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常温核融合現象 CFP (The Cold Fusion Phenomenon)は、「開いた (外部から粒子とエネルギーを供給され、背景放射線に曝された)、非平衡状態にある、高密度の水素同位体(Hand/D)を含む固体中で起こる、核反応とそれに付随した事象」を現す言葉で、固体核物理学(Solid-State Nuclear Physics)あるいは凝集体核科学(Condensed Matter Nuclear Science)に属すると考えられています。

CFRL ニュース No.92 をお送りします。この号では、次の記事を掲載しました。

1. CFP 研究の歴史から (6) — M. Okamoto et al. (1994) による核変換生成物の局在の最初の確認
2. D.J. Nagel “Lattice-enabled nuclear reactions in the nickel and hydrogen gas system” *Current Science*, Vol. 108, No. 4, 646 – 652 (2015)
3. 訃報: Dr. A. Karabut (– 2015. 3. 15)

1. CFP 研究の歴史から (6) — M. Okamoto et al. (1994) による核変換生成物の局在の最初の確認

常温核融合現象 (CFP) が、 $\text{PdD}_x(\text{Li}) \text{NiH}_x(\text{K}, \text{Rb})$ ($x \sim 1$) などの CF 試料 (CF materials) の中のどの場所で起こるのかという問題は、CFP における核反応の性質がどのようなものなのかに関係した重要な問題であり、最初の Fleischmann et al. (1989) [Fleischmann 1989] の論文でも取り上げられていた問題です。この問題にたいする、最初の具体的な回答を与えたのが Nakada et al. (1993) and Okamoto et al. (1994) の論文でした [Nakada 1993, Okamoto 1994].

1.1 Okamoto et al. による局在した核反応の確認

1993 年の ICCF3 における彼らの論文から、関連する部分を引用してみましょう:

“The depth profiles of Li, D and Pd were observed by SIMS technique for several Pd

test pieces cut from the Pd electrodes employed in the study of neutron emission from the heavy water electrolysis using Pd-D₂O-LiOD system. The depth profiles can be classified into two types; one is the profile with a structure and the other is the monotonous profile. The former was observed on the Pd test piece from the Pd electrode with neutron emission, while the latter was from the Pd electrode without neutron emission.“ [Nakada 1993 (p. 586)]

ほぼ 1 年後の ICCF4 において、彼らはより精密な実験結果を発表しました：

“The examples of the depth profiles of D, Li, Pd, Si, and Al are illustrated in Fig. 1. The profiles with bold line represent the depth profiles of each elements obtained from the Pd sample with the nuclear effect of neutron emission and excess heat generation, the medium line for Pd sample with only neutron emission, and the chain-line for Pd sample with no nuclear effect. The curves shown in these figures are normalized to the secondary ion intensity of Pd obtained in each analysis run to carry out the discussion on the concentrations on the same elements. Evidently from the figures, the depth profiles of the elements with no nuclear effects are monotonous as expected from the electrochemical point of view. (2) While, the depth profiles with some nuclear effects have some of irregular structures, especially in the surface within 2 μm for every element. The depth profiles of lithium and deuterium are very similar in each. This fact indicates that there is a very strong chemical relation between the lithium behavior and the deuterium behavior as discussed in the previous paper.” [Okamoto 1994 (p. 14-2)]

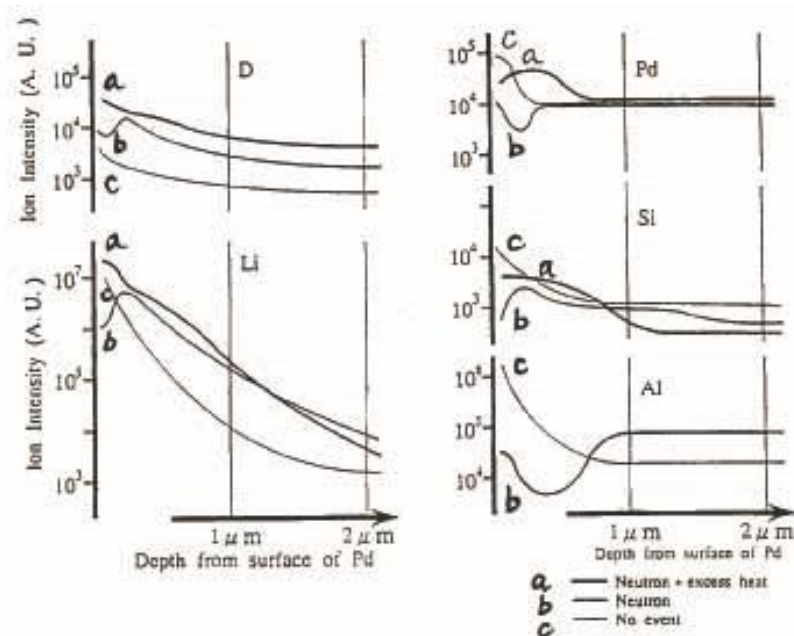
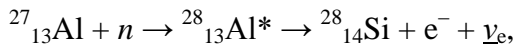


Fig. 1 Examples of depth profiles for each element ([Okamoto 1994 (Fig. 1)]).

この論文 ([Okamoto 1994]) を CFRL News No. 92 の次に掲示します:

<http://www.geocities.jp/hjrfq930/News/news.html>

我々は TNCF モデルを使って、Fig. 1 に示された $^{27}_{13}\text{Al}$ の減少と $^{28}_{14}\text{Si}$ の増加が、次の反応によって説明できることを示しました ([Kozima 1996c] [Kozima 1998 (Sec. 11.11e)]);



ここで、 ν_e は電子ニュートリノです。

Dr. Makoto Okamoto のエッセイが、次の CFRL website に掲示してあります:

<http://www.geocities.jp/hjrfq930/FTEssay/Essays/Okamoto.htm>

Okamoto et al. と同様に Bockris et al. [Bockris 1995] は陰極表面の厚さ数ミクロンの表面層で核変換が起こることを測定しています。

Dr. J.O'M. Bockris のエッセイ “*Cold Fusion 1999*” が次の website に掲示してあります:

<http://www.geocities.jp/hjrfq930/FTEssay/Essays/Bockris.htm>

1.2 多くの研究者が核反応の局在を予想していた

興味のあることは、Okamoto et al. の研究が行われたこの時期に、多くの研究者が表面の重要性に気付いていたことです。

周知のように、Fleischmann et al. は彼らの予想した核反応 (*d-d fusion reactions and other unidentified reactions*) が CF 試料の CF 試料 (PdD_x) の容積内 (bulk) で起こると結論しています:

“(a) Excess enthalpy generation is markedly dependent on the applied current density (i.e. magnitude of the shift in the chemical potential) and is proportional to the volume of the electrodes, i.e. we are dealing with a phenomenon in the bulk of the Pd electrodes.” [Fleischmann 1989 (p. 304)]

しかし、研究が進むにつれて、多くの研究者は試料 (CF 物質 CF materials) の表面に実験成功のカギがあることに気付いてきたようで、その最も明確な探求の成果が Okamoto et al. の上記 2 論文であったと行うことができます。

この時期の多くの研究者の文章に、そのことが記されています。しかしそこには、彼らの予想する核反応 (*d-d fusion reactions*) とは別の、副次的な現象が表面層で起こっていると考えられていた節が読み取れます。例えば、前号 (CFRL News No. 91) で取り上げた McKubre et al. では、次のように表現されています:

“This observation raises the interesting possibility that one or more species, other than deuterium, are required to be present in the cathode in order to observe excess power, species which are not present initially and are thus required to diffuse into the cathode,

presumably from the electrolyte. Analyses of used cathodes have revealed the presence of several light elements in the near-surface region (to a depth of several microns); in particular, lithium.” [McKubre 1993 (p. 18)]

また、Okamoto et al. では、表面層が重陽子の集積に関係した役割をすると考えられています：

“The process of anomalous accumulation of deuterium was discussed based on the formation of Pd-Li intermetallic compound in the surface area of Pd electrode.” [Okamoto 1994 (p. 14-7)]

他方、Dash et al. [Dash 1994] は、Pd 陰極表面での Ag and Au の発生を見出し、それが中性子の関係した核変換であろうという予想を述べています：

“Palladium cathodes from two experiments were analyzed microscopically after electrolysis in acidified light and heavy water. For both experiments, more excess heat had occurred in the heavy-water cell than in the light-water cell during electrolysis. For the first experiment, there were localized concentrations of Au detected in areas of the high-current density on both cathodes; greater concentrations of Au were found on the cathodes from the heavy-water cell. For the second experiment, there were concentrations of Ag detected near sites of surface melting on the cathodes from the heavy-water cell. Although occurring in only a small fraction of cathodes, these unexpected elements correlate roughly with measured excess heat and may have arisen through transmutation caused by neutrons from nuclear fusion reactions.” [Dash 1994]

さらに、先に取り上げた Bush et al. の Rb→Sr の核変換は (CFRL News No. 89)、Ni メッシュ試料という CF 物質の表面で起こることが明らかであり、試料表面の CFP における重要性を示したものでした：

“Appendix A provides an interpretation of these from the standpoint of hypothetical strontium production. An interesting finding from the standpoint of the CAF Hypothesis^{1,3,6} is the fact that, within experimental error, the ratio of the line height for mass number 86 to that for 88 was the same as that for the ratio of the rubidium signals at masses 85 and 87.” [Bush 1994 (pp. 346 – 347)]

この実験結果は、TNCF model を用いて説明されました [Kozima 1996a, 1998 (Sec. 11.11b)]。

さらに付け加えるならば、CFRL News No. 88 で取り上げた Morrey et al. の ⁴He の測定は、TNCF モデルを用いて、CF 物質 (この場合は PdLi_x) の表面層での Li-*n* 核反応によるものとして説明されたことは前述の通りです [Kozima 1996b, 1997, 1998 (Sec. 11.8a), 1999]

1.3 表面層における核反応の性質の探究

このようにして、常温核融合現象における核反応が表面層と深い関係があることが明らかになるにつれて、CF 物質としての体積試料 (bulk materials) と層状試料 (layer materials) が用いられるようになり、体積試料の場合にもその表面層における核変換が注目されるようになります。T.O. Passell の一連の実験はその中でも優れた成果をあげたものです[Passell 1996, 1998, 2002, 2006]。彼の実験閣下は基本的に TNCF モデルで説明できることを示しました[Kozima 1996d,1998 (Sec. 11.11d)].

このように歴史的な研究の流れで見ると、常温核融合現象における核反応が層状に局在した領域で起こることが明らかになったと言ってよいでしょう。JCF11で発表した論文 [Kozima 2011a, 2011b] では、上に概観した論文を含め、Miley et al. [Miley 1996, 1997], Enyo et al. ([Mizuno 1996a, 1996b] and [Ohmori 1996, 1997, 1999], Qiao et al. [Qiao 1997], Iwamura et al. [Iwamura 1998, 2005, 2006a, 2006b, 2006c], および [Celani 2010] など、多くの核変換の実験結果を我々のモデルで説明できることを示しました。

Dr. Michio Enyo のエッセイ “*Open Minded Attitudes to the Science*” が、次の CFRL website に掲示してあります:

<http://www.geocities.jp/hjrfq930/FTEssay/Essays/Enyo.htm>

最後に、水素吸蔵金属以外の金属を用いた実験について、まとめておきたいと思います。Dash et al. は Pd と硫酸塩 (sulfate) を被せた Pt 電極において、Pd 電極と同様な過剰熱が発生することを示しました [Noble 1995]。他方、Ohmori et al. [Ohmori 1996, 1997, 1999] は、Au および W 電極を用いて、表面に核変換によるとしか考えられない異種元素が生ずることを示しました。これらの実験結果は、電極内部よりは表面層が常温核融合現象(CFP)にとって重要であることを示しており、層状試料を用いた Miley et al., Iwamura et al., and Celani et al. の有効性とも関連した現象でもあります。

さらに、Szpak et al. は、電極-電解液の界面層の性質が常温核融合現象(CFP)に与える影響に早くから着目して研究を続けてきましたが、PdD_xを Ni, Au や Cu などの表面に co-deposit することで、水素吸蔵を起こさない金属を含めて、陰極表面に PdD_x (x < 1) 層を持った電極系でのCFPの研究を行っています[Szpak 1992, 1994, 2004, Mosier-Boss 1999]。

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<http://www.geocities.jp/hjrfq930/Books/bookse/bookse01.html>

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<http://www.geocities.jp/hjrfq930/Books/bookse/bookse.html>

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2. D.J. Nagel “Lattice-enabled Nuclear Reactions in the Nickel and Hydrogen Gas System” *Current Science*, Vol. 108, No. 4, pp. 646 – 652 (2015)

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アブストラクトを引用します。

Abstract

Thousands of lattice-enabled nuclear reaction (LENR) experiments involving electrochemical loading of deuterium into palladium have been conducted and reported in hundreds of papers. But, it appears that the first commercial LENR power generators will employ gas loading of hydrogen onto nickel. This article reviews the scientific base for LENR in the gas-loaded Ni–H system, and some of the tests of pre-commercial prototype generators based on this combination.

付言すれば、E-CAT については、この News No. 83 (213.12.10)でわれわれの立場からの寸評を載せておりますので、ご参考にしていただければ幸いです。

3. 訃報: Dr. A. Karabut (– 2015. 3. 15)



Dr. Alexander Borisovich Karabut

(– 2015. 3. 15)

(Photo by H. Kozima on April 11, 1995)

ロシアの Y.N. Bazhutov が下記の手紙で Dr. Karabut の逝去を知らせてくれました。Dr. Karabut は多くの論文を I. Savvatimova と共著で出していた優れた実験家で、個人的な付き合いでもその誠実な人柄で懐かしい思い出を残しています。ご冥福を祈ります。

“Dear colleagues!

With a big regret has to tell you that yesterday (15.03.15) after a short illness (stroke) in hospital Karabut Alexander Borisovich died. He was:

Our Veteran and one of Leaders Researchers in Russia of Cold Nuclear Transmutation,

The Winner of the International award HTYa of J. Preparata for 2007,

The Winner of the State Award USSR for 1982,

Member of Coordinating Council on the Problem of “Cold Nuclear Transmutation” (RFO),

Member of Editorial Board RCCNT&BL-(16-21) & constant participants of almost all RCCNT&BL,

PhD, Senior Researcher of NPO Luch.

Yuri Nikolaevich Bazhutov”

[追記 (2015.4.15)]

Alexander Karabut の M. Macy による業績紹介が雑誌 *Infinite Energy*, Issue 120, March/April 2015 にでました。

**Alexander Karabut: A Russian Scientist's –
Tenacity and Contribution –
by Marianne Macy**

次のサイトに掲示されています：

<http://www.infinite-energy.com/iemagazine/issue121/karabut.html>