justed through choice of the di-anhy-
dride, the length of the starting PEO
oligomer molecules, and partial re-
placement of the trifunctional mole-
cule with a difunctional molecule.

4. The film can be packaged once gela-
tion has occurred. Because the reac-
tion solvent is inert toward all cell in-
gredients, it is not necessary to
remove this solvent. Optionally, be-
cause the reaction solvent boils at a
temperature \( \approx 100 \text{ C}^\circ \) lower than does
a typical cyclic carbonate solvent, the
reaction solvent can be preferentially
evaporated before packaging.

This work was done by Mary Ann B.
Meador of Glenn Research Center and Dean
M. Tigelaar of Ohio Aerospace Institute. Fur-
ther information is contained in a TSP (see
page 1).

Inquiries concerning rights for the com-
mercial use of this invention should be ad-
dressed to NASA Glenn Research Center, In-
novative Partnerships Office, Attn: Steve
Fedor, Mail Stop 4–8, 21000 Brookpark
Road, Cleveland, Ohio 44135. Refer to
LEW-18205-1.

Catalysts for Efficient Production of Carbon Nanotubes
Some alloys have been found to work at lower temperatures.

Lyndon B. Johnson Space Center, Houston, Texas

Several metal alloys have shown promise as improved catalysts for catalytic thermal decomposition of hydrocarbon gases to produce carbon nanotubes (CNTs). Heretofore almost every experiment on the production of carbon nano-
tubes by this method has involved the use of iron, nickel, or cobalt as the cata-
lyst. However, the catalytic-conversion ef-
ficiencies of these metals have been ob-
served to be limited. The identification of better catalysts is part of a continuing program to develop means of mass pro-
duction of high-quality carbon nano-
tubes at costs lower than those
achieved thus far (as much as $100/g for
purified multi-wall CNTs or $1,000/g for
single-wall CNTs in year 2002).

The main effort thus far in this pro-
gram has been the design and imple-
mentation of a process tailored specifi-
cally for high-throughput screening of
alloys for catalyzing the growth of CNTs.
The process includes an integral combi-
nation of (1) formulation of libraries of
catalysts, (2) synthesis of CNTs from de-
composition of ethylene on powders of the
alloys in a pyrolytic chemical-vapor-
decomposition reactor, and (3) scan-
ning-electron-microscope screening of
the CNTs thus synthesized to evaluate
the catalytic efficiencies of the alloys.
Information gained in this process is put
into a database and analyzed to identify
promising alloy compositions, which are
to be subjected to further evaluation in a
subsequent round of testing.

The promising alloys identified thus
have been the following (composi-
tions in atomic percentages): 90 Co, 10
Ti; 20 Co, 70 Ni, 5 Ti, 5 Ta; 90 Co, 10 Mo;
20 Co, 75 Ni, 5 Mo; 80 Co, 10 Ti, 10 Al; 70
Co, 15 Ni, 15 Ti; 80 Co, 10 Ni, 10 Ti; 70
Co, 5 Ta, 5 Mo, 20 Mn; 80 Ni, 10 Mo, 10
A; 80 Co, 12 Ni, 8 Al; and 80 Co, 20 Cr.

Some of these alloys have been found
to catalyze the formation of carbon
nanotubes from ethylene at tempera-
tures as low as 350 to 400 °C. In con-
trast, the temperatures typically re-
quired for prior catalysts range from
550 to 750 °C.

This work was done by Ted X. Sun and Yi
Dong of Intermatix Corp. for Johnson Space
Center. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517,
the contractor has elected to retain title to this
invention. Inquiries concerning rights for its
commercial use should be addressed to:

Intermatix Corp.
351 Rheem Blvd.
Moraga, CA 94556

Refer to MSC-23477-1, volume and num-
er of this NASA Tech Briefs issue, and the
page number.

Amorphous Silk Fibroin Membranes for Separation of CO₂

Lyndon B. Johnson Space Center, Houston, Texas

Amorphous silk fibroin has shown promise as a polymeric material deriv-
able from natural sources for making membranes for use in removing CO₂
from mixed-gas streams. For most appli-
cations of silk fibroin, for purposes other
than gas separation, this material is used
in its highly crystalline, nearly natural
form because this form has uncom-
monly high tensile strength. However,
the crystalline phase of silk fibroin is im-
permeable, making it necessary to con-
vert the material to amorphous form to
obtain the high permeability needed for
gas separation.

Accordingly, one aspect of the pres-
ent development is a process for gener-
ating amorphous silk fibroin by treating
native silk fibroin in an aqueous methanol/salt solution. The resulting
material remains self-standing and can
be prepared as thin film suitable for
permeation testing. The permeability of
this material by pure CO₂ has been found
to be highly improved, and its mixed-gas
permeability has been found to exceed the mixed-gas permeabilities of
several ultrahigh-CO₂-permeable
synthetic polymers. Only one of the
synthetic polymers — poly(trimethylsilyl-
propyne) [PTMSP] — may be more
highly permeable by CO₂. PTMSP be-
comes unstable with time, whereas
amorphous silk should not, although at
the time of this reporting this has not
been conclusively proven.

This work was done by Christopher M.
Aberg, Anand K. Patel, Eun Seok Gil, and
Richard J. Spontak of North Carolina State
University and May-Britt Hagg of Norwegian
University of Science and Technology for John-
sen Space Center.

For further information, contact the JSC
Innovation Partnerships Office at (281) 483-
3809. MSC-24032-1.