

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: June 21, 1976

Project Title: Graduate - Postdoctoral Training in Dental Materials

Project No: E-19-560

Project Director: Dr. R. F. Hochman

Sponsor: National Institute of Health

Agreement Period: From 7/1/76 Until 6/30/77

Type Agreement: Training Grant No. 5 T01 DE00127-14 DTL

Amount: \$9,588

Reports Required: Statement of Appointment of Trainee
Interim Progress Report
Terminal Progress Report (only if project is not renewed).

Sponsor Contact Person (s):

Technical Matters

Contractual Matters

(thru OCA)

Dr. Louis Wachtel
Acting Chief
Biomaterials Program
Extramural Programs
National Institutes of Dental Research
Bethesda, Md. 20014

Defense Priority Rating: None

Assigned to: School of Chemical Engineering (School/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT TERMINATION

off

Date: 8/15/78

Project Title: Graduate-Postdoctoral Training in Dental Materials

Project No: E-19-560

Project Director: Dr. R. F. Hochman

Sponsor: DHEW/PHS/National Institute of Health

Effective Termination Date: 12/31/77

Clearance of Accounting Charges: 12/31/77

Grant/Contract Closeout Actions Remaining:

- ☐ Final Invoice and Closing Documents
- ☐ Final Fiscal Report
- ☒ Final Report of Inventions
- ☒ Govt. Property Inventory & Related Certificate
- ☐ Classified Material Certificate
- ☐ Other _____

Assigned to: Chemical Engineering (School/Laboratory)

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GRADUATE-POSTDOCTORAL TRAINING IN DENTAL MATERIALS

By:
R. F. Hochman
Metallurgy Program

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

FINAL REPORT
HEW/NIDR TRAINING GRANT NO. 5-T01-DE 00127(1-14)

July 20, 1978

FINAL REPORT

Graduate-Postdoctoral Training in Dental Materials
NIDR Training Grant DE-00127(1-14)

by

Dr. Robert F. Hochman

I. BACKGROUND

The NIDR dental materials training program at Georgia Tech was initiated July 1, 1963, under the direction of Dr. Robert F. Hochman whose involvement in medical-dental materials started in 1957. As the program developed it broadened from strictly graduate training to include postdoctorals and summer training for dental students. Its major function has been to provide the trainees with a strong background in metallurgy, ceramics and, more recently in polymers, plus training and understanding of new research tools and techniques so all of these may be brought to bear on dental materials problems. The training developed over the years to provide a more and more effective interplay between dental and physical science oriented personnel interested in dental materials. In addition to the obvious number of trainees which have benefited, and been initiated into the area of dental materials research, a wide number of Tech staff members in engineering, physical sciences, and biological sciences have been introduced to the basic problems of dental materials.

During the fourteen years of this grant, 12 predoctorals and 7 postdoctorals have been involved in the program, 8 predoctorals have completed their training and 5 postdoctorals have finished. The work of these trainees has resulted in 8 theses and 27 papers on dental-medical materials research.

In addition more than 25 dental students have taken part in summer research training (many for 2 and 3 consecutive years) and each worked on special materials research problems. Several of these problems have been awarded regional awards, and two projects, (Fred and Aubrey's and Butler's) were finalists in the National ADA table clinics with Fred and Aubrey receiving a second in 1968.

Of these trainees 7 are actively engaged in dental materials research and 3 others are partially involved or engaged in related research. In addition, of course, all of the summer dental trainees are actively engaged in dental practice. Dr. Aubrey is a practicing dentist and part-time clinic professor at the Emory Dental School, and Dr. Fred until recently has been at the NIDR.

II. TRAINEES

Of the predoctorals and postdoctorals trained in dental materials, the following are actively engaged in dental materials training and research.

Dr. Toru Okabe - Assistant Professor of Dental Materials, Dental School,
Medical College of Georgia

Dr. Kirk Bundy - Assistant Professor of Biomaterials, Johns Hopkins University,
Baltimore, Maryland

Dr. Richard Mitchell - Research Associate in Dental Materials, Dental School,
Medical College of Georgia

Dr. Larry D. Love - Associate Professor, Temple University Dental School.

Dr. Aaron Villastrigo - Recent DDS graduate and former special instructor
in dental materials, University of Texas Dental School,
San Antonio, Texas

Dr. M. Marek - Associate Professor of Metallurgy and Dental-Medical
Materials, Georgia Institute of Technology

Dr. Danny Averette - Ph.D. candidate in Metallurgy, Georgia Institute of
Technology

In addition three others are partially involved in bio-materials work; they are: Dr. S. W. Freiman, Research Scientist at the Illinois Institute of Technology (on leave with the EPA), Dr. John W. Koger, Senior Research Scientist, Oak Ridge National Laboratories and Dr. Evan Ling, Products Research Laboratories, St. Joseph Mineral Corp. It appears possible that another, Mr. John C. Caron, participates in a peripheral way in dental-medical materials research with the Celanese Company. Of the total trainees to date only three are fully outside the field of dental-medical materials research at present.

III. RESEARCH - THESES AND PUBLICATIONS

The research on the training programs to date have been principally designed for maximum training, however, the work has also yielded significant results in many areas. Some of the principal contributors have been in the understanding of corrosion and biocompatibility in the oral environment, particularly of dental amalgam and implants; the basic diffusion and, reaction kinetics of dental amalgam; the effects of ultrasonics on material reactions; and the use of ion implantation to improve the fatigue and corrosion resistance of dental alloys which provides the possibility of low cost, highly compatible, crown, bridge and implant

materials. This research has resulted in eight theses and more than 20 papers directly or indirectly related to the research on the training programs to date. To fully appreciate this work an indepth publication would be necessary, however, a list of these publications is provided below:

A. Theses

- (1) Quintal, J. A., "The Effect of Ion Implantation on Dental-Medical Alloys" - M.S. in Metallurgy (Dental Materials) - August 1975.
- (2) Chien, K. H., "The Effect of Ordering on Low Cycle Fatigue of Cu_3Au " - Ph.D. in Metallurgy (Dental Materials) - September, 1974.
- (3) Love, L. D., "Corrosion Characteristics of Dental Amalgam" - M.S. in Metallurgy (Dental Materials) - June, 1970.
- (4) Topolski, F. J., "The Effect of Ultrasonics on the Physical and Mechanical Properties of Metals" - M.S. in Metallurgy (Dental Materials) - June, 1969.
- (5) Horne, E. W., "Order Strengthening in Equiatomic Copper-Gold" - M.S. in Metallurgy (Dental Materials) - March, 1969.

B. Major Papers Presented and Published

- (1) D. F. Averette, R. F. Hochman, and M. Marek, "The Effects of Corrosion In Vitro on the Structure and Properties of Dental Amalgam," 56th Session of the IADR/AADR.
- (2) M. Marek and R. F. Hochman, "Corrosion Properties of a Low Silver, High Copper Dental Amalgam." 54th Session of the IADR (1976).
- (3) M. Marek, J. G. Rinker, and R. F. Hochman, "Solution Chemistry in Crevices and Stress Corrosion Cracks," Proceedings of the 6th International Congress on Metallic Corrosion, December 1975. To be published by NACE.
- (4) M. Marek, T. Okabe, and R. F. Hochman, "In Vitro Corrosion of Dental Amalgam Phases," Journal of Biomedical Materials Research, 10, 789 (76).
- (5) M. Marek and R. F. Hochman, "Mechanism of Crevice Corrosion of Dental Amalgam," Paper presented to the 53rd Session of the IADR, London, April 1975 (DMG microfilm).
- (6) Caron, J. C., "The Effect of High Condensing Pressures and Ultrasonics on the Hardness of Dental Amalgams" - M.S. in Metallurgy (Dental Materials) - June, 1967.

- (6a) M. Marek, T. Okabe and R. F. Hochman, "In Vitro Corrosion of Dental Amalgam Phases," Paper presented to the 1975 General Session of the AADR, New York, April 1975 (DMG microfilm).
- (6b) M. Marek, T. Okabe and R. F. Hochman, "In Vitro Corrosion of Dental Amalgam Phases," Accepted for publication, Journal of Biomedical Materials Research. Based in part on the preceding paper.
- (7) Freiman, S. W., "Diffusion of Mercury Into Silver-Tin Dental Alloy (Ag_3Sn) Including the Effect of Ultrasonic Energy" - M.S. in Metallurgy (Dental Materials) - June, 1965.
- (8) Koger, J. W., "A Study of the Kinetics of the Mercury Reaction With the Silver-Tin Dental Alloys" - M.S. in Metallurgy (Dental Materials) - March, 1965.
- (9) H. E. Grenga, J. L. Carden, T. Okabe, and R. F. Hochman, "Auger Analysis of Surface Films on Ag_3Sn ," J. Biomed. Mater. Res., Vol 9, pp 207-211 (1975).
- (10) T. Okabe, R. F. Hochman and L. O. Sims, "Amalgamation Reaction on Mercury-Plated Dental Alloys (Ag_3Sn)," J. Biomed. Mater. Res., Vol. 9, pp 221-236 (1975).
- (11) T. Okabe, R. F. Hochman and M. E. McLain, "Tracer Diffusion of Silver and Tin in a Dental Alloy (Ag_3Sn), J. Biomed. Mater. Res., Vol. 8, pp. 381-392 (1974).
- (12) M. Marek and R. F. Hochman, "Passivity of Dental Amalgam," Paper presented at the TMS-AIME/IMD and ASM/MSD Session, 1972 Materials Engineering Congress, Cleveland, Ohio, 1972.
- (13) M. Marek and R. F. Hochman, "A Study of Localized Corrosion Cell Reactions," Proceedings of the 1973 NACE Corrosion Science Symposium.
- (14) M. Marek, M. F. Butler and R. F. Hochman, "Crevice Corrosion in Dental Amalgam Restorations," Paper presented at the 51st Session of the IADR, Washington, D.C., 1973.
- (15) M. Marek and R. F. Hochman, "The Corrosion Behavior of Dental Amalgam Phases as a Function of Tin Content," Paper presented at the 51st Session of the IADR, Washington, D.C., 1973.

- (16) "Advances in Dental-Medical Implant Materials," Plenary Lecture, 65th Meeting European Federation of Corrosion, Dubrovnik, Yugoslavia, April 18, 1972, Published in Conference Proceedings and CEBELCOR Report.
- (17) M. Marek and R. F. Hochman, "Corrosion Behavior of Amalgam Electrodes in Artificial Saliva," Proceedings, 50th Meeting of IADR, March 23, 1972, Las Vegas, Nevada.
- (18) T. Okabe, R. F. Hochman and M. E. McLain, "Kinetic Factors in Amalgamation of Dental Alloy," Proceedings 50th Meeting of IADR, March 23, 1972, Las Vegas, Nevada.
- (19) T. Okabe, F. Ling and R. F. Hochman, "Amalgamation Reaction of Tin, Silver and Dental Alloy (Ag_3Sn)," J. Biomed. Mater. Res., Vol. 6, pp 553-563 (1972).
- (20) M. Marek and R. F. Hochman, "Crystallography and Kinetics of Stress Corrosion Cracking of Type 316 Stainless Steel Single Crystals," Vol. 27, No. 9, Sept., 1971 NACE, Houston, Texas.
- (21) R. F. Hochman, "Review of Metal Base Dental-Medical Implant Materials," Presented April 16, 1970, Clemson University, Proceedings, Materials for Implant Dentistry, to be published.
- (22) R. F. Hochman, "Fatigue Properties of Implants," Presented at National Meeting, AIME, February 1969, New York, NY.
- (23) R. F. Hochman and J. C. Caron, "High Strength Amalgams Produced by Changing the Fracture Characteristics with Different Condensing Methods," Presented March 21, 1968, Houston, Texas, Proceedings of the 1968 IADR Meeting.
- (24) R. F. Hochman and L. M. Taussig, "Improved Properties of 316L Stainless Steel Implants by Low Temperature Stress Relief," Presented at the joint ASM-ASTM Symposium on Orthopedic Materials, Detroit, Michigan, published J. of Materials, Vol. 1, No. 2, ASTM, June 1966.
- (25) R. F. Hochman, J. W. Koger and S. W. Freiman, "The Kinetics of the Mercury Reaction with Silver-Tin and the Effects of Ultrasonics on this Reaction," Presented by R. F. Hochman at the Proceedings of the Meeting of the IADR, July 1965, Toronto, Canada.
- (26) R. F. Hochman, S. W. Freiman and R. M. Gray, "The Effect of Ultrasonic Energy on Diffusion and Sintering," Presented by R. F. Hochman, June 23, 1965, at an International Conference on Sintering and Related Phenomena, published.

- (27) R. F. Hochman, "Metals in the Human Body," Metals Review, Vol. XXXVII, No. 8, August 1964, American Soc. for Metals, Cleveland, Ohio.

This list represents only the major presentations and publications and does not include numerous presentations and lectures to technical, dental and medical groups by members of the program staff and trainees, and a particular series of presentations by R. F. Hochman on "Advances in Dental-Medical Materials," at 14 different meetings of the ASM across the country.

IV. MAJOR ACCOMPLISHMENTS

1. The training of 12 predoctorals (1 still in training, 1 at an other institution) and 7 postdoctorals (1 still in training). Of the 12 having completed graduate training programs, 6 are engaged fully in dental-medical materials research and teaching and three others are involved, at least part-time in bio-materials related research.
2. In addition to the project director, 4 staff members at Georgia Tech have become actively involved in dental materials and dental materials research through association with this program.
3. More than 25 dental students (several for 2 or 3 consecutive summers) have been trained in materials research problems in summer programs beginning in 1964. In many cases these students came back for two or three years training several of their programs have resulted in very useful research. Initial work resulted in reports on "Electron Microscopy Evaluation of Ultrasonic Hardening of Silicate Cements" by William Heidecker and a report by Mr. Donald Alexander entitled "A Study of Order-Disorder Phenomena in Gold-Copper Dental Casting Alloys." A further study by the two students resulted in an excellent report on the solubility testing of silica cements. This has been followed by other studies which included, "A Review of Amalgam Failure Mechanisms," "Dispersion Hardening and Condensation Pressure Effects in Amalgam," "Silicate Dispersion Hardening," "A Special Process for Spheroidization of Dental Alloys," "A Study of Welding Characteristics of Orthodontic Wires," "The Application of Engineering Mechanics to Stress Concentrations and Dental Restorations," "A Study of Adhesion of Dental Polymers," and "A Study of Basic Corrosion Characteristics of Dental Amalgams and Corrosion Resistant Dental Alloy Amalgams," as well as a number of other smaller studies introducing the students to many research techniques including electron microscopy, electron diffraction, x-ray diffraction, microprobe

analysis, field ion microscopy, LEED, all forms of spectroscopy, as well as basic techniques in light microscopy, mechanical property testing, physical property (density, solubility, etc.) testing. A more recent study by a dental student, Leslie Kert, was to relate amalgam corrosion products with the biodegradation of various caries species. Knowledge in microbiology indicates bacteria degradation by heavy elements in solution, it appears that amalgam corrosion products may produce similar effects.

4. Dr. Steven Fred (formerly with the NIDR) and Dr. Jim Aubrey (practicing dentist and part-time clinic instructor at Emory) worked with the program director for three years in the summer dental student training program to produce a technique which resulted in a patent disclosure on a new method for spherodizing silver-tin dental alloy powder. These two young men won the local and regional ADA table clinic awards and placed second in the national ADA table clinic competition in 1968.
5. M. Forest Butler, now with a DDS and a certificate in pesio, served as a summer dental trainee for two years, 1970-1971, working on the corrosion characteristics of dental alloys. He won the regional table clinic award and will give a presentation at the 1972 national ADA table clinic competition in San Francisco. He is now a postdoctoral trainee in implant materials in a combined program between Emory and Georgia Tech.
6. The Program Director was invited to give the review paper on the application of metals in dentistry at the 1970 symposium on "Materials for Implant Dentistry," held at Clemson University, April 16-17, 1970.
7. The Program Director was invited to deliver the plenary lecture on advances in dental-medical materials at the 65th meeting of the European Federation of Corrosion in Dubrovnik, Yugoslavia, April 16-21, 1972.
8. A doctoral program has been approved in the Metallurgy Program in the School of Chemical Engineering and has been available to trainees on this grant since its inception in 1968.
9. A special course, MET 6605, entitled Dental-Medical Materials, was approved by the Graduate Council in 1968 and has been an offering available to students on this program since that time. An introductory course in this area was approved in 1970 as MET 4405.

10. The program director and staff members have given over 50 lectures in addition to those listed in Section III, on dental-medical materials in various cities around the country. This includes a series of 6 lectures for a dental student class at Emory in 1970 and approximately 2-3 talks per year to dental student classes in 1966, 1967, 1968, and 1969. Since 1970 Dr. Marek and Dr. Butler have presented these lectures.
11. Established a rapport and cooperation between various elements of the Emory Dental School and the Dental School of the Medical College of Georgia. Special exchange programs, lectures and consultantships on each others programs have resulted.
12. Interaction of the program with several materials producing companies has proven exceptionally fruitful to the program by providing materials and assistance. For example, the Jelenko Co. has been providing dental gold alloys at a cost of only the material cost; the L. D. Caulk Co. and its parent corporation Dentsply have provided much in the way of dental alloys including ingots of base alloys for study. In addition, alloys from Dental-Medical Division of Howmet, an ultrasonic unit from Cavitron, special sybralay materials from Kerr Mfg. Co. and other alloys from S. S. White and the Stern Dental Co. Our major assistance has been in studying methods of property improvement and corrosion characteristics. To quote from the director of research of the L. D. Caulk Co. regarding a special grant, "This grant is made to the Georgia Tech Foundation in the name of the Metallurgy Program under the direction of Dr. Robert F. Hochman. We feel that the caliber of work in this department is deserving of special support from industry. This initial grant to your Institution is a program we have to give special financial recognition of outstanding contributions to dental health through studies which lead to improved dental materials."
13. Developed the interest and awareness of dental materials problems on the part of many international and national materials researchers. For example, the cooperative work with Marcel and Antoine Pourbaix, internationally known research scientists in corrosion on the effects of corrosive environments on dental-medical implants, the work with Dr. John Scully, University of Leeds, Leeds, England, Dr. Neville Pugh, University of Illinois, Dr. Brian Ralph, University of Cambridge, Cambridge, England, all visiting professors at

Georgia Tech expressed interest in dental-medical material properties and corrosion phenomena after their introduction to our training program research. More recently Dr. B. Floyd Brown and Dr. C. S. Barrett, the latter an internationally eminent teacher and researcher, have been visiting professors at Tech and became related to much of our work in dental-medical materials as have been Dr. Roger Stahle from Ohio State and Dr. Harry Paxton, now V.P. of research at U.S. Steel, formerly on the Carnegie-Mellon staff.

14. Dr. R. F. Hochman assisted Dr. Floyd A. Payton, NIDR consultant, in presenting a workshop on the role of the biomaterials scientist in dentistry.
15. A special exhibit of Georgia Tech trainee and summer dental student projects on corrosion of dental amalgams was displayed as a prominent part of the NIDR exhibit at the 1971 American Society for Metals, National Metal Congress in Detroit.
16. R. F. Hochman, the project director, is a member of several national committees dealing with biomaterials and is chairman of the American Society for Testing and Materials (ASTM) F-4-20.4 national committee on composite materials. He is also a member of the ASM working committee on biomaterials and was a member for 3 years of the FDA's Panel on Orthopedic Devices.
17. Dr. Hochman has directed a small summer project in 1973 and 1974 from the Georgia Engineering Foundation (\$1500), for a student to pursue work in dental-medical materials. Mrs. Frances Smith, a one-year trainee later on the NIDR program was supported for the summer of 1973 and Miss Cheryl Howard a 3-2 student in engineering with Moorehouse was the next trainee. The work involved in vivo testing of alloys under stress and the results will soon be available as a publication. Mrs. Smith is continuing her doctoral work here at Tech on other support and Miss Howard has expressed an interest in becoming a trainee in dental-medical materials if support is available.
18. Dr. Hochman and Dr. Marek have received a special NATO Grant to purchase equipment and provide international cooperation (no personnel services) on localized corrosion with one of the first areas of the initial studies being on dental amalgam and other dental-medical materials.
19. There have been many other milestones which have been part of the development of this program. These include interaction with members of staff of the Institute and other universities to initiate a program of review of ideas

in dental materials. There has been the development of a number of basic phenomena which now bear further study clinically, i.e., effective hardening and reworking of dental amalgams and silicate restorations with ultrasonics, the basic understanding of the corrosion phenomena of dental amalgam, its normal passive state in the mouth and the conditions which change its characteristic passivity, improved casting of dental alloy with ultrasonics, method for more homogeneous spherodization of silver-tin alloy, a basic understanding of the tarnishing effects of dental gold, the characteristics of fatigue and creep of dental alloys and amalgam and the improvement of corrosion resistance and fatigue for a number of alloys for dental use, i.e., for low gold or no-gold replacement in bridges and crowns as well as for unique properties in implant applications.

20. Developed the initial fundamental basis for corrosion testing and evaluation of oral alloys on this program. Although much work remains, and the total effect of oral corrosion in relation to the stability of restorative materials is still far from resolved, the research studies on this training grant have revealed the importance of the singular factor.

Respectfully submitted,

Robert F. Hochman, Ph.D.
Project Director DE-00127