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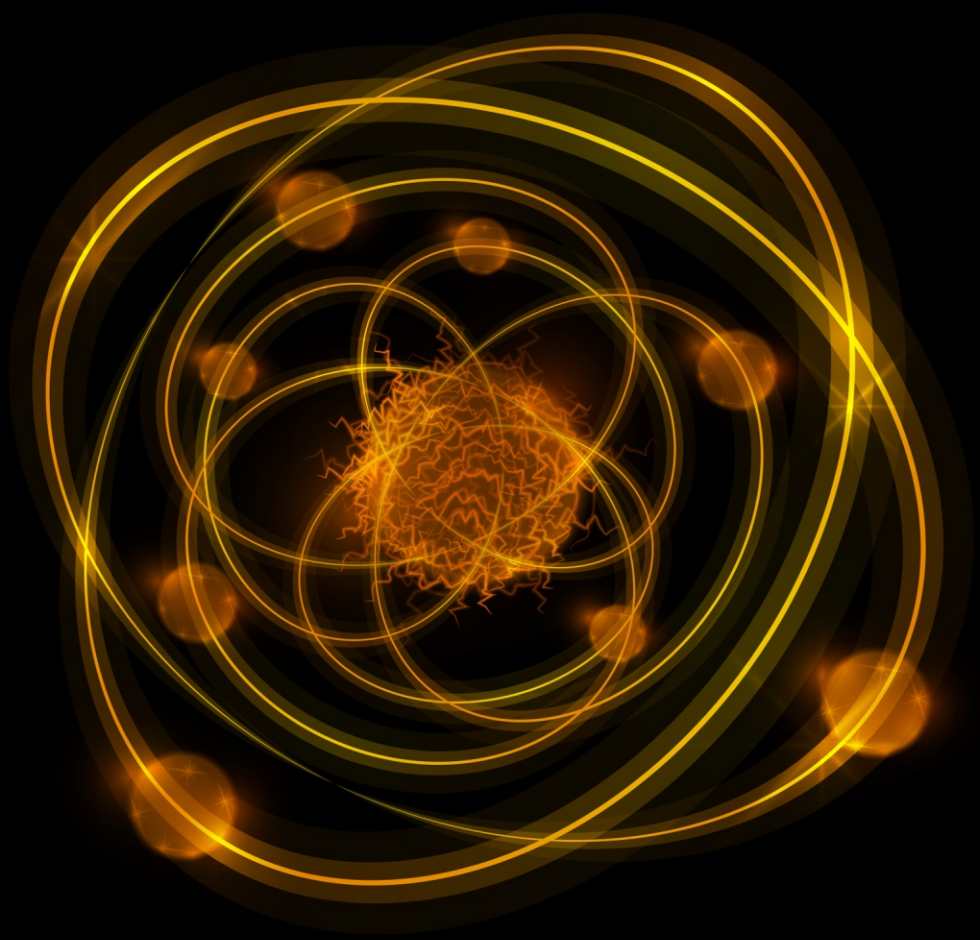

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Comment on the Recent Start of a New "IUPAC-Project"

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Abstract

The opening of a new IUPAC-project is highly appreciated. In the year 2009, the IUPAC had published an article "Discovery of the element with atomic number 112 (IUPAC Technical Report)" [1]* which contains a section on the work of the Marinov collaboration. It appears that this section is not always in agreement with conventional standards for scientific publications. This present comment focuses on these formal questions.

Keywords

IUPAC Project 2017-014-2-200, eka-Hg, Unresolved Problems

1. Introduction

The International Union of Pure and Applied Chemistry (IUPAC) has recently started a new project with the identification: "Project No: 2017-014-2-200" [2]. The central aim of this project is (quote): Over twenty-five years have elapsed since criteria that are currently used to verify claims for the discovery of a new element were set down... It is proposed to set up a project for an IUPAC/IUPAP Joint Working Group (JWG) to examine and update these criteria. (End of quote)

This appears to be a timely project, as there are questions as to whether or not the standards for scientific publications have been followed by the IUPAC in

*References relating to this paper are given as usual and as listed in the end of this paper. References in double parentheses, e.g. [[18]], are taken from the reference list in the IUPAC-paper [1].

their former publication [1].

Nearly all sections of that paper are well-written, in particular those sections concerning the work of Hofmann and colleagues. However, there are some problems with the standards for scientific publications when it comes to the work of the Marinov collaboration. These inconsistencies are discussed in this article.

2. Remarks Concerning Statements about the Marinov Collaboration

Problems dealing with the Marinov collaboration in [1] are considered step by step.

2.1. Problem 1

Ref. [1] (re: Marinov) quoting page 1336-1337:

"*This collaboration reiterates arguments for their discovery of the element with atomic number* 112 *through the existence of very long-lived hyper-deformed isomeric states of actinides* [*actinoids*] *and transactinides* [*tranactinoids*], *produced from multi-GeV protons in a thick W target and, in the case of eka-Hg, of subsequent spontaneous fission, a very nonspecific indicator. Unusually high fusion cross-sections induced by secondary products are required for nuclide formation, each several orders of magnitude beyond known behavior. Results from other research groups that attempted obvious corroboration studies using multi-GeV protons incident on a U target clearly indicated the production path was irreproducible as previously stressed* [[1] [3] [4]]. *The latter refutations have been challenged by Brandt* [[18] [25]], *a member of the Marinov collaboration, in which he rejects the negative results because the same exact experiment as conducted by Marinov was not followed. However, independent evidence is what* "*Criteria*" (*q.v.*) *demand. Cloning of methodology is an approach that could easily camouflage systematic error.*"

Problem 1: Reference [[18]] has nothing to do with Brandt, he is not even an author of that paper. Moreover, [1] states that *Cloning of methodology… could easily camouflage systematic error*. The repetition of an experiment is part of any standard procedure and it is trivial, that an experimental procedure may include a systematic error. It is a reality that Marinov and collaborators have not repeated their first experiment from 1971. In 1971 Marinov *et al.* published two papers in NATURE [3a] [3b] about the production of a new element with nuclear charge Z = 112 using an original, completely new and unexplored experimental method: They bombarded consecutively two metallic tungsten rods (nuclear charge Z = 74 and atomic weight A = 183.5) with 24 GeV protons at the PS-accelerator in CERN, Geneva (Switzerland). The first target (W1) was irradiated for one year with a total flux of 1×10^{18} protons and chemical procedures started 3 months later. The second target (W2) was irradiated for 4 months with 7×10^{17} protons. The chemical separations started a few days later in a

well-equipped nuclear laboratory in Harwell, Great Britain. They carried out a standard chemical separation of a mercury-fraction (Hg), presumably carrying element Z = 112 which belongs to the heavy end of the same group in the periodic table as Hg and which is also called eka-Hg. They produced a thin sample to study spontaneous fission events using a well-accepted detection-method for the observation of these fission events, called "Spark-Jump" technique. In this sample they observed during the following 37 days 93 spontaneous fission events. Such an event rate is far beyond any reasonable background effect for an experienced „fission events counting" research group. The team also isolated chemical fractions from the Pt-, Au-, Tl-, and Pb-tracers in the sample, in order to look for the respective eka-elements Z = 110, 111, 113, and 114. They did not report finding any trace of a spontaneous fission activity in any of these other samples. Spontaneous fission is observed only for heavy elements starting with thorium (Z = 90) and beyond, so the selective focus on eka-elements having Z ≥ 110 is clear.

This result was discussed world-wide; however, the international science community was not convinced. During the following decades Marinov and his co-workers published a long series of papers on this subject. The international science community, however, remained unconvinced, as shown in [1]. The central reasons for the rejection of Marinov's claim for the discovery of element 112 have been: The original experiment was never reproduced in exactly the same way as it was done in 1971, and it was not expected that one could find heavy elements in irradiations of heavy targets with protons.

One should remember: In those days around the year 1971, the discovery of new elements was essentially the domain of HEAVY ION accelerators in a few laboratories around the world. The heaviest nuclides known were short-lived and from elements up to Z = 105. The exciting and complex history of this research up to the year 1985 has been systematically described in a review by Seaborg and Loveland in [4]. It was generally assumed that no new heavy element was supposed to be produced by proton induced reactions. The simultaneous search for long-lived Superheavy Elements in NATURE up to the year 1985 had been systematically described in a review by Flerov and Ter-Akopyan in [5].

Another reason for the rejection of the Marinov approach had technical as well as logistic aspects: The highly radioactive target had to be transported from CERN in Switzerland to another laboratory in Europe within a short time of less than about 1 week. This was arranged once and could not be repeated. The reasons are not scientific, but rather of logistic origin and due to other real obstacles, such as radiation protection issues. In short: it was not possible. These logistic and security aspects, as well as the hostility towards the entire Marinov-approach made an exact reproduction of the original experiments reported in [3] impossible to date.

2.2. Problem 2

Ref. [1] (re: Marinov) quoting page 1337:

"*In his later* (*second*) *challenge*, *Brandt* [[25]] *alludes to two lines of evidence*

for unusually high cross-sections of secondary particles. Even if the JWP accepted his lines of evidence—which it does not—this would not bring the original claim for discovery of the element with atomic number 112 *by the Marinov group any closer to satisfying the criteria for discovery*".

Problem 2: Reference [[25]] is cited as having only one author, whereas the paper really has 16 authors. The authors of [[25]] never "alluded" to anything but rather they described observed experimental facts. These facts are due to "Unresolved Problems" as published by these same 16 authors in [6].

Fortunately the findings of [[25]] have been properly described and accepted in an official letter of Professor P. J. Karol (the corresponding author of [1]), dated February 13, 2012, to Professor H. Stöcker (GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany). The essential sentences in this letter are (quote): Secondly, comment on the studies in our publication was judgmental, but the criticism was directed solely at the interpretation of the experimental results and their pertinence to heavy element discovery claims made by A. Marinov and collaborators. There was no intent to disparage, in any way, the experimental results themselves. Indeed, I have been closely following Reinhard Brandt's work in this area for years, catalyzed by the early publication "Enhanced production of ^{24}Na by wide-angle secondaries produced in the interaction of relativistic carbon ions with copper, *Phys. Rev.* **C45**, 1194 (1992), by R. Brandt, G. Dersch, E.M. Friedlander, G. Haase, M. Heck V.S. Butsev, M.I. Krivopustov, B.A. Kulakov, E.-J. Langrock, F. Pille, H.H. Cui, and E. Ganssauge". (End of quote)

These facts, called "Unresolved Problems" in [6], have been studied further during recent years and published in [7]-[12]. The emphasis of this research has shifted over the years from "Na-production in copper by relativistic ions" to the measurement of excess neutron production which is far beyond theoretical model calculations in THICK Cu targets (or heavier elements such as e.g. Pb, U) irradiated with high-energy ions. The least understood experimental finding always was: Observed neutron fluxes above a certain projectile energy are about a factor of two LARGER than the fluxes calculated by any theoretical model. Consequently, the problems mentioned as being UNRESOLVED in [6] remain UNRESOLVED until today. The present state of our investigations is presented in [11] and [12]. These continued studies employed radiochemical experimental techniques together with studies using nuclear emulsion and correlated theoretical model calculations. Whereas radiochemical measurement of reaction products yields a very precise integral picture of all reaction products, nuclear emulsion shows differential pictures of single projectile-target interactions. With emulsion one can determine nuclear charges, energies and multiplicities of particles in the exit channel and follow the dynamics of several generations of products from one primary interaction. Using this combination of different research techniques, various irradiations at high-energy heavy ion accelerators were carried out in several laboratories. The combination of research opportunities leads to our present conclusions about unresolved problems in high-energy

irradiations of thick targets:

- using radiochemical research tools one observes too many neutrons being produced; an enhancement factor of 2 to 3 is observed, as compared to various model calculations.
- in nuclear emulsion irradiated with high-energy heavy ions one observes a large fraction of BURST-interactions along with the expected spallation interactions. These BURSTS appear to have too few tracks from low-energy particles (E < 0.5 GeV) and too many high-energy tracks (E > 0.5 GeV). The detailed description of these experiments can be found in [11] and [12].

No complete understanding can be presented for those experimental observations which are described as "unresolved problems" in [6]. Nevertheless, these studies may become relevant for possible future experiments using heavy ion accelerators, including those presently under construction. According to our studies it is clearly predictable that in future experiments BURST-interactions with excess neutron production will occur, for example inside a large uranium target. It appears that no theoretical model can properly simulate that situation. The authors know of only one experiment, where massive uranium targets have been irradiated with heavy ions beams, like 44 GeV ^{12}C. Ref. [7] describes this experiment and shows that the irradiation produced a secondary neutron flux, about a factor of two larger than predicted by any model calculation.

2.3. Problem 3

Ref. [1] quoting page 1337:

"*The Marinov collaboration also recently claimed discovery* [[24] [26] [27]] *of several long-lived, naturally occurring, very neutron-deficient thorium isomeric states, e.g.,* ^{210}*Th and long-lived isotopes* (*allegedly Rg*) *with mass numbers* 261 *and* 265 *in natural Au at the sub-ppb level of abundance. These claims are based on mass spectroscopic data where an inductively coupled plasma ion source is used and very low background count rates are observed*".

Problem 3: Ref. [[24]] reads (quote): "*A. Marinov, I. Rodushkin, A. Pape, Y.Kashiv, D. Kolb. R. Brandt, R. Gentry, H.W. Miller, L. Halicz, I.Segal.* (*unpublished, submitted to Phys. Rev. Lett.* 2007)". This paper never appeared in *Phys. Rev. Lett.* and it is not available for reference.

Note: Ref. [[26]] introduces a rather original application by Marinov *et al.* as new research tool—an "inductively coupled plasma-sector field mass spectrometer (ICP-SFMS)"—into the search for very heavy low-intensity nuclear species in nature. This type of research tool requires a very long half-life for these nuclides of much more than 10^7 years in order to be observable. The description of the details is accurate for the study of a thorium target. Ref. [[26]] is listed as [13] in this paper.

3. Outlook

We wish to submit one suggestion to the "IUPAP/IUPAC Joint Working Group

JWG)" mentioned in the Introduction: The scientific state-of-art in analytical (chemical and physical) investigations and in theoretical methods used for these experiments has changed considerably during the last twenty-five years (see [1]). The ICP-SFMS technique is just one of the new modern analytical tools. One should consider that presently unexplained experimental findings may indicate novel and unexpected reaction paths leading to unexpected results.

Last but not least, one should remember that around 1970 not only Marinov *et al.* claimed the observation of Z = 112 in a European laboratory, but also Hoffmann *et al.* [14] unexpectedly claimed in America to have observed the isotope ^{244}Pu ($T_{1/2} = 8 \times 10^7$ a) in a terrestrial sample. Both observations have neither been reproduced, nor have they been accepted by the international science community.

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Effect of Temperature on I-V Characteristic for ZnO/CuO

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Abstract

Research on nonmaterials has become increasingly popular because of their unique physical, chemical, optical and catalytic properties compared to their bulk counterparts. Therefore, many efforts have been made to synthesize multidimensional nanostructures for new and efficient nanodevices. Among those materials, zinc oxide (ZnO) has gained substantial attention owing to many outstanding properties. ZnO besides its wide band gap of 3.34 eV exhibits a relatively large excitons binding energy (60 meV) at room temperature which is attractive for optoelectronic applications. Likewise, cupric oxide (CuO) has a narrow band gap of 1.2 eV and a variety of chemo-physical properties that are attractive in many fields. Moreover, composite nanostructures of these two oxides (CuO/ZnO) may pave the way for various new applications. So in this thesis, eight samples of CuO/ZnO junction were synthesized and exposed to temperatures 60, 70, 80, 90, 100, 110, 120 and 130. The electrical properties of Schottky diode junctions were analyzed by I-V measurements under the influence of direct solar radiation and, lag of radiation (darkness) which shows the semi-logarithmic I-V characteristic curve of the fabricated photodiodes. Also energy band gap was estimated and the morphology and particle sizes of the as-prepared sample were determined by SEM. The SEM images of ZnO + CuO sample films were annealed at 60˚C to 130˚C step 10.

Keywords

Copper Oxide, Zinc Oxide, Thin Films, Monoethanolamine, Temperature, Current-Voltage (I-V) Characteristic

1. Introduction

During the last few decades, nanomaterials have been the subject of extensive

interest because of their potential use in a wide range of fields like, optoelectronics, catalysis and sensing applications. The physical and chemical properties of nanomaterials can differ significantly from their bulk counterpart because of their small size. In general, nanomaterials comprised novel properties that are typically not observed in their conventional, bulk counterparts. Nanomaterials have a much larger surface area to volume ratio than their bulk counterparts, which is one of the bases of their novel physical and/or chemical properties. Nanomaterials are classified into one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D).

In addition, metal oxide nanomaterials have drawn a particular attention because of their excellent structural flexibility combined with other attractive properties. These metal oxides nanostructures not only inherit the fascinating properties from their bulk form such as piezoelectricity, chemical sensing, and photo detection, but also possess unique properties associated with their highly anisotropic geometry and size confinement [1]. The combinations of the new and the conventional properties with the unique effects of nanostructures make the investigation of novel metal oxide nanostructures a very important issue in research and development both from fundamental and industrial standpoints.

Among the various metal oxides, zinc oxide (ZnO) possessed a considerable attention due to its unique properties and applications. In particular, ZnO nanostructures (NSs) are of intense interest since they can be grown by a variety of methods with different morphologies. Among the different growth methods, the chemical bath deposition method is low temperature, simple, inexpensive and environmentally friendly method. These are all factors which further contribute to the resurgent attention in ZnO. Specifically, one-dimensional ZnO nanorods (NRs) amongst other nanostructures are attractive components for manufacturing nanoscale electronics and photonic devices as well as their biomedical applications because of their interesting chemical and physical properties [2] [3]. Also ZnO NRs can easily be grown on a variety of substrates like metal surface, semiconductors, glass, plastic and disposable paper substrates etc. [4] [5] [6] [7]. Furthermore, a direct wide band gap ~3.37 eV and relatively large excitonic binding energy ~60 meV of ZnO along with many radiative deep level defects, make ZnO attractive for its emission tendency in blue/ultraviolet and full colour lighting [8] [9]. To utilize theses properties of ZnO in LEDs application, another p-type material is necessary as ZnO NRs is unintentionally n-type material. Since mostly polymers are p-type and their special properties, like low cost, low power consumption, flexible and easy manufacturing, all make polymers a better choice to use with ZnO NRs to fabricate a flexible device that utilizes the properties of both materials for large area lighting and display application [10] [11].

On the other hand, natural abundance of copper (II) oxide (CuO) as well as its low production cost, good electrochemical and catalytic properties makes the copper oxide to be one of the best materials for various applications. CuO also

has a variety of nanostructures and can be grown using the low temperature aqueous chemical method. It is one of the most important catalysts and is widely used in environmental catalyst.

2. Materials and Methods

2.1. Growth of CuO Thin Films

Copper oxide (CuO) thin films were prepared by dissolving 0.2 molar copper acetate and monoethanolamine in a 1:1 Molar ratio in 20 ml of 2-methoxyethanol solvent. Acetic acid was added drop wise to achieve a homogeneous solution. The above stock solution was vigorously stirred at 80˚C for 120 min. The Cu aqueous solution was filtered through a 0.2 μm poly-tetrafluoroethylene membrane and was aged for 24 h. The colour of the solvent became dark green. The precursor solution was uniformly deposited on cleaned ITO glass substrates by spin coating technique at a spin speed of 2000 rpm for 60 s. The coating process was repeated to attain the desired thickness. The films were annealed at 90˚C for 5 min after each layer deposition.

2.2. Growth of ZnO Thin Films

The precursor solution for fabricating zinc oxide thin films were prepared by dissolving 0.3 Molar zinc acetate and monoethanolamine (MEA) in a 1:1 Molar ratio in 20 ml of 2-methoxyethanol solvent. MEA was added as a stabilizer to ameliorate the solubility of the precursors. Acetic acid is then added to achieve a homogeneous solution. Above mixture was stirred at 70˚C for one hour. After stirring, the Zn aqueous solution was aged for 24 h. The colour of the solvent then became yellowish orange. The precursor solution was uniformly deposited on ITO cleaned glass substrates that coating in it CuO by spin coating technique at a spin speed of 2000 rpm for 60 s. The coatings were repeated to achieve the desired thickness of 561.56 nm. After each coating the films were baked at 70˚C for 5 min.

2.3. Samples of CuO and ZnO Films Annealed at Various Temperatures

The 8 samples of CuO and ZnO films were finally air annealed at various temperatures ranging from (60, 70, 80, 90, 100, 110, 120 and 130)˚C for three hours. Each layer was characterized by studying structural, electrical and optical properties. Glancing angle X-ray diffraction analysis of the films was performed with (XRD) system. Surface morphology of the film was studied by (SEM). Optical absorbance measurements were performed with UV-Vis spectrophotometer 1240 was performed at room-temperature. Electrical characterization of the resistive thin films and current voltage characteristics of p-n junction were performed at room temperature using Kiethley 4200-SCS semiconductor parameter analyzer equipped with.

2.4. Characterization Studies

Scanning Electron Microscopy (SEM)

The morphology and particle sizes of the as-prepared sample were determined by SEM ((SEM, Tuscan Vega LMU).. The SEM images of ZnO + CuO sample films were annealed at 60˚C temperatures are shown in Figure 1. These indicate that sphere-like ZnO + CuO sample films were annealed at 60˚C temperatures nanostructures obtained by this method are uniform in both morphology and particle size, but have agglomeration to some extent. The average size was calculated to be 1.5 μm from the measurements on the SEM micrographs. Corresponding histograms, showing the particle size distribution, are also presented in Figure 2. The mean particle size 1.5 μm estimated from SEM is in close agreement with the average crystallite size 1.514 μm as calculated from histograms line broadening. The microstructure and chemical composition of the film surface were analyzed using a scanning electron microscope (SEM, Tuscan Vega LMU). Their sizes are found to range from 1.5 to 1.514 μm.

3. Results

Table 1 clearly shows the lists of I-V reading for 8 samples for different temperature. The first column represents volts and the other columns show the current for different temperature.

Figure 3 shows the relationship between volts ZnO/CuO p-n junction and current for 8 samples with annealed different temperatures from 60˚C to 130˚C in the darkness. From Figure 3, it clearly shows that upon increasing the temperature from 60 to 130 in steps of 10˚C, the current increases with temperature when the voltage is fixed. From Table 2 and Figure 4, it is clear that the current of

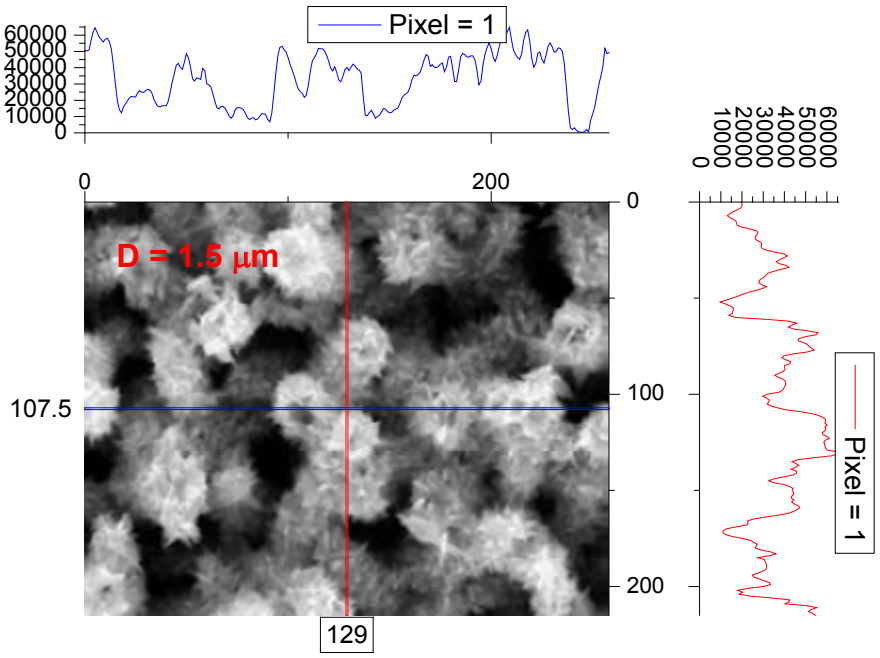

Figure 1. SEM images of the ZnO+ CuO sample films were annealed at 60˚C temperatures.

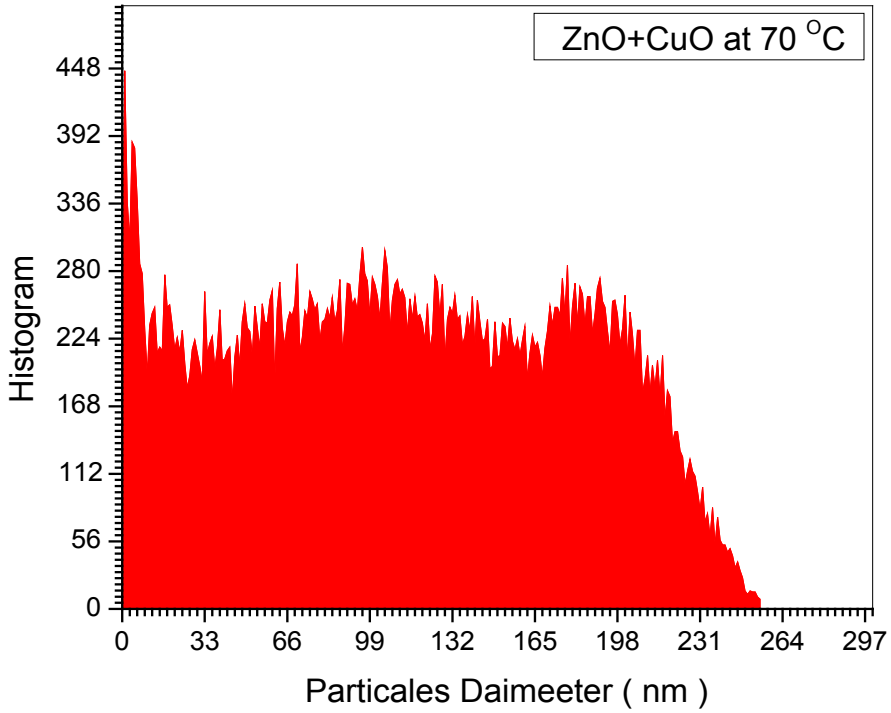

Figure 2. Particle diameter distribution of ZnO + CuO sample films were annealed at 60˚C temperatures.

Table 1. The I-V riding of ZnO/CuO p-n junction for 8 samples by heated for different temperatures in the darkness (without exposed to direct light).

Voltage (V)	I at60˚C (mA)	I at 70˚C (mA)	I at 80˚C (mA)	I at 90˚C (mA)	I at 100˚C (mA)	I at 110˚C (mA)	I at 120˚C (mA)	I at 130˚C (mA)
−10	−0.01408	−0.01498	−0.01628	−0.01809	−0.02033	−0.02236	−0.02459	−0.02705
−8.11712	−0.01359	−0.01445	−0.01571	−0.01746	−0.01962	−0.02158	−0.02373	−0.02611
−6.21522	−0.01255	−0.01336	−0.01452	−0.01613	−0.01812	−0.01994	−0.02193	−0.02412
−4.31331	−0.01042	−0.01108	−0.01205	−0.01339	−0.01504	−0.01654	−0.0182	−0.02002
−2.41141	−0.00609	−0.00648	−0.00704	−0.00782	−0.00879	−0.00967	−0.01063	−0.0117
−0.50951	0.00236	0.00251	0.00273	0.00303	0.0034	0.00374	0.00412	0.00453
1.39239	0.01766	0.01879	0.02042	0.02269	0.0255	0.02805	0.03085	0.03394
3.29429	0.04202	0.04471	0.04859	0.05399	0.06067	0.06673	0.07341	0.08075
5.1962	0.07379	0.0785	0.08533	0.09481	0.10653	0.11718	0.1289	0.14179
7.0981	0.10598	0.11274	0.12254	0.13616	0.15299	0.16829	0.18512	0.20363

ZnO/CuO p-n junction increase when temperature increases for each samples by annealed different temperatures under particular solar radiation.

4. Discussion

In this work the ZnO/CuO junction V-I characteristics was studied in two cases firstly exposed to light directly secondly when it was no light (in darkness).

When no light is exposed (in darkness), it was observed that upon increasing the temperature from 60 to 130 in steps of 10˚C, the current increases with temperature when the voltage is fixed. This may be attributed to the fact that the increase of temperature gives more electrons to gain thermal energy to move from the valance band to conduction band thus increases the current. It is also interesting to note that the current is nearly vanishes at a negative voltage equal to about −1.8 volt. This reflects the existence of reverse bias voltage and energy gap

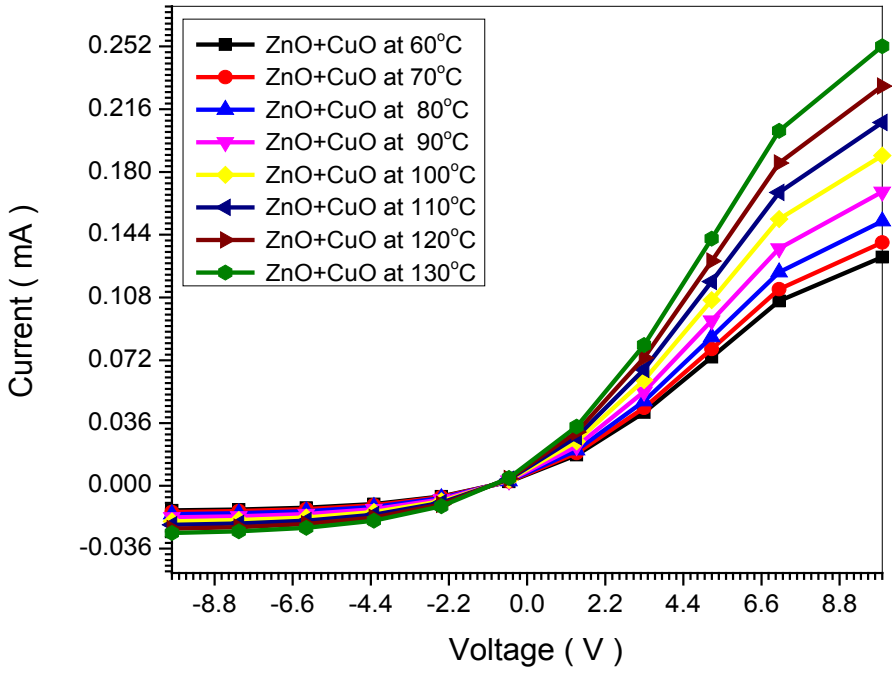

Figure 3. The I-V curves of ZnO/CuO p-n junction for 8 samples by annealed different temperatures in the darkness.

Table 2. The I-V riding of ZnO/CuO p-n junction for 8 samples by annealed different temperature.

Voltage (V)	I at60˚C (mA)	I at 70˚C (mA)	I at 80˚C (mA)	I at 90˚C (mA)	I at 100˚C (mA)	I at 110˚C (mA)	I at 120˚C (mA)	I at 130˚C (mA)
−15.000	−1.00916	−1.13389	−1.21924	−1.32526	−1.45633	−1.60196	−1.60196	−1.93837
−12.027	−0.8421	−0.94618	−1.01739	−1.10586	−1.21523	−1.33676	−1.33676	−1.61748
−9.0240	−0.65522	−0.7362	−0.79162	−0.86045	−0.94555	−1.04011	−1.04011	−1.25853
−6.0210	−0.44826	−0.50366	−0.54157	−0.58866	−0.64688	−0.71157	−0.71157	−0.861
−3.0180	−0.21915	−0.24624	−0.26477	−0.2878	−0.31626	−0.34789	−0.34789	−0.42095
−0.0150	0.03433	0.03857	0.04148	0.04508	0.04954	0.0545	0.0545	0.06594
2.9879	0.31463	0.35352	0.38013	0.41318	0.45405	0.49945	0.49945	0.60434
5.9909	0.6244	0.70157	0.75438	0.81998	0.90107	0.99118	0.99118	1.19933
8.9939	0.96649	1.08594	1.16768	1.26922	1.39474	1.53422	1.53422	1.8564
11.997	1.34399	1.5101	1.62376	1.76496	1.93951	2.13347	2.13347	2.58149

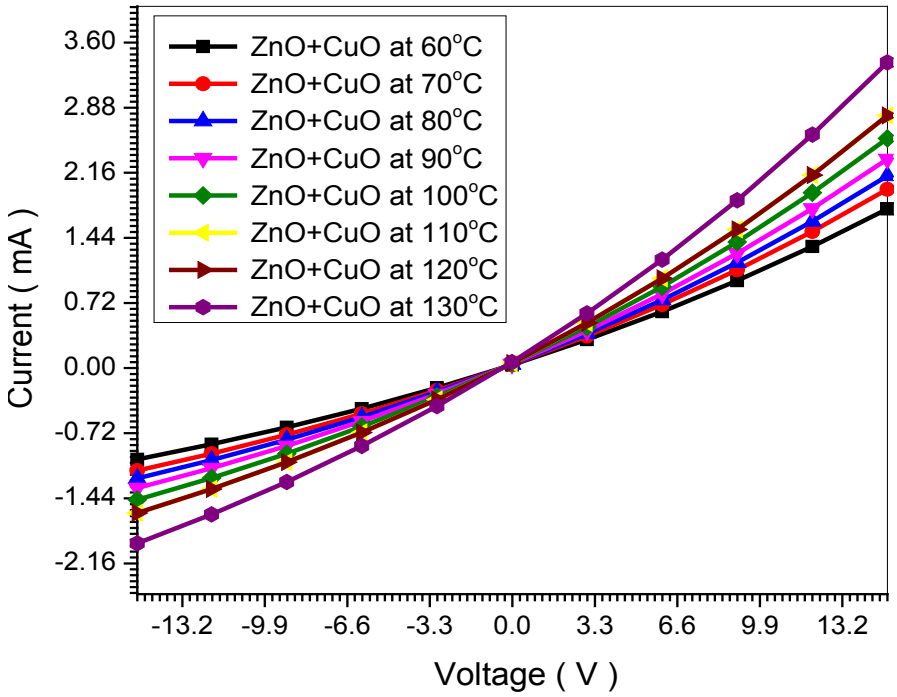

Figure 4. The I-V curves of ZnO/CuO p-n junction for 8 samples by annealed different temperatures under particular solar radiation.

of order 1.8 eV. The existence of negative reverse current is clearly conforms to relation:

$$I = I_0\left(e^{\beta V} - 1\right) - I_p$$

With V and I_p standing for operating voltage and photon generates current. For reverse bias the voltage is negative, thus the photon generates current dominance, thus $I = -I_p$ this current is assumed to be generated by invisible infra red photons in darkness. These infra red photons generated by human surrounding bodies and the building that exists near the ZnO/CuO diodes. These photon generate currents are less than that generated in light as we will see later

The V-I characteristics in **Figure 4** of ZnO/CuO unction in light shows again increase in current when temperature increases. This result again confirm the fact that, temperature increase, increases thermal energy, which in turn increases the number of electrons that absorb this energy and transfer to the conduction band. This causes electric current to increase. It is also very interesting to note that the energy gap E_g, which correspond to zero current, increases with temperature, which agrees with theoretical relations, when

$$n = n_0 e^{-\frac{E_g}{KT}} \text{ and } E_g = KT \ln \frac{n_0}{n}$$

where the energy gap E_g is equal to the voltage that corresponding to zero current.

The effect of light can be observed clearly when comparing the values of reverse current at a certain voltage say (2.2 volt), where I in darks is 0.01 mA, and

light is about 0.7 mA. This is relates to the fact that reverse current $I \sim I_p$. Thus in light current generated by visible photons is considerately large than that generated in dark by only free infra red photons.

5. Conclusion

The ZnO/CuO diode energy gap and V-I characteristics are sensitive to temperature as well as light. This sensitivity can be theoretically explained. Also it was found that for different temperature (60 to 130), the average Particle diameter varied from 1.5 micrometer to 92 nm which indicates that the particle size decreases with raising annealing temperature.

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Design and Comparative Analysis of Small Modular Reactors for Nuclear Marine Propulsion of a Ship

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Abstract

The fast growth in the size and difficulty of nuclear power plant in the 1970s produced an interest in smaller, modest designs that are intrinsically safe over the usage of design features. With the development of nuclear technology, there is the need for revolution in the Maritime sector, especially the advance marine propulsion. In current years, numerous reactor manufacturers are dynamically improving small modular reactor designs with even superior use of safety features. Several designs integrate the ultimate in greater safety. They totally remove specific accident initiators from the design. Other design features benefit to reduce different types of accident or help to mitigate the accident's consequences. Although some safety features are mutual to maximum SMR designs, irrespective of the coolant technology, other features are specific to liquid-metal cooled, water, gas, or SMR designs. Results: There have been more reactor concepts investigated in the marine propulsion area by different assemblies and research laboratories than in the power generation field, and much can be learned from their experience for land applications. The extensive use of safety features in SMRs potential to make these power plants extremely vigorous, protecting both the public and the investor. Conclusion: For these two considerations, it is recognized that a nuclear reactor is the ideal engine for naval advanced propulsion. The paper will present the work to analyze the concept design of SMRs and design a modular vessel consisting of a propulsion module.

Keywords

Design Analysis, Small Modular Reactor (SMR), Marine Propulsion, Nuclear Ship

1. Introduction

The growing demand for economical yet rapid program of mutually customers and merchandise has carried renewed momentum to the development of marine propulsion systems. New-fangled technologies are aiding the production of propulsion systems that are capable of driving vessels at advanced speeds; that are more efficient; that provide improved maneuverability; and that are quieter, with less vibration. Here, the latest developments in marine propulsion are carried into focus [1]. The main experience in operating nuclear power plants has been in nuclear naval propulsion, mainly aircraft carriers and submarines. This composed experience may become the basis of a proposed new generation of compact-sized nuclear power plants designs. This paper discovers nuclear propulsion by means of a case study, which sets the issues against accurate technical background. The probable use of developing Small Modular Reactor (SMR) nuclear technology onboard sea-going ships opens up new opportunities and this technology forms the base of the study reported [2].

The greatest suited idea for the modular ship is discussed including a review of tug/barge schemes. At present, there is growing interest in small modular reactors (SMRs) and their perfect applications. SMRs are newer generation reactors designed to produce electric power up to 300 MW, whose components and systems can be shop fabricated and then transported as modules to the sites for installation as demand arises. Most of the SMR designs approve advanced or even intrinsic safety features and are deployable either as a single or multi-module plant. SMRs are under development for all principal reactor outlines: water cooled reactors, high temperature gas cooled reactors, liquid-metal, sodium and gas-cooled reactors with fast neutron spectrum, and molten salt reactors. The key driving forces of SMR development are fulfilling the need for flexible power generation for a wider range of users and applications, substituting ageing fossil-fired units, attractive safety performance, and contributing better economic affordability. Near term deployable SMRs will have safety performance better to that of evolutionary reactor designs. However, important developments have been made in various SMR technologies in recent years, and some technical issues still attract considerable attention in the industry. These include for example control room staffing and human factor engineering for multi-module SMR plants, defining the source term for multi-module SMR plants with regards to defining the emergency planning zone, developing new codes and standards. Some potential advantages of SMRs like the elimination of public removal during an accident or a single operator for multiple modules are being challenged by regulators. Besides, although SMRs have lower upfront capital cost per unit, their producing cost of electricity will possibly be substantially higher than that for large reactors [3] (**Table 1**).

An energy absorption-based analysis is mandatory for the structural design in way of the engine room. In this way, during the impact, the energy will be dissolute through the hull and away from the reactor compartment by an

Table 1. Status of deployment of SMR designs and technologies (partial).

Design	Output	Type	Designers	Country	Status
KLT-40S	70	Floating NPP	OKBM Afrikantov	Russian Federation	Under construction
HTR-PM	210	HTGR	INET, Tsinghua University	China	Under construction
CAREM	30	PWR	CNEA	Argentina	Under construction
ACP100	100	PWR	CNNC	China	Conceptual Design
CAP150/200	150/200	PWR	CGNPC	China	Conceptual Design
AHWR-300	300	PHWR	BARC	India	Conceptual Design
IRIS	335	PWR	IRIS Consortium	Multi Countries	Conceptual Design
DMS	300	BWR	Hitachi GE	Japan	Conceptual Design
IMR	350	PWR	MHI	Japan	Conceptual Design
IMSR	185 - 192	MSR	Terrestrial Energy	Canada	Conceptual Design
MSTW	100	MSR	Seaborg Technologies	Denmark	Conceptual Design
ThorCon	250	MSR	Martingale	International Consortium	Conceptual Design

Source: IAEA, 2016.

elastoplastic collapse. In the ship Otto Hahn, this was achieved through cutting decks which would cut any object colliding into it, thus reducing impact penetration [4]. Another option is provided by sandwich material consisting of "Y" shaped frames which has proven energy absorption due to its plastic collapse [5].

2. Materials and Methods

2.1. Reactor Design Concepts

There have been extra reactor concepts examined in the maritime propulsion area by different producers and research laboratory than in the private citizen field, and much can be learned from their experience for land applications, mainly for small compact schemes.

2.2. Reactor Design Comparison

The reactor comparison will be based on the below constrains. The first and important is the burn-up. The second constraint is the thermal to electrical efficiency. This efficiency comprises the steam generator efficiency and the electric generator efficiency which differs according to the load. PWR designs work at the temperature range around 320˚C and 155 bar pressure with a temperature drop like to 30˚C and 9 bar pressure drop because of the process of the secondary steam cycle. **Table 2** covers a comparison of naval reactor designs in overall.

2.3. Small Modular Reactors (SMR)

SMRs deliver improvements in safety, construction, operational flexibility and economics. The enhancement in safety is achieved through lower fuel inventory, greater use of safety features and eliminating design features which are disposed to probable accidents [8] and since the SMR is built modularly, the proliferation risk is significantly reduced [9]. Upon authorizing SMRs are expected to have economy of mass production, reduced siting costs and majority of construction and assembly to be completed at the factory thus reducing capital cost and assembly time hence reducing financial risk [10].

Hyperion offers a liquid metal cooled, fast reactor with a thermal power of 70 MW_T. The efficiency of the transfer heat system using helium can be up to 40%. The size of the sealed unit is only 1.5 m in diameter and 2.5 m high with a cost of $50 million USD [11]. Some other properties of the reactor are given in **Table 3** [12].

3. Result and Discussions

3.1. Design Analysis

A matrix was used to find out the best performing SMR concept. A set of

Table 2. Characteristics of civil reactor designs [6] [7].

Reactor	PWR	BWR	MAGNOX	AGR
Fuel:	3% LEU	2.2% LEU	Natural Uranium	2% LE UO_2
Cladding	Zircalloy	Zircalloy	Magnesium alloy	St. Steel
Moderator	Light Water	Light Water	Graphite	Graphite
Coolant	Light Water	Light Water	Carbon dioxide	Carbon Dioxide
Outlet Temp.	318	318	360	620
Steam Temp.	285	286	345HP 330LP	540
Steam Pressure	69	75	150	40HP 11LP
Efficiency	32%	32%	33%	42%
Power Density	High	High	Low	Low
Burn-up	High	High	Low	Low

fundamental criteria were established each with differing importance. For each concept a subjective score between 1 and 5 was assigned for each criterion (1 negative or challenging, 5 positive or practicable).

In Figure 1 and Figure 2: Concept 1 complicated taking a conventional containership and separating it into two parts while keeping the same hullform. The aft end of the vessel converts the propulsion unit and the remains of the ship is the cargo unit.

Subsequently Concept 2 was established to clarify the problems by altering the hullform to one consuming podded propulsors that would have a much fuller form and advanced block constant. The similar coupling mechanism as that for Concept 1 is used.

Subsequently Concept 3 was considered to improve these loads. Concept 3 has a propulsion module that submerges and slots into a space in the aft end of the cargo module and is combined by hydraulic arms from the sides, roof and front of the propulsion module.

Table 3. Hyperion SMR characteristics.

Electrical output	25 MWE
Lifetime	8 - 10 years
Weight	Less than 50 tons including pressure vessel, fuel and primary coolant
Structural material	Stainless steel
Coolant	Lead-Bismuth
Fuel	Stainless clad, uranium nitride
Enrichment	Less than 20% U-235

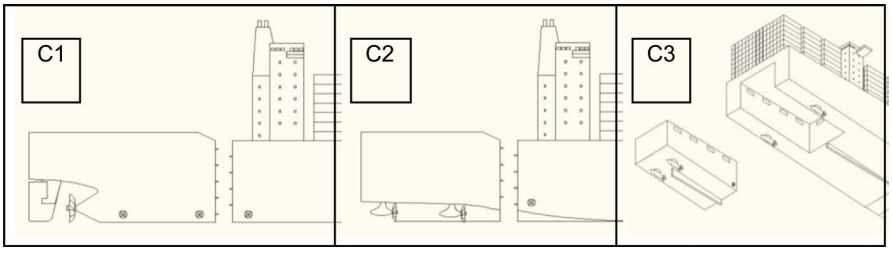

Figure 1. Concepts 1, 2 and 3 [13].

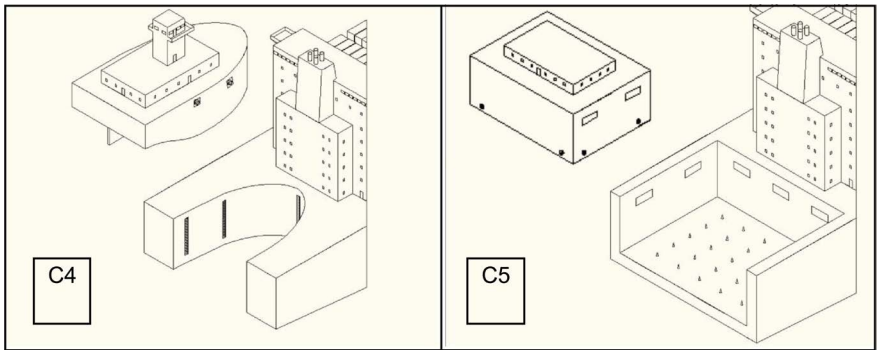

Figure 2. Concepts 4 and 5.

Concept 4 is like Concept 3 however removes the need to submerge by using the model of a barge system with a mechanically inflexible connection.

Concept 5 attempted to remove these coupling loads completely.

The results are as in Table 4. Concept 4, a barge system was the best performing and was therefore selected for further development.

3.2. Design Comparisons (Based on Three)

Light water reactors are the most common type of nuclear reactor around the world, in which light water is used as a moderator as well as the cooling medium. Uranium fuel is enriched to maintain the criticality of the reactor along entire fuel cycle. As the technology of LWR is already moderately mature and broadly adopted, the LWR SMR designs have their inherited advantages and are expected to be commercialized sooner than all other types of reactors. This low enrichment, along with the technological readiness of LWR, will significantly reduce the expected duration for licensing those SMRs. PWR reactors are easier to operate from a stability standpoint; it also has a lower cost for operation. The economic benefits due to technical matureness, easiness of licensing and the lower operational costs make PWR SMRs attractive to vendors and investors. Together HTGRs and fast neutron reactors are hypothesized more recently. Though more interesting and attractive, they also have much more difficulties and uncertainties than the traditional LWR designs. HTGR reactors normally use gases like carbon dioxide or helium as coolant and graphite as the moderator. Consequently, the graphite-composed core will have a huge heat capacity and structural constancy even at high temperatures. The coated fuel also allows high burn-up and retains fission products. However, the concepts of HTGR are still quite new; thus the costs for licensing, construction and operation will be higher. Among the four fast reactors, there is one gas-cooled and three liquid-metal-cooled fast reactors. Fast reactors differ from thermal reactors as they use fast neutrons to sustain the fission chain reaction, and thus do not need a neutron moderator. Also producing less waste, fast reactors also need less

Table 4. Concept decision matrix.

Concept Criteria	Importance	Alternative Concepts				
		C 1	C 2	C 3	C 4	C 5
Module Design	17.5	1	1	2	4	3
Propulsion	10	5	4	3	3	4
Coupling system	20	1	1	4	4	5
Coupling forces	20	2	2	4	4	5
Coupling mechanism	20	1	1	2	5	4
Application to different vessels	10	2	2	2	5	1
Cable power connection	2.5	5	5	3	2	5
Total	**100**	**1.8**	**1.7**	**2.93**	**4.15**	**3.95**

uranium fuel, as they permit nuclear fuels to be bred from almost all the actinides, including abundant sources of depleted uranium and thorium, and wastes from conventional light water reactors. This "breed and burn" process gives fast reactors a much larger efficiency as compared to other type reactors.

Nevertheless, several obstacles need to be conquered to promote the use of fast reactors. Firstly, critical mass in a fast reactor is much higher than in a thermal reactor because of the low cross sections of most materials at high neutron energies. As a result, significantly higher enrichment is normally necessary for the reactor; uranium fuels are enriched up to 20% (45). The high enrichment induces a somewhat greater proliferation risk. Fast reactors are also more expensive to build and operate comparing to LWRs. After each cycle, nuclear fuel will be moved from the core to be replaced by new fuel. According to researches, the heavy metal compositions for a typical light water reactor in US before and after running for three years are: uranium dropping from 100% to ~93.4%; from 4.2% enrichment to 0.71%; plutonium rising from 0% to 1.27%; minor actinide from 0% to 0.14% and fission products from 0% to 5.15% (**Figure 3**).

Among the three reactor classes, fast neutron reactors have the highest fuel efficiency although producing least radiotoxic wastes. Fast reactors allow fully exploiting the energy potential of uranium fuels by converting the fertile U-238 in

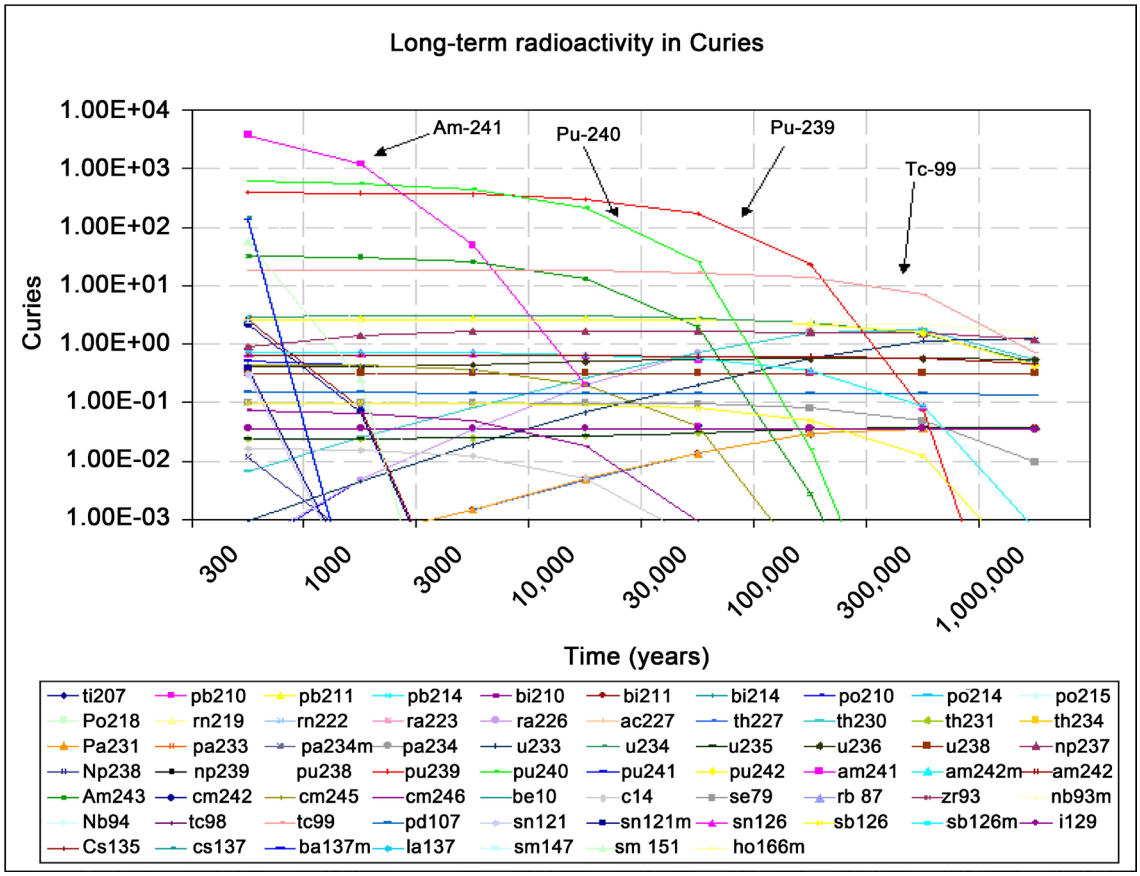

Figure 3. The long-term activity of all the radioactive nuclides burnt to 45 MWd/kg. Data as computed by https://whatisnuclear.com/ [14].

the wastes to fissile Pu-239 and reusing the fissile materials; thus, they can extract sixty-to-seventy times more energy from uranium than thermal reactors do. A higher efficiency means a smaller input required, for producing the same amount of energy. On the other hand, researches have indicated that actinides tend to have a higher probability of fission at fast energies, so fast reactors can burn more efficiently the long life transuranic wastes and significantly reducing the activity and the required isolation time of the nuclear wastes. Since these three factors above, it seems genuine to put the four fast neutron spectrum reactors as best candidates for the study.

3.3. Calculations of the Nuclear Propulsion System

The submarine nuclear propulsion system includes steam turbines, to which the steam is delivered from the cooling system of the reactor. Nowadays almost all nuclear submarines are equipped with two-contour nuclear cycles cooled with light water, of PWR type. The steam generated in the steam generator is most frequently delivered to two turbines (turbo generator and the main turbine, see Figure 4). The calculations of a typical cycle of a two-contour nuclear power plant with steam separation and live steam interstage superheating were done. In this system the live steam parameters were equal to: pressure—7MPa, temperature—285.8˚C ([9]), while the division pressure was optimized to obtain 1.05 MPa for the degree of dryness equal to 0.85 (end of expansion in the HP part). Internal efficiencies of the turbines were assumed at the level of 90% while the pressure in the condenser was assumed equal to 6 kPa. The assumed power output of the turbine was equal to 70 MW (large nuclear submarine). The gross efficiency (neglecting boat's own needs) of this cycle was equal to 32.1%. The mass flow rate was 90.14 kg/s. Revolutions of the high-pressure part were set at the level of 4800 rev/min while for the low-pressure part: 2000 rev/min. Preliminary thermodynamic and flow calculations have made the basis for designing the

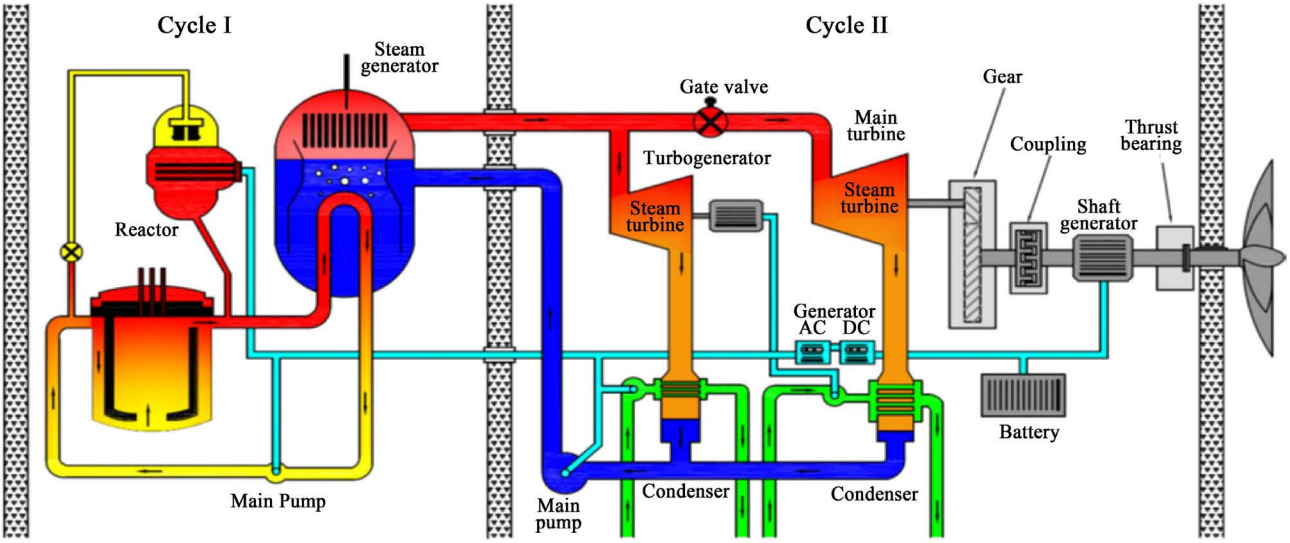

Figure 4. Simplified scheme of nuclear propulsion system in two-contour PWR cycle [15].

flow paths of the high-pressure turbine part and the low-pressure part (see **Figure 4**). The high-pressure part had six stages having circumferential efficiency not exceeding 90%, while in the low-pressure part 7 stages were obtained with circumferential efficiency over 90%.

4. Conclusions

As nuclear-powered ship is wide-ranging high powered, container ships and icebreaking vessels are appropriate for initial implementation of nuclear propulsion. Growing nuclear propulsion to other ship types, such as slower-going bulk carriers, will generally require higher service speeds than the traditional fossil fuel ship. The success of nuclear propulsion finally is tied to the success of nuclear fission in general. Absorbed opposition will be faced from the hydrocarbon and renewable energy industries, and any other lucrative industries which stand to lose out from the acceptance and widespread use of nuclear energy. The Nuclear Marine Propulsion system is a mainly energy system that consumes nuclear fuel for energy ensuing in heat, while to produce mechanical energy or output power essential to turn the propeller used steam turbine. Nuclear marine reactors consume a maximum level of burn-up fuels, for example, uranium-zirconium, uranium-aluminum, and metal ceramic fuels. On the other hand, land-based reactors consume uranium dioxide UO2. These factors deliver the naval vessels theoretical infinite range and mission time. For these two considerations, it is recognized that a nuclear reactor is the perfect engine for nuclear marine propulsion.

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