

SOL-GEL PROCESS FOR CERAMIC NUCLEAR FUELS

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Introduction

Processing of ceramic materials is known to mankind from very early ages. The first products were the baked earthen pots and later the sophisticated china pottery. Generally, the ceramic materials are associated with high chemical stability at elevated temperatures without large change in the physical properties. These properties associated with ceramic materials make them highly attractive for their use as nuclear fuel materials. Oxides, carbides, nitrides, silicides of uranium, thorium and plutonium and their mixtures fall in this category. Powder metallurgical routes have been established for the production of oxide, carbide and nitride fuels. The established procedures have been used industrially for the production of UO_2 , $(U,Pu)O_2$, $(U,Pu)C$ pellets successfully. Fabrication of UO_2 pellets using powder metallurgical process for the power reactors is a very well established route. However, the following problems are associated with the fabrication of Pu or U-233 fuels using powder metallurgical route.

1. Handling of large quantity of highly toxic radioactive powders.
2. Large number of mechanical steps in the fuel fabrication flow sheet.
3. Difficulties in remotisation of the process as a consequence of the above.
4. Increase in the man-rem problems with the aging of the fabrication facility because of ^{241}Am built up.

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Sol-Gel Processes

For the above reasons, the powder metallurgical routes are considered not ideally suited for the fabrication of Pu or ^{233}U bearing fuels as they involve fabrication facility to be housed in glove-boxes and remote handling. In early sixties, attempts were made to develop solution-based fuel fabrication processes for the production of Th- ^{233}U fuels. Solution-based routes were first investigated for the production of spherical coated particle fuel for the High Temperature Gas cooled Reactors (HTGR). The coated fuel microspheres (UC_2 , UThC_2) were manufactured by using new solution/sol-based routes called Sol-Gel process. The name Sol-Gel process is a generalized heading for chemical routes which involves the gelation of a droplet of sol or solution of the desired fuel material into a gel microsphere. These are washed, dried and heat treated to obtain high density microsphere. These processes offer a large number of advantages over the conventional powder route. Sol-gel processes do not require handling of radioactive powders and involve handling of fluids or fluid like materials which are ideally suited for the remote handling. These processes also minimize the number of mechanical operations and thus reduce the man-rem problems.

Various countries having plutonium fuel development programme developed different versions of sol-gel processes. At ORNL, USA, a sol dehydration process was developed. The process was demonstrated for the production of ThO_2 , UO_2 , $(\text{U,Pu})\text{O}_2$, and $(\text{U,Th})\text{O}_2$ microspheres. Another sol-based process was developed at CNEN in Italy called SNAM process. The process was a combination of external gelation of sol droplets in organic medium. At KFA, Germany, a solution-based process called 'external gelation (KFA) process' was developed for ThO_2 and UO_2 microspheres. At Harwell, UK, another version of external gelation called 'gel supported precipitation' was developed for UO_2 , $(\text{U,Pu})\text{O}_2$ microspheres. KEMA process,

also known as Internal Gelation process, was developed at KEMA laboratories in Netherlands and in many other laboratories like at ORNL, KFA, in Russian labs, in Czechoslovakia labs, at Wurenlingen in Swiss labs, BARC, India, etc.

The sol-gel routes are designed to use the output of reprocessing plant in the form of solutions and convert them into consolidated gel particles, thus eliminating the powder handling and the associated hazards. Vibro- compaction of multiple sizes of high density microspheres in fuel pin cladding has been used to fabricate VIPAC type fuel pins. The history of irradiation behavior of power reactor fuels favour pellet fuel. Thus, a hybrid process involving the sol-gel process in the front end of fuel fabrication merged with the pellet making process called Sol-Gel Microsphere Pelletisation (SGMP) process was developed to get the best of the two processes.

Internal Gelation Process

Internal Gelation Process (IGP) is one of the well studied process in BARC for the preparation of gel microspheres of UO_2 , ThO_2 , $(\text{U,Pu})\text{O}_2$, $(\text{Th,U})\text{O}_2$, etc. The process uses the solutions of the nitrates of uranium, thorium and plutonium or their desired mixtures. The cooled (-0°C) metal nitrate solutions are mixed with urea and HMTA (hexamethylenetetramine) solution in cooled condition (-0°C). The droplets of this mixture are contacted with hot oil (silicone oil $\sim 90^\circ\text{C}$) to make gel microspheres. These gel microspheres are washed first with CCl_4 to remove the silicone oil and then with NH_4OH solution to remove excess gelation agents – HMTA, urea and ammonium nitrate. The washed particles are dried at 150°C in air and then calcined upto 500°C to remove residual organic matter and ammonium nitrate. The calcined microspheres are then reduced in N_2+H_2 mixture at 600°C . The UO_2 microspheres thus produced are sintered at 1200°C for 3 hrs to produce $>99\%$ TD microspheres. The flow chart of the Internal Gelation Process is given in Figure 1.

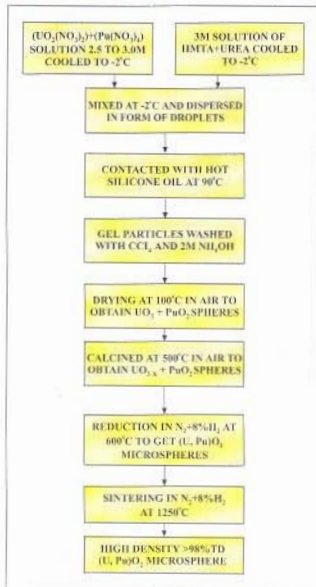


Fig.1 Flow Chart for Internal Gelation Process

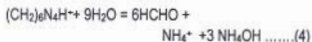
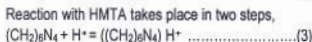
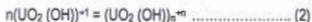
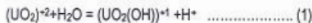
The gelation behaviour of feed solution comprising of metal nitrate solution, HMTA and urea is the deciding factor for the properties of the gel particles.

Studies have been carried out in FCD, BARC, to establish the gelation behaviour of the feed solution as a function of gelation temperature and the quality of resultant gels.

Results of these studies for feed solution containing uranium and thorium solution as a function of feed composition have been consolidated to yield gelation field diagram.

The gelation behaviour of the feed solution is understood from the way urea and HMTA react with

metal nitrate solutions. Urea ($\text{CO}(\text{NH}_2)_2$) reacts with the heavy metal ions $\text{U}(\text{VI})$, $\text{Pu}(\text{IV})$ and $\text{Th}(\text{IV})$ at low temperature $\sim 0^\circ\text{C}$ to form complexes which prevent hydrolysis at low temperature of these metal ions by HMTA ($((\text{CH}_2)_6\text{N}_4)$). The metal ion complexes dissociate during gelation as they are unstable at higher temperatures. Metal ions hydrolyze as per reaction (1)



Ammonium hydroxide generated reacts with hydrogen ion to neutralize and form the metal ion polymer $(\text{UO}_2(\text{OH}))_n^{+n}$. The properties and molecular weight depends on the kinetics of reactions. Reaction (3) is ionic in nature and thus fast, and reaction (4) is comparatively slow. Thus, the properties of the gel depend on whether the hydrolysis is caused by reaction (3) or by reaction (4). When large molar ratio of HMTA/U is present, majority of hydrolysis is completed by the reaction (1). Resultant gel because of fast kinetics does not allow growth of crystallites and the gel formed is transparent or translucent.

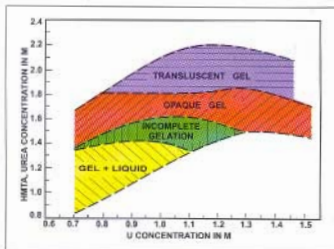


Fig.2 Gelation field diagram for uranium

The gels formed with lower molar ratio of HMTAJU in the solution are predominantly formed by reaction 4 and thus the crystallites of the polymer are allowed to grow because of slow kinetics. These variations are clearly seen in the gelation field diagram as shown in Figure 2.

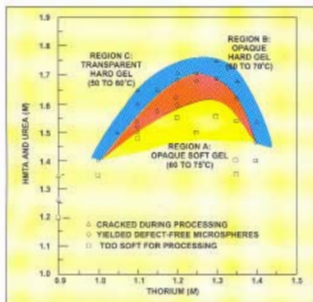


Fig.3 Gelation field diagram for thorium

Figure 3 shows gelation field diagram for thorium.

Feed compositions having uranium molarity between 1.0 to 1.4 M have been successfully used for the preparation of UO_2 gel particles. These gel particles have been sintered to make >99%TD UO_2 microspheres of 500 to 700 μm dia. Figure 4 shows sintered UO_2 microspheres. These microspheres are well suited for the vibro-compaction of fuel pins.

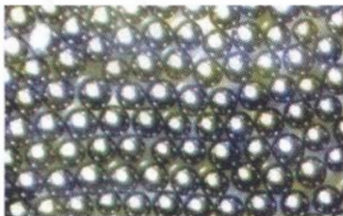


Fig.4 Sintered UO_2 microspheres of 700 μm dia

Regions involving lower molarity of uranium (0.7 to 0.9M) have been used for the preparation of UO_2 of smaller diameters between 70 to 100 μm dia. The regions involving higher molarity of uranium >1.35 M use lesser quantity of gelation agents HMTA and urea per kg of uranium processed. Using two sizes of microspheres, fuel pins can be vibro-compacted to give 82-83% smear density in the fuel pin. Such fuel pins have been fabricated and irradiated in Fast and Thermal Reactors in many countries. In pile and post irradiation examination, results of such experiments with mixed oxide and carbide fuels have been very encouraging.

SGMP

SGMP processes for the fabrication of UO_2 and $(U,Pu)O_2$ pellets have been studied in Fuel Chemistry Division and Radio Metallurgy Division of BARC. Originally, gel spheres containing carbon pore former were used for the process which required very long and highly controlled heat treatment schemes. The SGMP process was modified by the use of gelation field diagram. Compositions of feed solutions suitable for obtaining crushable UO_2 microspheres were identified by observing the regular change of dry gel properties as a function of feed composition.

The flow chart of SGMP for oxide pellets is given in Figure 5. Suitable feed compositions along with the calcination and reduction steps of heat treatment have been chosen to optimize the properties of the dry gel microspheres that do not shrink during further heat treatment and are soft. The compositions suitable for the SGMP are having higher molarity of uranium (>1.4 M) in feed solution. The pressed pellets are sintered at desired temperature to make high density pellets. Low Temperature Oxidative Sintering (LTS) procedure has been used to make UO_2 pellets suitable for PHWR. Figure 6 shows various stages of SGMP for making sintered UO_2 pellets.

Two fuel bundles using SGMP pellets have been successfully irradiated at MAPS.

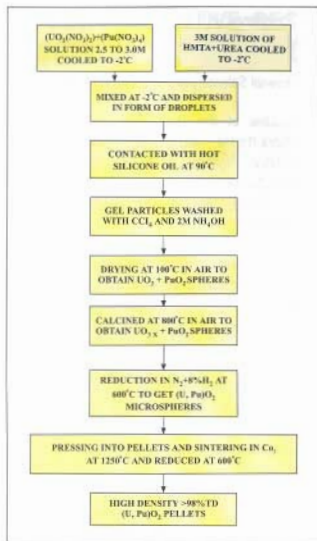


Fig. 5 Flow chart for SGMP UO₂ pellets

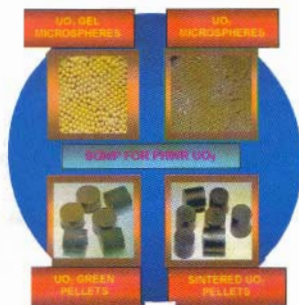


Fig. 6 Stages of SGMP for UO₂ pellets

A similar SGMP process has been optimized for the preparation of ThO₂ and (Th,2%U)O₂ pellets for their use in fabrication of fuel elements for AHWR. Various stages of SGMP for ThO₂ are seen in Figure 7.

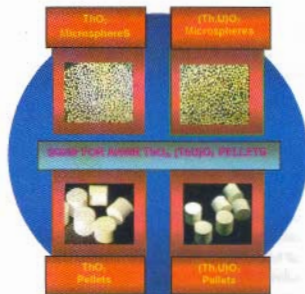


Fig. 7 Stages of SGMP for ThO₂ pellets

A glove box facility for the preparation of (U,Pu)O₂ microspheres has been set up at FCD. Figure 8 gives the details of the gelation setup in a glove-box.



Fig. 8 Gelation equipment in glove-box



Fig. 9 Fore-runner facility at FCD

A fore-runner sol-gel facility has been set up at FCD. This setup is operated using a fully computerised control system. The setup has been used as a demonstration facility and has also been used for the qualification of equipment suitable for all future sol-gel facilities. The fore-runner facility is seen in Figure 9. A demonstration plant for sol-gel MOX microspheres is being set up at A3F Tarapur and another sol-gel facility is being set up at FCD, IGCAR at Kalpakkam.

The Sol-Gel Team

The team responsible for the development of sol-gel process comprises of following officers of FCD and RChD : Dr. S.K.Mukerjee, Mr R.V.Kamat, Mr S.Suryanarayana, Mr S.Venkateswaran, Mr S.B. Rajure, Mr J.K. Joshi, J. Radhakrishna, Mr N. Kumar, Dr J.V. Dehadraya, Dr. K.T. Pillai, Mr Ashok Kumar, Mr A.C. Deb, Mr Rajesh Pai, Mr V.R. Ganatra, Mr Y.R. Bamankar, Mr T.V. Vittal Rao, Mr L.B. Pable, Dr.D.D. Sood (IAEA), and Dr. V.N. Vaidya.

For Further Reading

1. "A Study of Chemical Parameters of the Internal Gelation Based Sol-Gel Process for Uranium Dioxide," V.N. Vaidya, S.K. Mukerjee, J.K. Joshi, R.V.Kamat and D.D. Sood, *Journal of Nucl. Mater.*, 148(1987), 324-331.

2. "Experience in BARC on the Preparation of Gel Microspheres of Uranium, Thorium and Plutonium Fuels", V.N. Vaidya and D.D. Sood, *Material Science Forum*, Vol 48-49 (1989).
3. "Studies of the Preparation of Thoria and Thoria-Urania Microspheres using Internal Gelation Process", N. Kumar, R.K. Sharma, V.R. Ganatra, S.K. Mukerjee, V.N. Vaidya and D.D. Sood, *Nuclear Technology*, 96 (1991), 169-177.
4. "Carbothermic Reduction of (UO_3+C) Microspheres to (UO_2+C) Microspheres", S.K. Mukerjee, G.A. Rama Rao, J.V. Dehadraya, V.N. Vaidya, V. Venugopal and D.D. Sood, *J. Nucl.Mater.*, 199 (1992), 247-257.
5. "Uranium Nitride: Its preparation, Oxidation and Vaporisation", D.D. Sood, S.K. Mukerjee, V.N. Vaidya and V. Venugopal, *J. Metals, Materials and Process*, 5, 1, 13-22 (1993).
6. "Oxidation of Uranium Mono Carbide Microspheres", S.K. Mukerjee G.A. Rama Rao, J.V. Dehadraya, V.N. Vaidya, V. Venugopal and D.D. Sood, *J. Nucl. Mater.*, 210 (1994), 97-106.
7. "Preparation of Carbon Free Gel - Microspheres Suitable for Fabrication of High Density Pellets UO_2 Pellets", S. Suryanarayana, N. Kumar, Y.R. Bamankar, V.N. Vaidya, and D.D. Sood, *Trans PMAI* 22, (1995), 30-34.
8. "Kinetics and Mechanism of $\text{UO}_2 + \text{C}$ Reaction for $\text{UC}+\text{UC}_2$ Preparation", S.K. Mukerjee, J.V. Dehadraya, V.N. Vaidya and D.D. Sood, *J. Nucl. Mater.*, 210 (1994) 107-114.
9. "Fabrication of UO_2 pellets by Gel Pelletisation Technique without Addition of Carbon as Pore Former" S. Suryanarayana, N. Kumar, Y.R. Bamankar, V.N. Vaidya, and D.D. Sood, *J. Nucl. Mater.*, 230 (1996), 140-147.

AN ULTRA-SENSITIVE RESONANCE IONISATION MASS SPECTROMETER AS A MEDICAL DIAGNOSTIC TOOL FOR ^{41}Ca MONITORING

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Determination of rare radioactive and stable isotopes has gained importance in environmental, nuclear physics and medical applications [1,2]. For example, determination of ^{89}Sr and ^{90}Sr isotopes in the air is important to understand the effects of nuclear fallout as a result of nuclear reactor accidents and above ground nuclear weapon tests. Accurate determination of rare nuclides in various samples is also important for estimating the yields of nuclear detonations [3]. Determination of rare isotopes is possible largely due to the development of laser based methods such as diode laser resonance ionisation mass spectrometry and collinear resonance ionisation spectroscopy.

Determination of long-lived rare ^{41}Ca ($T_{1/2} = 1.04 \times 10^5$ yr) isotope is important for applications in cosmo-chronology and nuclear physics. In cosmo-chronology, determination of extremely low levels of ^{41}Ca would enable radio dating in the region of 10^4 – 10^6 years. In nuclear physics applications, determination of ^{41}Ca : ^{40}Ca ratio in calcium rich materials (ca. walls) allows one to determine the cross section of ^{41}Ca (n, γ) ^{42}Ca nuclear reaction.

Over the past two decades, new applications using stable isotope tracers have been developed for trace element metabolism in the human body. One of the primary advantages with the stable isotope techniques is that it can be used on children including infants and pregnant women who are considered as high risk group with respect to malnutrition. Stable isotope techniques also enable monitoring the availability over extended period of

time. The available techniques, however, are often insufficient to generate the desired information.

Studies on calcium kinetics in the human body lead to vital information about the growth and decay of bones in humans. Osteoporosis, a known bone disorder, is caused by excessive loss of calcium, which results in about two million hip and spine fractures every year. Although osteoporosis occurs both in men and women, women are at higher risk due to the reduction in estrogen production at menopause. Since nearly 80% of the Indian women are anaemic during pregnancy [4], osteoporosis is a major concern.

The radioisotope ^{41}Ca (about 60ng) can be injected for in-vivo study of calcium kinetics in the human body [5]. In order to study the calcium kinetics for extended periods, one need to use methods, which can provide high sensitivity. The ratio of ^{41}Ca is expected to be $\sim 10^{-9}$ – 10^{-12} relative to stable ^{40}Ca isotope. Therefore, determination of ^{41}Ca in presence of stable calcium isotopes requires a technique which can give an abundance sensitivity of $\geq 10^{10}$. Most of the conventional mass spectrometric techniques can yield abundance sensitivities of $\leq 10^6$; therefore such techniques can not be used in applications for the determination of rare isotopes. In such cases, one need to employ special analytical techniques such as Accelerator Mass Spectrometry (AMS) or Resonance Ionisation Mass Spectrometry (RIMS). Resonance ionisation mass spectrometry is considered as a cost-effective alternative to the expensive AMS.

A combination of high-resolution laser spectroscopy and conventional mass spectrometry has opened up exciting applications in several areas due to its high sensitivity and selectivity. High elemental selectivity (in several cases, high isotope selectivity) is achieved by utilization of lasers with sufficiently narrow linewidth and high sensitivity is achieved by choosing a combination of appropriate atomizer, mass spectrometer and excitation laser(s).

Laser Spectroscopy of Calcium

Calcium has six stable isotopes namely ^{40}Ca (96.941%), ^{42}Ca (0.647%), ^{43}Ca (0.135%), ^{44}Ca (2.086%), ^{46}Ca (0.004%) and ^{48}Ca (0.187%). The long-lived ^{41}Ca radio-isotope has an abundance of $\sim 10^{-10}\%$.

Studies on isotope shifts (IS) and hyperfine structure (HFS) of calcium isotopes are of interest due to several reasons. The nuclides ^{40}Ca and ^{48}Ca are both doubly magic. Determination of HFS (in case of odd isotopes) and IS of calcium isotope chain yield information about the effects associated with the addition of neutron in the $f_{7/2}$ shell. The isotope shift can be related to the nuclear parameter ($\lambda^{A,A}$) by the expression

$$\delta\nu^{A,A} = F \times \lambda^{A,A} + M \times \frac{A' - A}{A'A} \quad (1)$$

In case of calcium, the nuclear parameter ($\lambda^{A,A}$) can be replaced with mean square nuclear charge radius $\delta\langle r^2 \rangle^{A,A}$. Therefore, isotope shift can be directly related to the mean square nuclear charge radius of the isotope

$$\delta\nu^{A,A} = F \times \delta\langle r^2 \rangle^{A,A} + M \times \frac{A' - A}{A'A} \quad (2)$$

The values of F and M for a transition can be determined if the isotope shifts and the $\delta\langle r^2 \rangle^{A,A}$ values for a chain of isotopes are known. King's plot analysis has been carried out for the $4s^2 \ ^1S_0 - 4s4p \ ^1P_1$ (422.7nm) and $4s4p \ ^1P_1 - 4s4d \ ^1D_2$ (732.8nm) transitions and the F, M values determined are

tabulated in Table 1 along with the field and mass shifts. As expected, in this case, the isotope shifts are predominantly mass shift, since the field shifts are quite small owing to the small or negligible nuclear deformations. The computed isotope shifts of ^{41}Ca for the two transitions were in good agreement with the reported experimental values.

Table 1 : Computed field shift parameter (F), mass shift parameter (M) and field and mass shifts for two calcium transitions

Property	422.7nm	732.8nm
F (MHz / fm ²)	-173.93	-7.76
M (MHz·amu)	362755.09	736620.07
Field Shift $\delta\nu_{FS}^{41,40}$ (MHz)	2.09	0.09
Mass Shift $\delta\nu_{MS}^{41,40}$ (MHz)	221.19	449.15
Isotope Shift $\delta\nu^{41,40}$ (MHz)	223.28	449.24
Calculated	221.8	447.9
Experimental		

Determination of magnetic dipole (A) and electric quadrupole (B) constants for the odd isotopes, would enable determination of nuclear magnetic moment (μ), electric quadrupole moment (Q) and the nuclear spin (I). In the absence of hyperfine anomaly, the hyperfine structure of the rare isotopes can be determined based on the HFS of known odd isotopes. The spectroscopic investigations of this nature would enable one to identify efficient photoionisation schemes for the selective ionisation of ^{41}Ca isotope.

RIMS of Calcium

A resonance ionisation mass spectrometer for the selective determination of ^{41}Ca isotope requires high detection efficiency and high isotopic selectivity apart from complete suppression of isobars (i.e., high elemental selectivity). Since high elemental selectivity is inherent in the laser excitation process,

the aspects related to sensitivity and selectivity are discussed below.

Sensitivity

If the efficiency of atomisation (η_{at}), transportation (η_t), interaction (η_{int}), ionisation (η_{ion}) and detection (η_{det}) are close to 100%, then single atom detection can be achieved. The probability of single atom detection (η_{sad}) is expressed as

$$\eta_{sad} = \eta_{at} \times \eta_t \times \eta_{int} \times \eta_{ion} \times \eta_{det}$$

In a resonance ionisation mass spectrometer, it is possible to ionize all the atoms in the interaction region and detect them. Therefore the overall sensitivity is dependent on atomization, transportation and interaction efficiencies. By choosing appropriate combination of lasers, atom source and mass spectrometer (viz., cw lasers, filament atomisation source and a QMS) one can achieve an overall efficiency of 10⁻⁶% [7].

Selectivity

Selectivity is defined as the ability to ionize the desired isotope while leaving the unwanted isotopes unexcited. Isotopic selectivity for a transition is defined as the ratio of the intensity of the isotope of interest at its resonance to the intensity of the interfering isotope at the resonance frequency of the isotope of interest.

For a two-step resonance ionisation, selectivity is defined as

$$S(\omega_1, \omega_2) = \frac{I_{M1}(\omega_1, \omega_2)}{I_{M2}(\omega_1, \omega_2)} \quad (3)$$

where, $I_{M1}(\omega_1, \omega_2)$ is the abundance of the isotope in the excited plume when the first laser is tuned to ω_1 and second excitation laser is tuned to ω_2 for isotope M1 and $I_{M2}(\omega_1, \omega_2)$ is the abundance of isotope M2.

For example, an optical selectivity of 10⁵ implies that the abundance of the isotope can be increased

to 100% (in the excited plume), if the initial abundance of the isotope is 0.001%.

The overall selectivity in a RIMS process comprises of selectivity due to the optical excitation and selectivity due to the mass spectrometer.

$$S = S_{mass} \times S_{opt} \quad (4)$$

When the abundance of the rare isotope is 10⁻¹⁰, the desired selectivity of the RIMS process must be $\geq 10^{10}$. Since most of the conventional mass spectrometers can provide selectivity (i.e., abundance sensitivity) of $\sim 10^6$, the desired optical selectivity due to the laser excitation process is $\sim 10^4$.

Since the isotope shifts of the calcium isotopes are small, it requires two-step excitation in order to achieve an overall selectivity of 10⁴. A typical photoionization scheme for the selective ionization of ⁴¹Ca is given below.

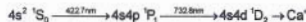


Table 2 : Optical selectivities of calcium isotopes for the $4s^2 \ ^1S_0 \xrightarrow{422.7nm} 4s4p \ ^1P_1 \xrightarrow{732.8nm} 4s4d \ ^1D_2 \rightarrow Ca^+$ photoionisation scheme

Isotope	Selectivity (Against ⁴⁰ Ca)	
	Present work	Ref.[10]
⁴¹ Ca	5.5 x 10 ⁵	2.5 x 10 ⁵
⁴² Ca	1.3 x 10 ⁷	1.3 x 10 ⁷
⁴³ Ca	5.3 x 10 ⁷	5.3 x 10 ⁷
⁴¹ Ca	1.8 x 10 ⁸	1.9 x 10 ⁸
⁴⁶ Ca	8.1 x 10 ⁸	9 x 10 ⁸
⁴⁸ Ca	2.2 x 10 ⁹	2.5 x 10 ⁹

The optical selectivities of calcium isotopes have been calculated using spectral simulation method developed by us (Table 2) for a laser linewidth of 0.5MHz [8]. The details of spectral simulation method can be found in our recent report [9].

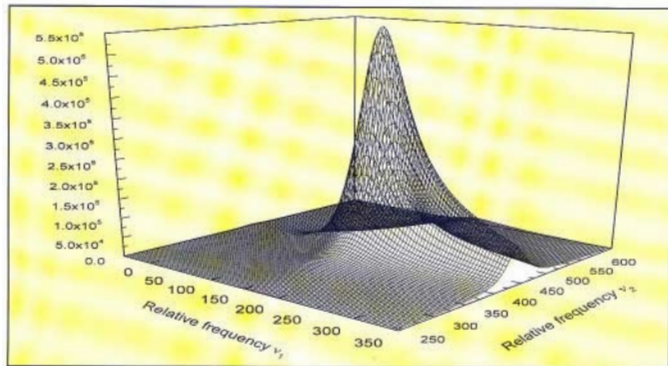


Fig.1 Optical selectivity of ^{41}Ca as a function of detuning of first and second excitation lasers

Isotope selectivity of ^{41}Ca as a function of detuning of both the excitation lasers is plotted as three-dimensional plot in Fig. 1. The present calculations indicate that an optical selectivity of 5.5×10^5 can be achieved when the first and second excitation lasers (having a linewidth of 0.5MHz) are tuned to +166MHz and +445MHz respectively from the resonance of ^{40}Ca position. These frequency positions correspond to the most intense $7/2 - 9/2$ and $9/2 - 11/2$ HFS components. When lasers with a linewidth of 50MHz are employed for both the first and second excitation steps, the optical selectivity is found to be 2.2×10^5 , which is adequate for the applications intended.

Conclusion

Determination of ^{41}Ca in various samples requires an isotopic selectivity of $\sim 10^{10}$ and ionisation efficiency of 10-5%. This can be achieved by the development of a diode laser RIMS system consisting of a filament atomiser, quadrupole mass spectrometer and diode lasers. From our theoretical study, the linewidth requirement of excitation lasers is found to be $\sim 50\text{MHz}$. Based on these parameters,

it is possible to build a diode laser based resonance ionisation mass spectrometer at a cost of about rupees eighty five lakhs. Sensitivity of such RIMS system enables one to study the calcium kinetics for more than a year. This makes ^{41}Ca analysis affordable not only for use in bone research, but also as a routine diagnostic tool in the hospitals. Apart from this, development of a cw laser RIMS opens exciting possibilities for the determination of other rare isotopes up to an abundance ratio of $1:10^{10}$.

References

1. D. Fink, J. Klein and R. Middleton., *Nucl Instrum. Meth. in Phys. Res.* 52B, 572 (1990).
2. P. Muller, B.A. Bushaw, K. Blaum, S. Diehl, Ch. Geppert, A. Nahler, N. Trautmann, W. Nortershauser and K. Wendt, *Fres. J. Anal. Chem.* 370, 508 (2001).
3. S.B. Manohar, B.S. Tomar, S.S. Rattan, V.K. Shukla, V.V. Kulkarni and Anil Kakodkar, *BARC News Letter No.* 186, 1 (1999).
4. G.V. Iyengar and P.P. Nair, *Sci. Tot. Environ.* 249, 331 (2000)

5. R.R. Johnson, D. Berkovits, E. Boaretto, Z. Gelbart, S. Gehlberg, O. Meirav, M. Paul, J. Prior, V. Sossi and E. Venezel, *Nucl. Instrum. Meth. in Phys. Res.* 92B, 483 (1994).
6. W. Nörtershäuser, N. Trautmann, K. Wendt and B.A. Bushaw, *Spectrochim. Acta* 53B, 709 (1998).
7. K. Wendt, K. Blaum, B.A. Bushaw, F. Juston, W. Nortershauser, N. Trautmann and B. Wiche, *Fres. J. Anal. Chem.* 359, 361 (1997).
8. M. Sankari, P.V. Kiran Kumar and M. V. Suryanarayana, *J. Phys.* 33B, 4927 (2000).
9. M. V. Suryanarayana, M. Sankari and P.V. Kiran Kumar, *BARC Report 2001/08*.
10. B.A. Bushaw, W. Nortershauser and K. Wendt, *Spectrochim. Acta* 54B, 321 (1999).

COMPUTER CENTRE INAUGURATED AT BAL KALYAN NAGARI, MANKHURD

October 27, 2001 was a red-letter day for the 400 children of the Bal Kalyan Nagari (BKN), Mankhurd. Dr Anil Kakodkar, Chairman, Atomic Energy Commission and Secretary, Government of India, inaugurated a Computer Centre in BKN on that day. BKN is an institution (administered by Children's Aid Society (CAS), Govt. of Maharashtra), for the socially and financially deprived children (age group 8 to 18) and is situated outside the main gate of Anushaktinagar residential complex. The Chairman's mother and wife also accompanied him. It is pertinent to mention here that the computers at the Computer Centre (six used computers but in very good condition) were donated by BARC to this institution during August 2001. Volunteers residing in Anushaktinagar impart free training on computers to the children.



Dr Anil kakodkar, Chairman, AEC & Secretary, Department of Atomic Energy, moving among the children of the Bal Kalyan Nagari, Mankhurd

A function was organised by BKN for the inauguration ceremony. Prominent authorities of CAS, children and staff of BKN and dignitaries from other social organisations and BARC attended the function. Ms Kamal Abani, a social worker from BARC colony, actively involved with the institution for the last so many years, introduced the chief guest. Mr M.S.S. Murthy, Deputy Chief Officer of CAS, traced in length about the history of the Society, which is in existence since the year 1927. Mr D.N. Mandlekar, IAS, Administrator, CAS, profusely thanked BARC for donating the computers and also stressed the need for computer education among the children of the institution, as it would help them to become self-reliant when they leave the institution at the age of 18 years. The chief guest, Dr Anil Kakodkar, who spoke passionately, exhorted the children to have all-round development so that, when they grow up, they should be in a position to help the society. He stated that helping the socially needy children is everyone's responsibility. Dr Kakodkar also pointed out that BKN is a neighbour of Anushaktinagar and the volunteers from the colony are already helping the inmates of BKN. He also extolled the staff of BKN for the good work.

Mr S.A. Jadhav, Administrator, BKN, while proposing the vote of thanks, said that BKN is specially thankful to Dr Anil Kakodkar, Chairman, AEC, and

Mr B. Bhattacharjee, Director, BARC, for the kind gesture shown by them in gifting the computers to the BKN. He thanked Dr Kakodkar and his family members for sparing their valuable time to visit the centre and encouraging the children in their endeavour to become good citizens. He also thanked officers from BARC specially Mr H.K. Kaura, Head, Computer Division, Mr P.S. Dhekne, Officer-in-Charge, Computer Centre, Mr V.R. Sadasivam, IFA, Mr V.P. Kansra, Director, NRG, Dr Vijai Kumar, Head, Library & Information Services Division, Mr R.S. Chhokra, Project Manager, FRDL a & PPAP, Dr M.C. Abani, Head, Radiation Safety Systems Division and Mr R.S. Sadagopan, Scientific Officer, for their valuable help in providing computers to BKN.

To sum up, the function, albeit different from the ordinary, was a grand success.

TRAINING COURSE ON HEALTH AND SAFETY

The 22nd Course on 'Accident Prevention and Promotion of Occupational Health and Safety' was conducted during October 8-19, 2001. This year, for the first time, the course was conducted jointly by the Radiation Safety Systems Division (RSSD), BARC, and the Directorate General Factory Advice Service & Labour Institutes (DGFASLI), Mumbai. A total of 45 persons from the middle management/supervisory level from BARC as well as other DAE units participated in the course.

In his Welcome address, Dr M.C. Abani, Head, Radiation Safety Systems Division, BARC, gave an outline of the course and also stressed the importance of safety training in inculcating safety culture in the Centre. Giving a brief outline of the DGFASLI activities, Mr S.G. Dutta, Director-in-Charge (Safety), stated that DGFASLI is involved in framing the Health and Safety Acts and Rules and also in assessment of health and safety status of Factories. He added that DGFASLI is also involved

in conducting various safety training programmes in the country, including the Advanced Diploma Course in Industrial Safety which is a prerequisite for being employed as a Safety Officer in Factories. Mr Dutta appreciated BARC's efforts in conducting the training course in collaboration with DGFASLI and assured full cooperation for the venture.



Dr V. Venkat Raj, Director, Health, Safety & Environment Group, BARC, inaugurating the 22nd Training Course on 'Accident Prevention and Promotion of Occupational Health and Safety'

In his Inaugural address, Dr V. Venkat Raj, Director, Health, Safety and Environment Group, BARC, stressed the importance given to conventional safety in the operations conducted in the Centre. Stating that BARC gives as much equal importance to conventional safety as to radiation safety, he recalled that a major Safety Committee functioning under the safety organisation in the Centre exclusively reviews the conventional and fire safety aspects. He desired that, for the successful running of the safety programme in the Centre, the lessons learnt in the training course should be diligently put into practice by the participants.

The highlights of the training course were lectures on health, safety and environment topics, visit to the Safety Centre of DGFASLI and a feed back session.

Mr S. Narayan, Head, Industrial Hygiene & Safety Section, RSSD, BARC, coordinated the training course from BARC side. He proposed a vote of thanks.

TRAINING COURSE ON 'RADIOIMMUNOASSAY AND ITS CLINICAL APPLICATIONS'



Mr P. Krishniah, IAS, Executive Officer, Tirupati Tirumala Devasthanam (TTD), inaugurating the 42nd Training Course on 'Radioimmunoassay and its Clinical Applications'

The 42nd training course on 'Radioimmunoassay and its Clinical Applications', jointly organized by BARC and Sri Venkateswara Institute of Medical Sciences (SVIMS), Tirupati, was conducted during July 16-31, 2001 at Tirupati. This course was inaugurated by Mr P. Krishniah (IAS), Executive Officer, Tirupati Tirumala Devasthanam (TTD) in a function presided over by Dr N. Ramamoorthy, Associate Director, Isotope Group & Chief Executive, BRIT. Prof. N. Kochupillai, Head (Retired), Department of Endocrinology & Metabolism, All India Institute of Medical Sciences, New Delhi, delivered the key-note address. The course was attended by 18 medical doctors specialized in areas such as endocrinology, pathology and pharmacology from all over India.

The Radioimmunoassay training course was started at BARC in the year 1980 to train prospective users of radioimmunoassay kits with the methodology and its quality control aspects. The Radioimmunoassay course is generally held twice a year with 20-24 candidates in each batch.



Participants and faculty of 42nd Training Course on 'Radioimmunoassay and its Clinical Applications'

However, in the year 2001, three courses were conducted – two at BRIT laboratories, Navi Mumbai, and the third at Sri Venkateswara Institute of Medical Sciences, Tirupati. With over 1000 medical and paramedical personnel trained in the 42 courses conducted thus far, the RIA training has been the crucial catalytic factor for the growth of RIA in India. At present, there are over 500 RIA laboratories in India, thanks to the RIA training programme. At least 40 trainees from more than 15-20 countries have also received training in RIA in India. In addition, one exclusive International Training Course on RIA for IAEA-sponsored candidates was also held in 1986.

BRNS – IANCAS NATIONAL WORKSHOP

The Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) conducted its 45th National Workshop at Indian Institute of Horticultural Research (IIHR), Bangalore, during September 12-20, 2001.

Dr A.M.Krishnappa, Vice-Chancellor, University of Agricultural Science, Bangalore, in his inaugural address, reminisced his experience in handling radioisotopes and encouraged the participants to take advantage of this Workshop on the use of radioisotopes. Mr D.S.C. Purushotham, Director,



Inauguration of the 45th BRNS-IANCAS National Workshop on 'Radiochemistry and Application of Radioisotopes' at Indian Institute of Horticultural Research (IIHR), Bangalore, by Mr D.S.C. Purushotham, Director, Nuclear Fuels Group, BARC, on September 12, 2001. Seated (left to right) are Dr S.B. Manohar, President, IANCAS and Head, Radiochemistry Division, BARC, Mr D.S.C. Purushotham, Dr A.M. Krishnappa, Vice-Chancellor, Univ. of Agriculture Science, Bangalore, Dr P. Parvatha Reddy, Director, IIHR, Dr M.D. Awasthi, Head, Division of Soil Science & Agricultural Chemistry, IIHR

Nuclear Fuels Group, BARC, delivered the keynote address on the commitment of DAE to Nuclear Power production and the status of various on-going programmes aimed at achieving the goal. Dr S.B. Manohar, President, IANCAS, highlighted the activities of the association and gave a lecture on the theory of radioactivity. Three days of the Workshop were devoted to the applications of radioisotopes in agriculture, and Dr S.F.D'Souza, Head, Nuclear Agriculture & Biotechnology Division, BARC, and his colleagues gave lectures and conducted experimental work on the plant behaviour in the uptake of various elements, fertilizers and studies on plant growth. Dr K.V. Chetty, Fuel Chemistry Division, was the Coordinator of the Workshop on behalf of IANCAS and Dr S.C. Kotur, IIHR, Bangalore, was the Director of the Workshop.

Dr V. Venugopal, Vice-President, IANCAS, gave a lecture on Nuclear Reactors and presided over the Valedictory function and Dr D.R. Bongirwar, Head, Food Technology Division, highlighted the irradiation techniques in food preservation.



Inauguration of the Workshop on 'Radioactivity and Isotope Applications' at Raigad Military School and Jr Science College. Seated (left to right) are Retd. Lt. Commandant Viraj Lad, Mr Ram Vadke, Chairman, School's Committee, Dr S.B. Manohar, President, IANCAS and Head, Radiochemistry Division, BARC and Dr V. Venugopal, Vice-President, IANCAS and Head, Fuel Chemistry Division, BARC

IANCAS conducted a 2-day School Workshop on invitation from Raigad Military School and Jr. Science College for 200 students of 10th to 12th standard and 50 science teachers. Dr S.B. Manohar, Head, Radiochemistry Division, and Dr V. Venugopal, Head, Fuel Chemistry Division, delivered basic lectures on 'Radioactivity', 'Production and Applications of Radioisotopes' and 'Importance of Nuclear Energy in the present context'. Dr U.M. Kasar and Dr R.B. Manolkar carried out the demonstration experiments on 'Determination of Half Life of ^{137m}Ba', 'Measurement of Natural Radioactivity in ⁴⁰K Salts' as the resource persons on behalf of IANCAS.



Dr Anil Srivastava, Resource Person from BARC conducts the experiments.

A video show, provided by the Publicity Division, DAE, on the 'Blessing to Humankind' and 'Atoms for Peace' was well appreciated.

Financial support was extended by BRNS for the BRNS-IANCAS National Workshop and to the thematic bulletins.

SALE OF RADIATION PROCESSED SPICES LAUNCHED

Annapurna Mahila Mandal launched the sale of radiation processed spices under the trade name 'Pumanna' at their Shradha outlet at Dadar. A function to mark the occasion was arranged by Annapurna Mahila Mandal at Vartak Hall, near Portuguese Church, Dadar, on Saturday, November 24, 2001. Dr Anil Kakodkar, Chairman, Atomic Energy Commission & Secretary, Department of Atomic Energy, was the Chief Guest. Mr B. Bhattacharjee, Director, BARC and Member, Atomic Energy Commission, presided over the function. Ms Prema Puro, Secretary, Annapurna Mahila Mandal, welcomed the gathering and stressed the importance of the radiation processing technology. She was confident that the use of this technology will benefit the public at large and generate employment for the needy women. She also mentioned that the stall run by Annapurna Mahila Mandal at Anushaktinagar was getting good response from the customers. Dr Kakodkar lauded the efforts of Annapurna Mahila Mandal in the launching of radiation processed spices in Mumbai for the first time in the country. He expressed the hope that the radiation processed spices will not only cover Maharashtra and other states in India but also the export market. He assured cooperation of the scientific community to the efforts of Annapurna Mahila Mandal in taking radiation processing technology to the kitchen.



Dr Anil Kakodkar, Chairman, AEC, unveiling the plaque of the sales counter of Annapurna Mahila Mandal during the launch of the sale of radiation processed spices

Mr B. Bhattacharjee, in his presidential remarks, also greatly appreciated the efforts of Annapurna Mahila Mandal. He provided an overview of the advantages of the radiation processing technology for spices and its benefits to farmers and traders. Dr (Ms) A.M. Samuel, Director, Bio-Medical Group, BARC, cleared the doubts related to the safety of radiation processed foods and allayed the fears about the technology in the public mind. Mr W.M. Sonawane, Asstt. Commissioner, FDA, Thane region, explained the role of FDA in licensing and sale of radiation processed products. Many scientists from BARC and members of Annapurna Mahila Mandal were present on this occasion. An exhibition and audiovisual display was arranged by DAE. Radiation processed spices were kept for sale at the counter by Annapurna Mahila Mandal. The response to the sale of spices was quite encouraging.

WORKSHOP ON THE USE OF IAEA TECDOC-348

A five-day lecture series-cum-workshop by Fuel Reprocessing Projects Programme, BARC, during October 1-5, 2001 on the 'Use of IAEA TECDOC-348 for Seismic Design of Nuclear Facilities Handling Limited Amount of Radioactivity'. The aim



A typical glove box handling small amount of radioactivity

of this workshop was to create awareness about the seismic design aspects for these facilities. Around 40 officers from various Divisions of BARC and Tarapur participated in this workshop. Various topics, such as the concepts of vibration and seismic engineering, classification of various low activity facilities based on their radiological hazard potential, seismic design aspects of civil structures, evaluation of seismic design motion for the design of mechanical systems and components, nuclear piping systems and electrical and instrumentation systems, hydrodynamic effects during an earthquake event, aseismic features in the design, etc. were covered. This kind of multi-disciplinary activity generated lot of interest in the participants of this workshop. The coordinator for this workshop was Mr R.S. Soni from FRPP, BARC. The faculty for the various lectures for this workshop were drawn from the various Divisions of BARC such as FRPP, RSD and A & CED. The workshop was

inaugurated by Mr V.P. Balakrishnan, Chief Design Engineer, FRPP, and the concluding remarks were given by Mr D.D. Bajpai, Head, Fuel Reprocessing Division, BARC.

BARC SCIENTISTS HONOURED



Dr R.C. Chaubey, Head, Genetic Toxicology & Chromosome Studies Section, Cell Biology Division, was among the twenty scientists selected from Central and South America,

Asia, Africa, and Eastern Europe for presenting his work at a Special Session on "Science in Countries with Developing Environmental Mutagenesis Program" at Shizuoka, Japan, during October 21-26, 2001. This session was organized as a part of the 8th International Conference on Environmental Mutagens. The selection was made by International Association of Environmental Mutagen Societies, the Alexander Hollaender Committee of the Environmental Mutagen Society (USA) and the Organizers of the 8th ICEM, Japan. During the Conference, he presented the paper entitled, "A correlative study between micronucleus assay and DNA strand breaks measured by comet assay in gamma irradiated mice".



Prof. P. Rama Rao of Rare Materials Project, Mysore, has been elected a Fellow of the Indian National Academy of Engineering (INAE) at the meeting of the

Governing Council held on October 20, 2001 in recognition of his distinguished contribution to "Engineering"

As per convention, he will be invited to an Induction Ceremony for formal admission to the Fellowship of the Academy at one of its functions in which he will be presented a Certificate.

Edited and published by Dr Vijai Kumar, Head, Library & Information Services Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085.

Editorial Management : T.C. Balan; Computer graphics & layout : P.A.S. Warriar

BARC Newsletter is also available at URL:<http://www.barc.ernet.in> (for private circulation only)