

BASIC CERAMICS RESEARCH AND THE NATIONAL SCIENCE FOUNDATION

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ABSTRACT

The National Science Foundation serves as a primary source of support for research and education at academic institutions in the USA. Awards are based on merit review of submitted proposals. Intellectual merit, broader impacts, diversity of participants and the integration of education and research are key factors in funding decisions. Although ceramics is an integral part of many NSF activities, one program within the Division of Materials Research focuses exclusively on basic science research on ceramics for individual investigators and small groups. Funding opportunities exist that specifically support projects with industry or international linkages, junior investigators, undergraduate institutions and cooperative efforts. Large group efforts (centers, institutes and similar frameworks) are supported by other programs. Similarly, infrastructure is provided through instrumentation funding and support for national facilities.

INTRODUCTION

In the USA, the National Science Foundation (NSF) is an independent federal agency with annual budget of ~\$6 billion. NSF supports education and basic research at the frontiers of discovery across many fields of science and engineering.^[1] Several of the directorates – Mathematical and Physical Sciences (MPS), Engineering (ENG), and Geosciences (GEO) – cover research areas of primary interest to ceramists. Primarily, funding is provided to academic institutions (and non-profit organizations) based in the USA; however, a few selected NSF programs focus exclusively on small businesses. NSF's responsibilities to initiate and support various activities are laid out in the latest five-year strategic plan (Table 1).^[2]

Table 1: Responsibilities of NSF

Basic scientific research and research fundamental to the engineering process
Programs to strengthen scientific and engineering research potential
Science and engineering education programs at many levels and in most fields of science and engineering
An information base on science and engineering appropriate for development of national and international policy
Fostering the interchange of scientific and engineering information nationally and internationally
Maintaining facilities in the Antarctic and promoting the U.S. presence through supporting and managing a vigorous U.S. national research program in the Arctic and Antarctic
Addressing issues of equal opportunity in science and engineering

NSF's vision is to advance discovery, innovation and education beyond the frontiers of current knowledge, and empower future generations in science and engineering. Four goals: discovery, learning, research infrastructure and stewardship, are linked to investment priorities.

MERIT REVIEW and FUNDING DECISIONS

NSF provides three types of awards: grants, contracts and cooperative agreements. Grants are a flexible funding mechanism that allows the principal investigator (PI) to change scope (with NSF approval) in response to new information and discoveries made. Contracts are usually used for the delivery of specific products, services and studies (e.g., surveys, analysis and evaluation). Cooperative agreements are normally reserved for large projects, such as, research centers, policy studies, large curriculum projects, major instrumentation development and multi-user facilities. They are used when the project being supported requires substantial agency involvement to help assure suitability or acceptability of certain aspects during the project performance period.

Awards are made based on proposals received by NSF; the majority (>95%) undergo an external merit review process. Generally, proposals may be submitted to NSF according to the grant proposal guide as unsolicited proposals or in response to specific announcements or solicitations. Most proposals must be submitted within a window (i.e., between a range of dates), or by a specific deadline that is listed in the solicitation. Unless otherwise specified, all proposals are evaluated according to intellectual merit and broader impacts.^[3] During 2007, the National Science Board that governs NSF, approved a motion to enhance support of transformative research by amending the review criteria.^[4] Transformative research describes a range of endeavors which promise extraordinary outcomes, such as: revolutionizing entire disciplines; creating entirely new fields; or disrupting accepted theories and perspectives — in other words, those endeavors which have the potential to change the way challenges in science, engineering, and innovation are addressed. Supporting more transformative research is viewed to be of critical importance in the fast-paced, science and technology-intensive world of the 21st Century.

Usually recommendations for funding are made by program directors' assessment of the proposal along side three or more external reviews. Program directors are experts (in their areas of responsibilities) with a Ph.D. (or equivalent) plus six or more years of successful research, research administration and/or substantial managerial experience in academe, industry, or government. They are provided broad discretion in their recommendations taking into consideration additional factors, such as, innovation; other support that the PI has for related research; geographic balance; junior faculty; NSF program balance; impact in terms of education, science or society; multidisciplinary and risk versus pay-off. As well, as indicated in the Grant Proposal Guide (GPG),^[5] program directors take into account the extent that projects broaden the diversity of participants, and the degree that education is integrated with research.^[6]

CERAMICS RESEARCH AT NSF

Research in the area of ceramics is supported across NSF in various programs.^[7] In addition to funding from three of the research directorates – MPS, ENG and GEO, opportunities for

ceramics research and education may be found in the Education and Human Resources (EHR) directorate and the Office of International Science and Engineering (OISE). Recently ENG reorganized [8] and developed a set of strategic direction documents.[9] One new ENG program of particular interest to the ceramics community is Energy for Sustainability.[10] At this time, it has 38 active awards covering topics, such as, wind turbines, fuel cells, hydrogen generation, and photovoltaic devices. Within the MPS directorate, there are five divisions and an office of multidisciplinary activities. One division, the Division of Materials Research (DMR), serves as the primary focus for materials research and education.

THE DIVISION OF MATERIALS RESEARCH (DMR) IN MPS

In DMR, the emphasis is placed on making new discoveries about the behavior of matter and materials; creating materials and new knowledge about materials phenomena; and addressing fundamental materials questions that often transcend traditional scientific and engineering disciplines and may lead to new technologies. DMR provides support for individual investigators and small group activities (with five or fewer investigators), as well as large group efforts and infrastructure for research and education. The topical programs for individuals and small groups are: Ceramics (CER), Electronic Materials (EM), Biomaterials (BMAT), Solid-State and Materials Chemistry (SSMC), Condensed Matter Physics (CMP), Condensed Matter and Materials Theory (CMMT), Metals (MET) and Polymers (POL). Awards are made within these programs (in some cases with the assistance of the Office of Special Programs (OSP)) in a variety of ways (Table 2). DMR also provides support to larger group efforts (Table 3) and infrastructure support in terms of instrumentation [11] and national facilities.[12]

Table 2. DMR Awards to Individual Investigators and Small Groups

Type of Proposal	Proposal Guidelines	Submission Date
Unsolicited proposals	GPG NSF 08-1 Jan. 2008	DMR submission window: Sept. and Oct. (annually)
Focused Research Groups (FRGs)	http://www.nsf.gov/mps/dmr/awards/frgs.jsp	
Grant Opportunities for Academic Liaison with Industry (GOALI)	07-522 Solicitation (NSF-wide)	
Research in Undergraduate Institutions (RUI)	00-144 Announcement (NSF-wide)	
Faculty Early Career Development (CAREER)	08-557 Solicitation (NSF-wide)	Mid July (annually)
Materials World Network (MWN)	07-574 Solicitation (OSP)	Early Nov. (annually)

THE CERAMICS PROGRAM (CER) IN DMR

CER supports basic research and education in ceramics (e.g., oxides, carbides, nitrides and borides) as well as diamond and inorganic carbon-based materials.[13] The objective of the program is to increase fundamental understanding and develop predictive capabilities for relating synthesis, processing, and microstructure of these materials to their properties and ultimate performance in various environments and applications. Typically, 20-30 research awards are

made each year. A few examples of recent awards illustrate the breadth of the program (Table 4). Details of all NSF awards are provided through a searchable website.^[14]

Table 3. Large Group Efforts Supported or Managed in DMR

Type of Proposal	Proposal Guidelines	Competitions
Materials Research Science and Engineering Centers (MRSEC)	07-563 Solicitation	Every 3 years
Partnerships for Research and Education in Materials (PREM)	05-615 Solicitation	Every 2 to 3 years
Science and Technology Centers (STC)	03-550 Solicitation (NSF-wide)	Every 2 to 3 years
International Materials Institutes (IMI)	08-558 Solicitation	Every 2 to 3 years
Research Experiences for Undergraduates (REU) Sites	07-569 Solicitation (NSF-wide)	Mid Aug. (annually)

Table 4. Descriptions of Recent Representative Awards in CER

Award, Type	Materials	Applications	Examples of Education or Diversity Activities	PI
0747896, CAREER	Hetero-structures of perovskites	Spintronic devices, sensors, solid oxide fuel cells	California Alliance for Minority Participation (CAMP) program; workshop with community colleges	Yayoi Takamura
0705299, FRG	Sapphire and GaN	Optical devices, such as, lasers and light emitting diodes	Research experiences (high school & college students); community outreach (Nanoscale Informal Science Education Network)	Helen Chan
0704354	Semiconducting Oxides (titanium dioxide)	Catalysts, sensors, energy conversion devices	Development of industry-supported laboratory course; examination of mentorship models; promotion of ethics	Edmund Seebauer
0604314, GOALI	Boron carbide	Wear resistant coatings; Protection	Research experiences for elementary and/or high school teachers; Industry	Manish Chhowalla
0606464	Amorphous films (zirconia and hafnia)	Gate dielectrics in microelectronics	Summer research at the university for high school students (Alice in Wonderland project)	Alexander Demkov
0710630, MWN	"Biomorphic" SiC ceramics	New directions in composites	International collaboration; course development; public outreach	Katherine Faber
0604004	Complex oxide	Solid oxide fuel cells	Public outreach programs, incl. an exhibit at the California Science Center	Sossina Haile
0603993	Chalcogenide glasses (EELS analysis)	Photonics, tele-communication, sensors and memory devices	Experiments at Argonne National Laboratory; coordination with on-campus underrepresented group and K-12 programs	Nan Jiang

CONCLUSIONS

NSF serves as an important financial resource for academic institutions, non-profit organizations and small businesses in the USA conducting research and education in many fields of science and engineering. Moreover, NSF's focus extends beyond research results to building a solid base for a diverse and globally-engaged workforce of the future. Support is available for individual investigators all the way through to large groups, as well as for instrumentation and facilities. The scope across NSF is broad from engineering new and improved devices and manufacturing processes, to uncovering fundamental understanding of phenomena. Ceramics research and education is supported across the foundation in many different programs.

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- ⁹ ENG strategic planning documents (<http://www.nsf.gov/eng/general/strategic/index.jsp>).
- ¹⁰ Energy for Sustainability (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=501026&org=CBET).
- ¹¹ Instrumentation in DMR (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5452&org=DMR&from=home).
- ¹² National Facilities in DMR (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5359&org=DMR&from=home).
- ¹³ CER information (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5352&org=DMR&from=home).
- ¹⁴ NSF award information (<http://www.nsf.gov/awards/about.jsp>).