

**Direct In-situ Growth of CNTs on Pristine Lunar Simulants.** S. Wright<sup>1</sup>, Z. Ronau<sup>2</sup>, Y. H. Kim<sup>1</sup>, G. Sumanasekera<sup>2</sup>, M. J. Rahman<sup>3</sup>, C. Park<sup>4</sup>, S. Chu<sup>4</sup>, J. Gruener<sup>5</sup>, J. Edmunson<sup>6</sup>, <sup>1</sup>Civil and Environmental Engineering, <sup>2</sup>Physics and Astronomy, <sup>3</sup>Mechanical Engineering, University of Louisville, KY 40292, <sup>4</sup>NASA Langley Research Center, <sup>5</sup>NASA Johnson Space Center, <sup>6</sup>NASA Marshall Space Flight Center (Contact: gamini.sumanasekera@louisville.edu; young.kim@louisville.edu)

**Introduction:** In-space manufacturing is an emerging technology that focuses on synthesizing materials for various purposes while reducing the payload from Earth. This study reports a recent achievement in the direct synthesis of nanomaterials using fine particles of lunar regolith simulant.

The research demonstrates the conversion of organic waste materials, specifically methane, into valuable carbon nanotubes (CNTs) using plasma with the optimum argon and hydrogen contents. These nanotubes act as fillers in voids and provide crack-bridging, resulting in strength improvements and optimizing the performance of host matrices such as lunar regolith-based geopolymers and shielding materials.

The hypothesis of this study is to test the feasibility of growing CNTs on lunar regolith simulant particles. Previous studies have shown that CNTs can be synthesized on fly ash particles, making this hypothesis testable. For this study, two types of lunar regolith simulants—JSC-1A and CSM-LHT-1—were selected.

**Approaches:** The sample preparation includes two approaches: 1) mixing with catalysis (FeO) and 2) as-it-is lunar regolith simulant. It turns out the formation of CNTs is feasible in both approaches. Herein, the direct in-situ growth of CNTs on the pristine JSC simulant (left) and CSM simulant (right) using Plasma Enhanced Chemical Vapor Deposition (PECVD) of methane gas was presented. The PECVD method included 30 minutes of the carrier gas mixture Ar:H<sub>2</sub> (60:40 ratio with a 25sccm flow

rate) excited to plasma phase by 25W of radio frequency (RF) power supply and the tube furnace was kept at a temperature of 700°C. After the initial 30 mins, the Ar:H<sub>2</sub> flow was reduced to zero. During the subsequent 30-min phase, the CH<sub>4</sub> gas was introduced at a flow rate of 20sccm. The CH<sub>4</sub> was excited to plasma with a RF power of 25W, while the temperature was maintained at 700°C. The system pressure with the CH<sub>4</sub> plasma was ~800mTorr.

**Findings:** Raman spectroscopy confirms the presence of multiwalled CNTs. Fig. 1 shows three distinct peaks identified as the G-band (around 1580 cm<sup>-1</sup>), the D-band (around 1350 cm<sup>-1</sup>), and 2D band (around 2600 cm<sup>-1</sup>) (marked with red dashed lines) for both JSC and CSM samples.

Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) were utilized to confirm the synthesis of carbon nanotubes (CNTs) on lunar regolith simulants. As illustrated in Fig. 2, CNTs were identified on both types of simulants. The growth of CNTs was observed on the surfaces of particles across these simulants. EDX provided confirmation of the elemental composition of the area of interest, revealing that iron (Fe) was present alongside carbon (C), which comprises the CNTs.

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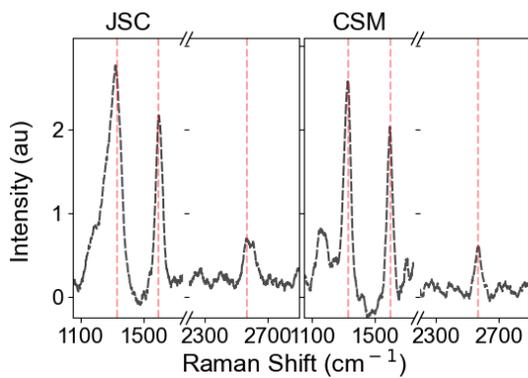


Figure 1: Raman spectroscopy results: JSC-1A (Left); CSM (Right)

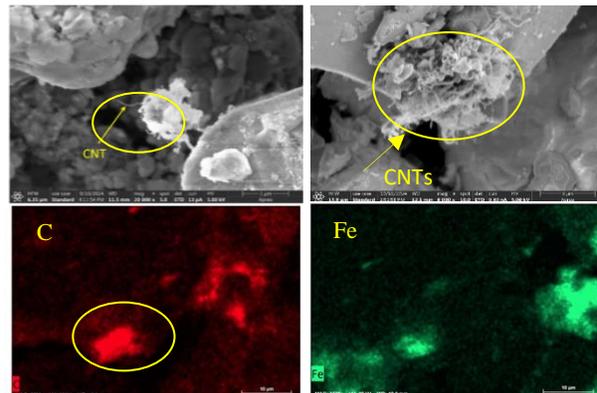


Figure 2: SEM images and EDX confirm the existence of CNTs on the regolith (Top left: JSC-1A; Top right: CSM; Bottom left and right: High Carbon concentration around Fe in CSM)