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STRUCTURE STUDIES OF AMALGAM
V. THE MARGINAL STRUCTURE OF OCCLUSAL AMALGAM FILLINGS

by

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INTRODUCTION

Previous studies by *Kanai* (1966) have demonstrated that, under certain conditions, burnishing of the margins of occlusal amalgam fillings immediately after packing produces a considerable reduction of both mercury content and porosity in these vulnerable areas. Later studies by *Jørgensen et al.* (1966) showed that the crushing strength of amalgam is governed in particular by the porosity of the amalgam, while the influence of the mercury content upon this property is relatively moderate.

The present work was undertaken to examine the structure of the occlusal amalgam margins when a greater number of variables was introduced.

MATERIALS AND METHODS

True Dentalloy (The S. S. White Dental Mfg. Co., G. B.) was selected for use in this investigation because amalgams resulting from this alloy show a very sharp contrast between the γ -phase and the two reaction phases γ_1 and γ_2.

All the experimental fillings were made in cavities cut in cylinders of plexiglass with a diameter of 12 mm and a height of 10 mm. The cavities had a diameter of 5.0 mm and a depth of 3.5 mm, and they were bounded "occlusally" by a conical face which formed an angle of 120° with the cavity wall (Figures 1 and 2). The cavity and the conical surface had both a roughness of the same order as dental cavities cut with a steel fissure bur. The roughness was determined by means of a Perth-O-Meter.

The amalgam was in all cases mixed in a Wig-L-Bug, 20 seconds with pestle followed by 2 seconds without pestle. Condensation was started immediately after the initial manipulation of the amalgam (see below), and was carried out on a specially designed balance (see *Jørgensen,* 1967, Figure 2), which enabled the use of a constant condensation pressure of 2 kg. The condensation was in all cases finished within 7 minutes after trituration.

The initial manipulation and the condensation of the amalgam were carried out in three different ways.

A. The Eames' technique. The amalgam was mixed with an initial mercury content of 48 % (1.120 g of alloy and 1.034 g of mercury). The mix was divided into six parts of about the same size, and no mercury was expressed outside the cavity. Each increment was condensed into the cavity with 30 evenly distributed thrusts of a pearshaped plugger with a diameter of 1.8 mm,

Fig. 1. Experimental cavity with amalgam filling. The cavity was prepared in plexi-glass.

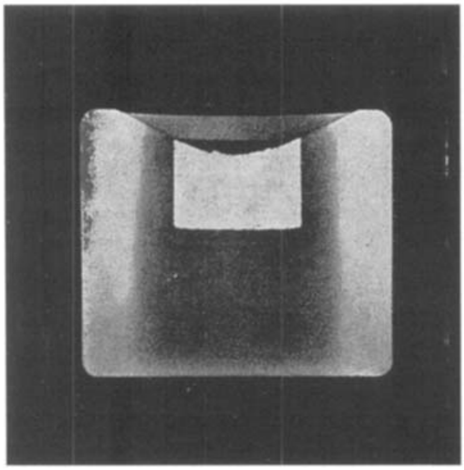

Fig. 2. Section of experimental cavity with amalgam filling. The cavity has a diameter of 5 mm and a depth of 3.5 mm.

and expressed mercury was removed as well as possible with this plugger after condensation of the increment.

B. Traditional technique. The amalgam was mixed with an initial mercury content of 60 % (1.120 g of alloy and 1.680 g of mercury). Immediately after mixing the mercury content was reduced to 48 % ± 0.5 % by expression of excess. The subsequent procedure was as described for the Eames' technique.

C. Wet technique. The amalgam was mixed with an initial mercury content of 60 % (1.120 g of alloy and 1.680 g of mercury). All expression of mercury was carried out inside the cavity. The subsequent procedure was as described for the Eames' technique, except that a contra-angled plugger with a flat, circular working point (cf. Jørgensen, 1967) was used because it was found better suited for removal of the relatively large amounts of mercury excess from the cavity than the pear-shaped plugger. The diameter of the flat plugger was 1.8 mm. Special experiments showed that the structure of the "occlusal" margins of fillings prepared by technique A or B with flat plugger was not significantly different from the marginal structure of fillings prepared with pear-shaped pluggers. Therefore the differences between the experimental results reported below cannot be ascribed to the use of different pluggers in techniques A, B and C.

The condensation was completed in three different ways.

1. The cavity was not overfilled, and burnishing was omitted. Only five of the six increments were used. The surface of the filling was smoothed with a wad of dry cotton-wool.

2. The cavity was filled with the five increments and overfilled with the sixth. Excess was removed with a sharp carving instrument, and the filling surface was smoothed with a wad of dry cotton-wool.

3. The cavity was filled with the five increments and overfilled with the sixth. The amalgam was then burnished with a slightly convex, circular burnisher (diameter 4.0 mm) under a pressure of 2 kg.

Burnishing was carried out by moving the instrument from the filling toward and across the filling margin. The whole circular area of the filling margin was given one treatment by the burnisher.

Techniques A, B, and C were each combined with 1, 2, and 3, so that 9 different test groups resulted. Ten fillings were made for each of these 9 groups. After the preparations had been cut

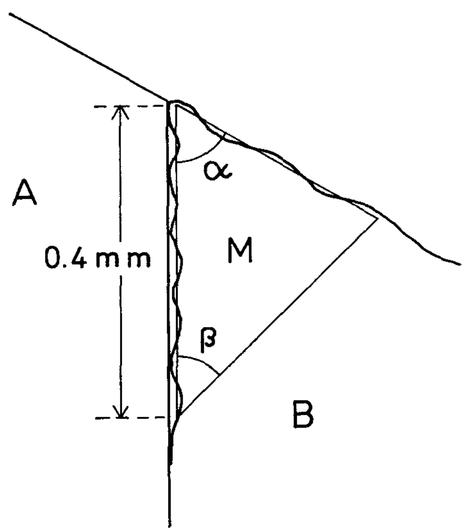

Fig. 3. The positioning of the triangular counting screen on the projected microphotograph of an amalgam margin. A, the cavity wall. B, amalgam filling. $\alpha = 60°$. $\beta = 45°$. The picture of the projected margin was enlarged 450 times.

through (see below) a total of 20 filling margins was thus available for the structural study in each of the 9 groups.

When the amalgam had set cavity with filling was cut through lengthwise in the middle, mounted in Palatal, polished and etched by a technique previously described (*Jørgensen*, 1967). The polished preparations were used for the quantitative determination of the porosity of the "occlusal" margins, while the same preparations in etched conditions were used for determination of the amount of γ-phase in the margins.

The quantitative determinations were made by a modification of the Point Counter method — also previously described (op. cit.) — with the difference, however, that in the present investigation the shape of the counting screen was adapted to the geometrical shape of the occlusal margins (Fig. 3). It should be pointed out that the upper edge of the screen was placed so as to coin-

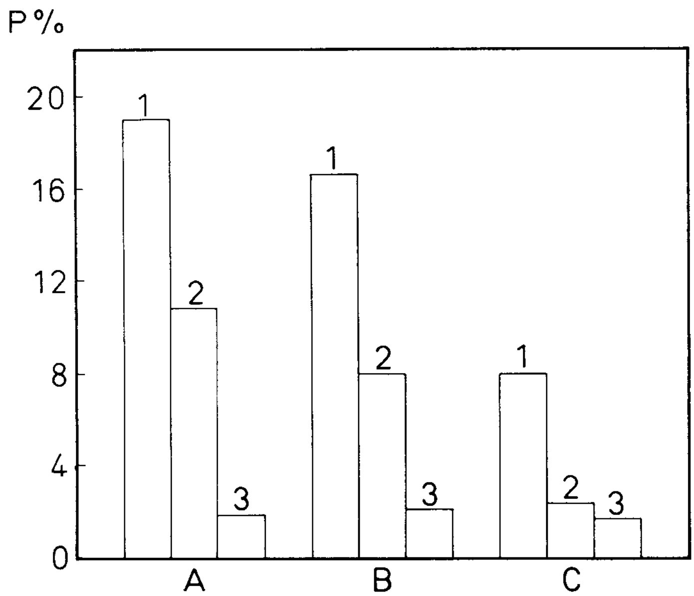

Fig. 4. The percentage porosity of the amalgam margins studied. A, the Eames' technique. B, traditional technique. C, wet technique. 1, the cavities not overfilled, the margins not burnished. 2, the cavities overfilled, the margins not burnished. 3, the cavities overfilled, the margins burnished. The difference between C_2 and C_3 is statistically significant.

cide with the estimated mid-line of the surface roughness, and that corresponding to this edge only the points covered by the amalgam were counted. The vertical edge of the screen was likewise placed as mid-line for the surface roughness, but as regards this area all the points of the screen were diagnozed and counted; the surface roughness corresponding to the cavity wall is thus partly included in the measurement found for the porosity.

The counting screen had 560 points in all, but the number of counted points was always somewhat lower owing to the position of the upper edge of the screen.

The accuracy of the method has been reported in earlier works (*Kanai*, 1966; *Jørgensen*, 1967). Further, 5 times repeated counts were made of the porosity in 4 different margins at such time intervals that it was not possible to remember the position of the counting screen on the preparation pictures from one time to another. Mean value and standard deviation for these measurements were as follows: 14.9 ± 0.30, 22.4 ± 0.15, 27.5 ± 0.28, and 16.4 ± 0.23.

RESULTS

The measured results appear in Tables I—IV. Tables I and II show mean value, standard deviation, and standard error for porosity and γ -phase, respectively, while Tables III and IV give the corresponding t-test values. Figures 4 and 5 illustrate the results diagramatically, while Figures 6—8 show examples of amalgam margins with different degrees of porosity.

Techniques A, B, and C showed highly significant differences in porosity when combined with marginal techniques 1 or 2. In combination with marginal technique 3 (overfilling, burnishing, car-

TABLE I

The porosity (%) of the amalgam margins studied

Technique	1	2	3
A. Eames'	19.0 ± 3.6 ± 0.75	10.8 ± 1.3 ± 0.29	1.9 ± 1.0 ± 0.23
B. Traditional	16.6 ± 4.4 ± 0.98	8.0 ± 2.6 ± 0.58	2.1 ± 1.2 ± 0.27
C. Wet	8.0 ± 3.1 ± 0.69	2.4 ± 0.9 ± 0.20	1.7 ± 0.5 ± 0.11

The figures 1, 2 and 3 refer to the three methods of marginal technique.
N = 20

TABLE II

The γ -phase (%) in the amalgam margins studied

Technique	1	2	3
A. Eames'	6.6 ± 2.2 ± 0.49	11.2 ± 2.7 ± 0.60	12.3 ± 3.0 ± 0.67
B. Traditional	5.3 ± 2.4 ± 0.54	10.3 ± 1.7 ± 0.38	11.0 ± 2.1 ± 0.47
C. Wet	6.6 ± 2.8 ± 0.63	13.3 ± 3.0 ± 0.67	12.1 ± 2.6 ± 0.58

The figures 1, 2 and 3 refer to the three methods of marginal technique.
N = 20

TABLE III

Values for Student's t-test for the figures in Table I

Technique	A 2	A 3	B 1	B 2	B 3	C 1	C 2	C 3
A 1	10.3		3.0			10.8		
A 2		23.4		4.3			24.0	
A 3					0.6			0.7
B 1				7.6		7.2		
B 2					9.1		9.0	
B 3								1.4
C 1							7.8	
C 2								3.2

Degrees of freedom = 38
The difference was highly significant when $t \geqq 3.6$
The difference was significant when $3.6 > t \geqq 2.7$
The difference was probably significant when $2.7 > t \geqq 2.0$

TABLE IV

Values for Student's t-test for the figures in Table II

Technique	A 2	A 3	B 1	B 2	B 3	C 1	C 2	C 3
A 1	6.0		1.8			0.0		
A 2		1.3		1.3			2.3	
A 3					1.2			0.2
B 1				7.6		1.5		
B 2					1.2		3.9	
B 3								1.2
C 1							7.3	
C 2								1.4

Degrees of freedom = 38
The significance of the t-values as defined under Table III.

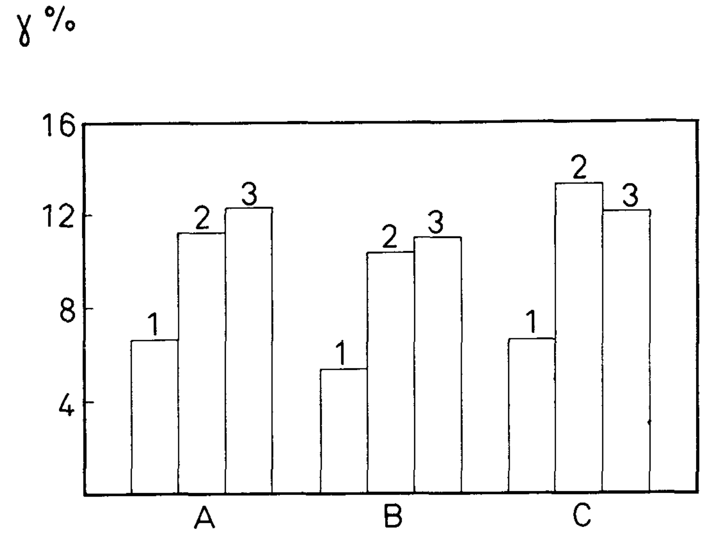

Fig. 5. The percentage content of γ-phase in the amalgam margins studied. *The designation for the differnt combinations of technique as in Fig. 4.*

ving away the excess), on the other hand, there was no difference between A, B, and C with regard to porosity. Technique C in combination with 1 and 2 produced a highly significant reduction in marginal porosity when compared with techniques A and B; if technique C was used the porosity could be brought down quite appreciably by burnishing the filling margins in addition to overfilling the cavity (the difference between C2 and C3 is significant).

With regard to the content of γ-phase of the margins Tables II and IV show that a highly significant increase of this phase was achieved by substituting marginal technique 2 for 1. Burnishing of the margins (substitution of technique 3 for 2), on the other hand, had only a moderate influence on the γ-phase content. The difference between techniques A, B, and C in terms of γ-phase in the filling margins was also rather negligible, only technique B_3 and C_2 showed highly significant difference.

Thus, the results of the 9 combinations lead to the conclusion that techniques A_3, B_3, and C_3 were equivalent. On the other hand, they were superior to all the other combination, on a signif-

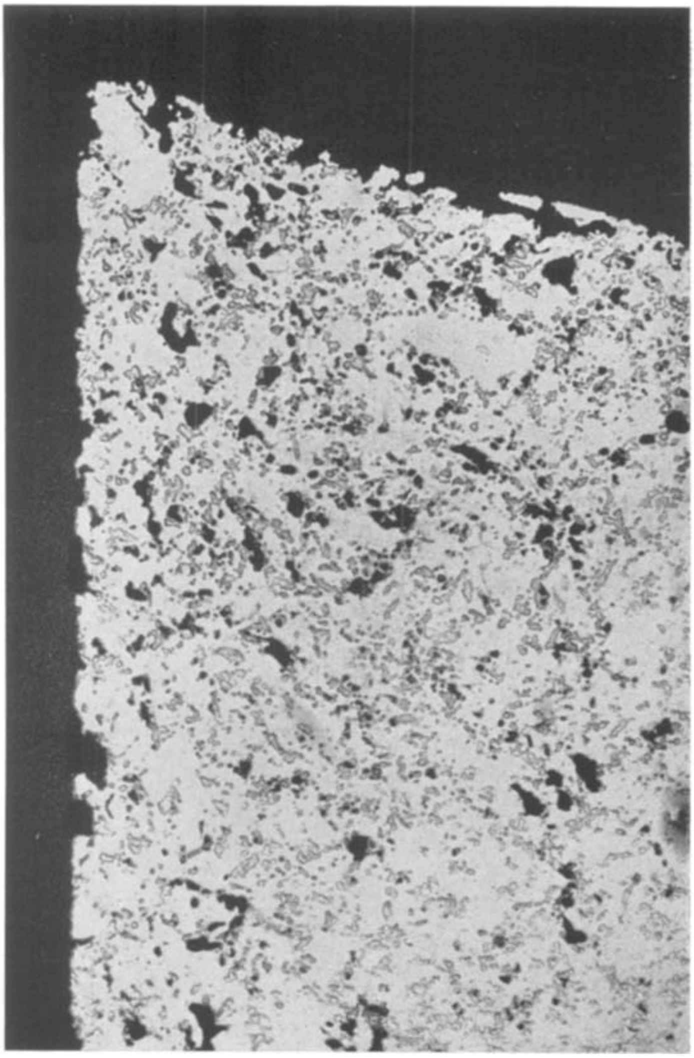

Fig. 6. Amalgam margin with a porosity of about 20 %. x 125.

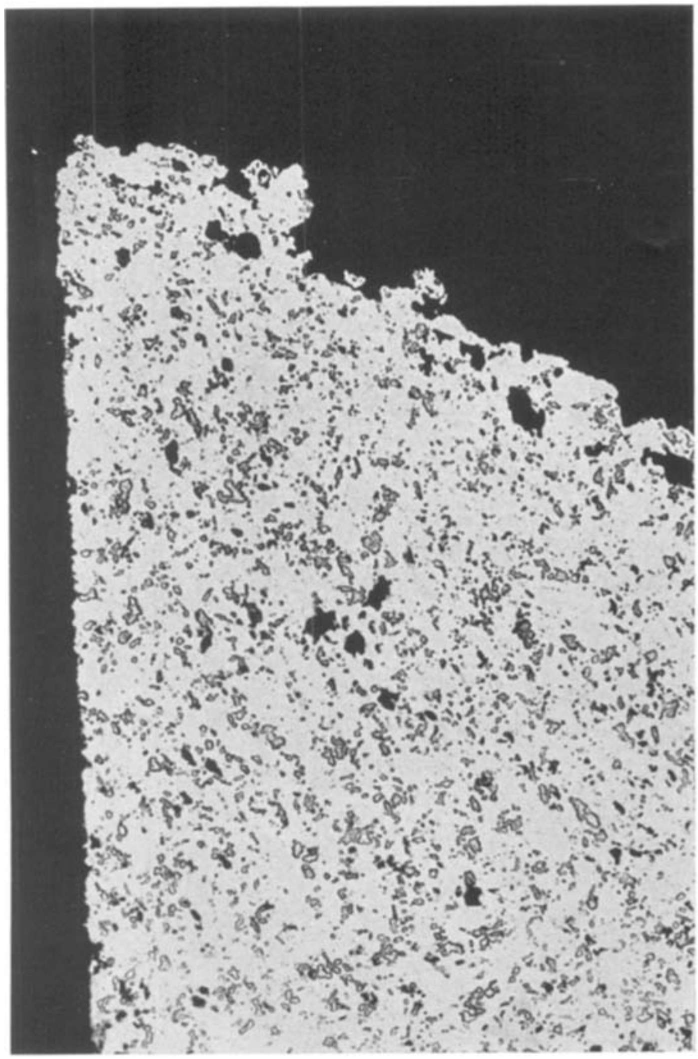

Fig. 7. Amalgam margin with a porosity of about 10 %. x 125.

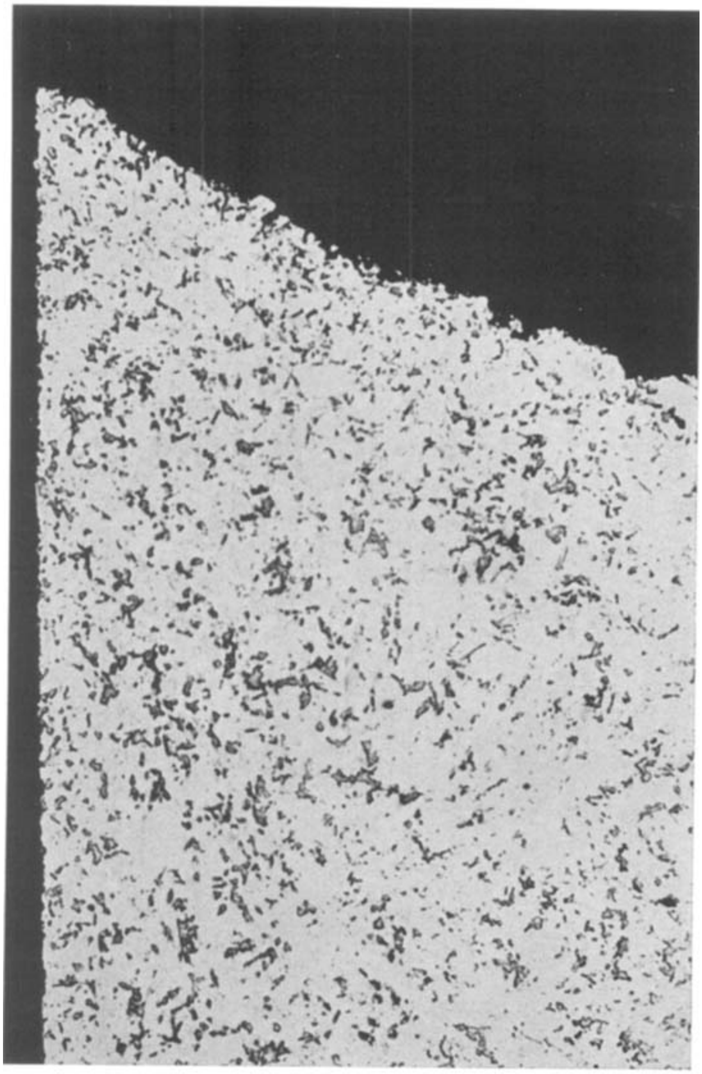

Fig. 8. Amalgam margin with a porosity of about 1 %. x 125.

icant and highly significant level, respectively. The results obtained with C_2, however, came very close to the optimal group.

SUMMARY

The present work is an analysis of the marginal structure of experimental occlusal amalgam fillings. The initial manipulation of the amalgam was carried out in three different ways: The Eames' technique, traditional technique, and wet technique. The condensation of the margins was also done by three different methods, which are described in detail in the text.

The results show — in agreement with previous, less comprehensive, studies by *Kanai* — that optimal structure of the filling margins can be obtained only by systematic overfilling and burnishing of the margins and by subsequent removal of the excess by carving. If this technique is adopted the quality of the margins will be the same with any of the three methods of initial manipulation.

The definition of optimal structure (lowest possible porosity, and highest possible content of γ -phase) is based on previous studies, some of which have already been published.

RÉSUMÉ

ETUDES SUR LA STRUCTURE DE L'AMALGAME.
V. STRUCTURE DES BORDS DES OBTURATIONS OCCLUSALES D'AMALGAME.

Cette étude présente une analyse de la structure des bords d'obturations occlusales expérimentales. L'amalgame a été préparé de trois manières différentes: technique d'Eames, technique traditionelle et technique "mouillée". De même, la condensation des bords a été effectuée selon trois méthodes différentes, dont l'article donne une description détaillée.

Il ressort des résultats obtenus, ainsi que lors des études moins étendues faites antérieurement par *Kanai,* que l'on ne peut obtenir une structure optimale au niveau des bords de l'obturation qu'en pratiquant systématiquement l'obturation avec un excès d'amalgame que l'on brunit sur les bords et en enlevant ensuite l'excès avec un instrument tranchant. Lorsqu'on emploie cette technique, la qualité des bords de l'obturation est indépendante de la méthode choisie pour la préparation de l'amalgame.

La définition de la structure optimale (porosité aussi petite que possible, teneur en phase γ aussi grande que possible) est basée sur d'autres études dont certaines ont déjà été publiées. Les résultats de ces études devant faire plus tard l'objet d'une discussion d'ensemble, les auteurs n'ont pas eu l'intention de présenter ici les arguments qui ont conduit à la définition ci-dessus.

ZUSAMMENFASSUNG

DIE KANTENSTRUKTUR IN OCCLUSALEN AMALGAMFÜLLUNGEN

Die vorliegende Arbeit präsentiert eine Analyse der Kantenstruktur in experimentellen occlusalen Amalgamfüllungen. Das Amalgam wurde auf drei verschiedene Weisen vorbehandelt: Eames Technik, traditionelle Technik und nasse Technik. Die Kondensierung der Kanten wurde ebenfalls nach drei verschiedenen Methoden ausgeführt, die im Text näher beschrieben sind.

Die Ergebnisse zeigen — ähnlich früheren, weniger umfassenden Untersuchungen von *Kanai* — dass eine optimale Struktur der Füllungskanten nur durch systematische Überfüllung und Glättung der Kanten und durch anschliessendes Wegschneiden des Überschusses erzielt wird. Bei Anwendung dieser Technik ist die Qualität der Kanten unabhängig davon, welche der drei Vorbehandlungsmethoden verwendet wurde.

Die Definition der optimalen Struktur (mindest mögliche Porosität, grösstmöglicher Gehalt an γ phase) baisert auf anderen, zum Teil bereits veröffentlichten Untersuchungen.

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