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# 球床式高温气冷堆一回路硼酸类物质研究


## 摘要

高温气冷堆一回路冷却剂化学环境复杂，杂质的来源、形态及沉积行为对系统运行可靠性与安全监测具有重要影响。本文针对 HTR-10 尘埃过滤器中发现的白色结晶沉积物开展了物相鉴定与成因分析。采用 X 射线衍射、拉曼光谱和傅里叶变换红外光谱对样品进行了表征，结果表明该沉积物主要由 $NH_4B_5O_8{\cdot}4H_2O$、$(NH_4)_3[B_{15}O_{20}(OH)_8]{\cdot}4H_2O$ 和 $H_3BO_3$ 组成，通过 SEM 观察了沉积物的形貌，通过 EDS 和 ICP-MS 分析了 B 含量，并通过 STA 对晶体的热行为进行测试。结合 HTR-10 的结构特征与运行条件分析，推测沉积物中的硼主要来源于堆芯含硼碳砖，而铵根则可能与二回路联胺或其分解产物经微量跨壁迁移进入一回路有关。研究首次在高温气冷堆一回路中识别出硼酸类沉积物，揭示了一回路中含硼杂质迁移转化与沉积的新现象，可为异常化学过程识别、杂质来源追踪以及冷却剂化学监测与净化策略优化提供参考。



## 关键词

高温气冷堆、硼酸、腐蚀、结构表征



## Abstract

The primary-circuit coolant chemistry of high-temperature gas-cooled reactors is highly complex, and the sources, chemical states, and deposition behavior of impurities are of great importance to system reliability and safety monitoring. In this study, the white crystalline deposits found in the HTR-10 dust filter were investigated through phase identification and formation mechanism analysis. The samples were characterized by X-ray diffraction, Raman spectroscopy, and Fourier transform infrared spectroscopy. The results showed that the deposits were mainly composed of $NH_4B_5O_8{\cdot}4H_2O$, $(NH_4)_3[B_{15}O_{20}(OH)_8]{\cdot}4H_2O$, and $H_3BO_3$. The morphology of the deposits was observed by SEM, the boron content was analyzed by EDS and ICP-MS, and the thermal behavior of the crystals was examined by STA. Based on the structural characteristics and operating conditions of HTR-10, it is inferred that the boron in the deposits mainly originated from the boron-containing carbon bricks in the core, while the ammonium species were likely related to trace migration of hydrazine or its decomposition products from the secondary circuit into the primary circuit through micro-leakage across the heat-transfer boundary. This study reports for the first time the identification of borate deposits in the primary circuit of a high-temperature gas-cooled reactor, revealing a new phenomenon involving the migration, transformation, and deposition of boron-containing impurities in the primary circuit. The findings can provide reference for the identification of abnormal chemical processes, impurity source tracing, and the optimization of coolant chemistry monitoring and purification strategies.



## Keywords

High-temperature gas-cooled reactor; boric acid; corrosion; structural characterization



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