *soroban* (abacus), and also to read and write; in this way, merchants' children were forcibly educated. Furthermore, at this time, there were a large number of *ronin*s, or unemployed samurais, who had advanced education and plenty of time, but were financially suffering. They opened *juku* or private schools in every corner of the nations towns and villages. Popularised education improved the literacy of the Japanese to the highest level in the world, as high as 50% (80% for male and 20% for female).

Another feature of *sankin kotai* was that the Edo culture was distributed to remote towns and villages. Samurai returning home from Edo brought a variety of souvenirs, including *Ukiyo-e* prints, which served as sight-seeing guides of Edo, and fashion books to show portraits of Kabuki players, new hair style and kimono patterns.

The taxation in this period is said to be *go-kou go-min*, meaning 50% of the harvest for the government and 50% for peasants' consumption. In view of the population ratio among four classes at that time: peasants 84% and other three (samurai, artisans and merchants combined) 16%, the government was taking much more rice than they consumed

Genroku and Yoshimune's Reforms

Peace and prosperity enjoyed a peak in the middle of the Edo Period, or Genroku Period (1688-1706). This period is characterised by the climactic development of consumer technologies, consolidation of traffic and transportation networks, urban infrastructure, and education. All these conditions have some resemblance to the phase of rapid economic growth of Japan in 1970-80s. Hence, this phase is often called *Showa Genroku*.

Every peak is accompanied with a trough. The Genroku prosperity was followed by a serious depression. Here, stepped in the eighth Shogun, *Yoshimune Tokugawa*, who in 1720 issued the "Prohibition of Production of New Articles" Law, stating that since everything is now inadequate supply, any article of new brand should not be produced. The production of new cakes, kimonos, and anything new was banned. This situation is closely analogous to the present day Japan where the domestic market is saturated by the collapse of so-called "bubble" economy.

From that time on, ruled. The Prohibition Law is strongly criticised by historians for retarding technological progress in Japan, although Yoshimune tried to strengthen economic power of the Tokugawa Government by encouraging local industries and promoting the expansion of arable land.

The people of Edo responded to Yoshimune's Prohibition Law by extensively recycling resources: used paper was collected for use as raw material for new paper; ash from ovens was gathered for use as fertiliser; and people were enthusiastically absorbed in low-cost hobbies and entertainment such as *haiku* (short poems), cultivating *asagao* (morning glory), *joruri* (a sort of ballad sung to the accompaniment of the *shamisen*, a 3-string instrument), *bonsai* (growing miniature trees as old as hundreds of years in a small pot), *ikebana* (the art of flower arranging), *chano-yu* (the tea ceremony), *hana-mi* (admiring cherry blossom), *momiji-gari* (going to admire the colours of autumn) and *o-matsuri* (parading and dancing festivals).

Another undertaking Yoshimune actively promoted was education. He accested Dutch culture except for Christianity. He permitted citizens to attend *shoheiko*, a government operated school for young samurai, as long as they dressed neatly. Furthermore, Yoshimune encouraged *daimyos* to establish their own government and private schools.

In the areas of science and technology, a mathematician, *Takakazu Seki* , invented the calculation of determinants, and a surgeon, *Seishu Hanaoka*, prepared an anaesthetising agent, *Tsusen-San*, with which he anaesthetised a female patient and successfully excised a breast cancer, 37 years before Crawford Long, the American surgeon, used ether as a genral anaesthetic. *Tadataka Ino* , was a merchant. At 50 years, he learned astronomy and the art of surveying and made a highly accurate map of the whole of Japan in 17 years, walking on foot throughout Japan. Errors in his map are said to be within 1/1000.

By the end of Edo Period, several private schools were teaching young people. Among them were: *Tekijuku*, in Osaka, founded by *Koan Ogata*, for teaching science and medicine in Dutch, and *Shokasonjuku* in Yamaguchi, presided over by *Shoin Yoshida*. Many of the young *samurai*, who greatly contributed to the Meiji Restoration, were trained and educated at these schools: *Yukichi Fukuzawa* and *Masujiro Omura* at Tekijuku; and *Takayoshi Kido*, *Shinsaku Takasugi* and *Hirobumi Ito* at *Shoka sonjuku*.

By the 19th century, the old socio-economic structures were beginning to collapse: peasant uprisings had become commonplace, the *samurai* and even the *daimyo* were deeply in debt to the merchants, and the Tokugawa Government's repeated attempts to improve the economic situation failed. The leadership of the *Shogun* in question and further weakened by the arrival of Perry's ships, forcing Japan to conclude unequal commercial treaties with the United States and several European countries. In 1867, the *Shogun* was forced to resign and the imperial government was restored under the young Meiji Emperor.

Reference

1. *Sankin kotai.* As a part of the Tokugawa's peace-keeping strategy, the daimyos were forced to spend half their time in Edo attending the Shogun and the other half in their home domains, leaving their families in Edo.This system is called *sankin kotai*, or alternate attendance. As a result of this system, a daimyo was required to go back and forth between Edo and his own domain every other year, forming a large procession, called *daimyo gyoretsu*. A grandiose scene of daimyo gyoretsu is often depicted in Ukiyo-e. The sankin kotai compelled daimyos to spend enormous amounts of money, which was the Tokugawa's hidden intention.

Correspondence: Japan Society of Applied Physics • Oyo-Buturi International • Kudankita Building 5f • 1-12-3 Kudankita, Chiyoda-Ku, Tokyo 102-0073, Japan • Phone +81 3 3238 1045, Fax +81 3 3221 6245 • E-mail jsapedit@mb.infoweb.ne.jp • http://wwwsoc.nacsis.ac.jp/jsap