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**6. AUTHOR(S)**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Army Research Laboratory Adelphi MD United States

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Army Research Laboratory Adelphi MD United States

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Mechanochemical Synthesis of Carbon Fluorides

Dr. Jeffrey Read
Dr. Wishvender K. Behl
• Li/CF$_x$ batteries are being developed to replace the currently fielded BA5590 and 5390 primary batteries.

• Li/CF$_x$ batteries have twice the specific energy and energy density of Li/SO$_2$ batteries.

• This chemistry, typically used for applications at 1000 hour rates or longer, has been adapted to operate at 10 hour rates with high specific energy.

• Several issues arise when the Li/CF$_x$ chemistry is adapted to higher rate large format batteries.
• Cost of CF$_x$ (at $0.50/g$, $50$ in materials for a battery)
This patent describes a simple method to synthesize carbon fluorides at room temperature. This method replaces the commonly used method of making carbon fluorides by reacting carbon with fluorine gas at high temperatures. The synthesized carbon fluoride is used as a cathode material in high energy density Li/CF$_x$ cells and batteries.
This method consists of reacting carbon with cobalt trifluoride at room temperature to make carbon fluoride.

Carbon powder is mixed with cobalt trifluoride and milled for 6-10 hours using a Spex Milling machine.

Carbon fluoride formed by this reaction is separated from other reaction products by washing with sulfuric acid and distilled water.

\[
\text{C} + \text{CoF}_3 \rightarrow \text{CF} + \text{CoF}_2
\]

\[
\Delta G_{\text{reaction}} = -56 \text{ KJ/mole}
\]
• The new method is simpler and less hazardous than the prevailing method of making carbon fluorides which involves reacting carbon with fluorine gas at high temperatures

• The reaction products consisting of carbon fluoride and cobalt difluoride are easily separable and cobalt fluoride can be recycled to reduce costs

• The room temperature carbon fluoride performs as well in lithium/carbon fluoride cells as its high-temp counterpart

• Li/CF$_x$ cells using room temperature synthesized carbon fluoride cathodes show lower voltage delay
New Technology

- The invention simplifies the process of synthesizing carbon fluorides and eliminates the use of highly corrosive fluorine gas and high temperatures.

- The reactive milling process employed by ARL alters how fluorine is introduced into the carbon structure yielding carbon fluorides which show improved performance in Li/CF$_x$ cells.
As depicted in the graph below, the ARL invented CF\textsubscript{x} formulation (A) result is a 20% higher initial running voltage and a smaller voltage delay than the commercial CF\textsubscript{x} preparation (B). Other features/capabilities/intellectual property offered by this invention include the following:

- Easily accessible starting materials
- Cost comparable to existing Li/CF\textsubscript{x} cells
- Straightforward production, easily learned

IP includes novel composition of matter and processes for separation of the resultant carbon fluoride; recycling the reaction by-products; and assembly of the cell using the separated carbon fluoride powder
The synthesized carbon fluoride will be used in the fabrication of Li/CF$_x$ primary batteries for use in radios and other communication devices.
Li/CF$_x$ batteries were among the first commercially successful lithium battery systems, and they are found in a wide range of low-to-medium current applications. This ARL invention not only retains all the favorable aspects of traditional Li/CF$_x$ batteries, but its improved performance characteristics could expand potential applications in the current estimated $1.5$ billion marketplace:

- Automotive: Tire pressure monitoring systems
- Public Safety: Toll tags, emergency signal lights
- Utilities: Electric, water and gas smart meters
- Commerce: Powered credit cards
This technology would benefit from a CRADA agreement. ARL is seeking a patent license agreement to synthesize and manufacture carbon fluoride on a larger scale. This will reduce the cost and make it economically attractive when compared to the current commercial practice of producing carbon fluoride through high temperature synthesis with fluorine gas.

- TRL 4 – Fully functioning prototype cell fabricated using ARL process
- The inventor team is available to work with commercialization partner
- Non-provisional patent application filed